Southland
Wood Residue
Supply Assessment

A report prepared for Wood Energy South, Venture Southland, and the Energy Efficiency Conservation Authority.

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Executive Summary

A significant opportunity exists for industrial energy users in Southland to obtain their energy requirements from locally sourced renewable wood fuels. The findings of this report demonstrate there are good opportunities for Southland-based industrial users of energy to develop long-term relationships with regional forest owners who are seeking to develop additional markets for their lower-value log grades.

The corporate forest estate within the project area is significant and stable, providing the backbone of the wider Southland forestry industry, and providing reliable woodflow supply to the downstream wood processing industry. Woodflows from across Otago and Southland are planned to increase significantly in forthcoming years. Already a considerable industry in the southern regions, forestry is soon to become even larger and significant as a contributor to the regional economy. Over the next decade there will be a considerable increase in the expected harvesting across these regions. Including the eucalyptus resource, currently there is an estimated 1,000,000 tonne of logs annually harvested in the Southland region. This is expected to rise to 1,200,000 tonne by 2019, and then increasing to an ongoing sustainable yield of 1,550,000 tonne by 2039. This steadily increasing harvest volume provides increasing opportunities for users of wood energy, which will be sustained into the future.

From the existing 2014-15 Southland total harvest volume an estimated 250,000 tonne of lower-value log products will be produced from these forests. Of this, an estimated 160,000 tonne is committed to the Dongwha-owned Medium Density Fibreboard (MDF) processing plant in Mataura. An additional estimated 20,000 tonne of billet wood is sold to either existing energy markets, or to the MDF plant. The remaining 50,000 tonne of lower-value logs is sold to export markets, via Port South in Bluff. It is estimated that an additional 45,000 tonne of unrecovered residue is left unrecovered in the forests, remaining there due to the lack of profitable markets for these logs and the high cost of extraction. A strong wood energy market has the potential to provide the incentive for forest owners to recover these residues.

It is also estimated that there is between 30,000 and 40,000 tonne of woodlot and shelterbelt logs being chipped annually, in Southland. This yield is likely to be less sustainable, as it is being generated from existing shelterbelts, many of which are not being replanted. The entire chip from these in-situ operations is currently being used as bedding for dairy farm herd homes, dairy pads, or laneways.

The South Otago forest estate (taking in the Clutha District) is already of high importance to the Southland wood-processing sector, and also to the potential for a thriving Southland wood energy sector. The proximity of the South Otago forest estate is demonstrated when using Mataura as the end destination. In this example an estimated 55,000 hectares of Southland forests falls within 120km of Mataura, and 47,500 hectares of South Otago (Clutha) forests falls within the same distance.

Of the existing 2014-15 South Otago total harvest volume an estimated 225,000 tonne of lower-value log products will be produced from these forests. Of this, an estimated 65,000 tonne is committed to the Dongwha-owned Medium Density Fibreboard (MDF) processing plant in Mataura. An additional estimated 20,000 tonne of billet wood is sold to either existing Dunedin-based energy markets, or to the MDF plant. The remaining 105,000 tonne of lower-value logs are sold to export markets, usually via Port Chalmers wharf. The proportional split of destinations for these markets is dependent on the forest owner, their market agreements, and their proximity to the markets. Unlike the Southland industry – which favours supply to the more proximate MDF plant at Mataura - it is common for just 30-35% of South Otago lower value logs to be sent to the domestic market, and the balance exported. It is estimated that an additional 40,000 tonne of billet-wood type logs is left unrecovered in the forests, remaining there due to the lack of profitable markets for these logs.

The graph in Figure 1 shows the expected increase in lower-value residues from within the Southland region and South Otago, over time. The top half of the graph shows the portions that are available volumes, and the bottom half of the graph demonstrates the volumes that are already committed to domestic markets such as the MDF plant, or dairy farms.

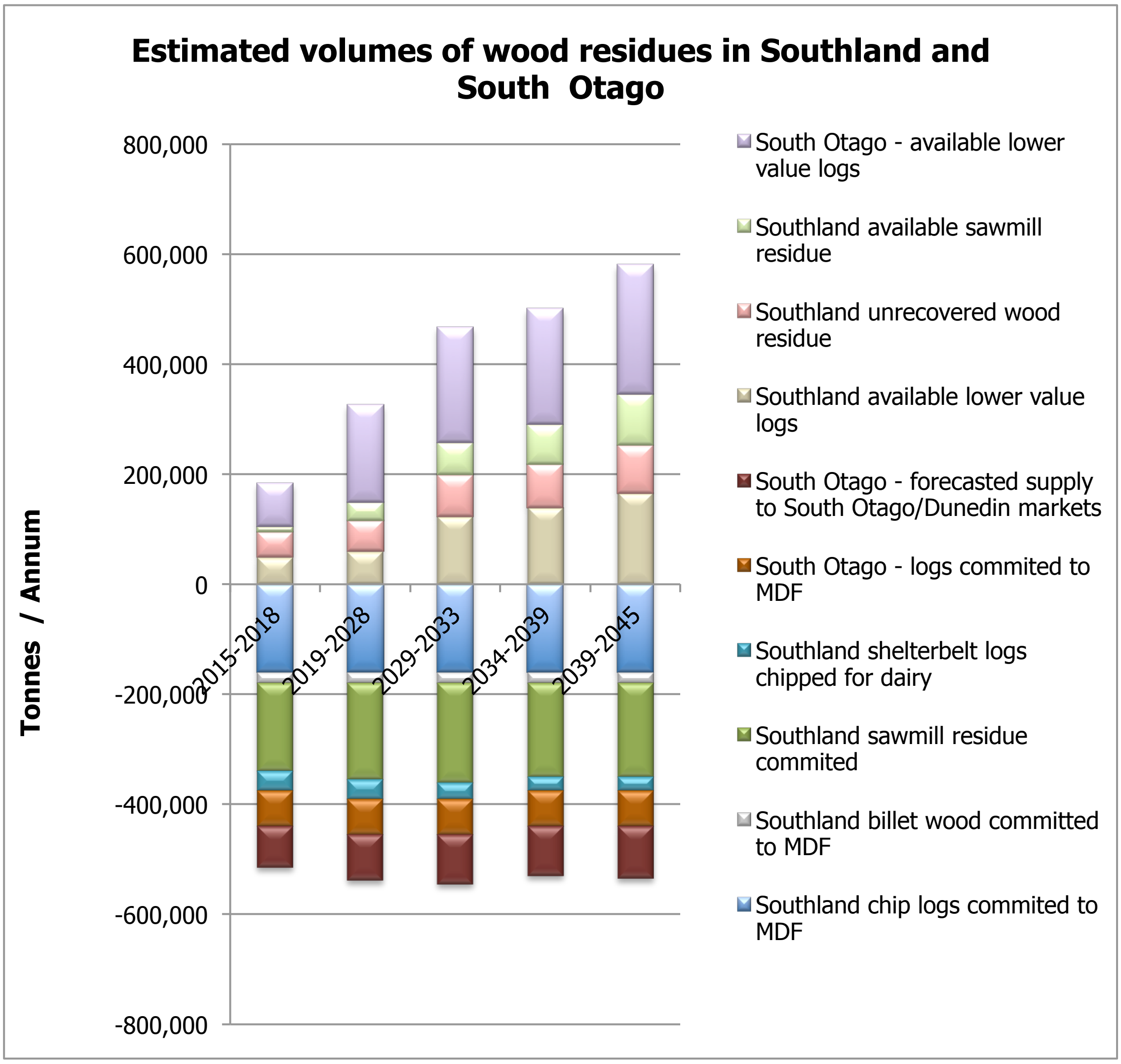


Figure 1 Estimated volume of lower-value residues from Southland and South Otago

The majority of the "available volume" currently is exported as pulp logs, but for the purposes of this report is considered as an available resource. Also, within the graph above, a proportion of residue from South Otago that is currently available has been represented as being unavailable, due to the likelihood of a large industrial heat energy user requiring that resource. That portion is labelled "South Otago – forecast to supply to South Otago/Dunedin markets".

As the graph in Figure 1 shows, industrial-scale energy users have strong potential to secure some of the export-oriented pulp log supply or to provide an alternative domestic option to the MDF plant for chip logs. Corporate forest owners within this area value the reliability and stability of the Dongwha MDF plant and are committed to ensuring continual input into that plant. The expanding Southland regional resource means that the MDF plant will not suffer from a shortage of supply and will benefit from increasing supplies of wood chip from sawmills and also more proximate suppliers of chip log. The MDF plant is not expected to increase its log requirements beyond that already demanded and, given the significant increase in forecast harvest volumes, there will be an increase in the availability of low-value residues over coming years.

The export pulp market, though at times buoyant and providing good returns for forest owners, is a highly fluctuating market whose long-term averages are only slightly higher than the domestic chip price. It is important to note, too, that the export pulp grade specification has higher quality requirements than the domestic chip log grade. As a result, there is always a proportion of the total volume of forest harvested which will need end-markets that are less discerning of quality than that posed by the export markets.

The existing availability of 95,000 tonnes of lower-value forest residues from Southland alone provides 881,600 GJ of energy (gross calorific value (GCV)), amounting to 679,250 GJ (net calorific value (NCV)). Add the existing South Otago volume of 79,000 tonnes, and 1,614,720 GJ (GCV) of energy is available (1,244,100 GJ (NCV)). The difference between the gross calorific value and net calorific value is the energy required to evaporate the moisture content of the wood fuel during the burning process. In 10-12 years this supply will more than double.

In addition, there are significant volumes of wood chip being produced from sawmills. Currently a significant proportion of the wood chip production is under contract to either the Dongwha MDF plant at Mataura, or to the plethora of dairy farms in the region. There is also some existing use of the sawmill chips by industrial users within the area. With the increasing forest harvest volumes predicted, and the needs of the MDF plant being reliably met, there will be increasing opportunities for large scale energy users to purchase green chip directly from sawmills. For substantial growth of wood fuel as an energy source, green chip will need to be scaled, as there is a limit to the seasoned chip resource. The seasoned chip resource is not, however, constrained in the immediate future.

A unique aspect of the Southland forest estate is the high proportional volume of eucalyptus forest grown specifically for chipping. Currently all of this 10,500-hectare forest estate is export-focussed, but if domestic pricing is competitive there is an opportunity to divert portions of the annual 200,000 tonne of chip production into the domestic energy market. This considerable eucalyptus resource has the ability to significantly bolster consistent supply into the local energy market.

The regional Southland forest resource was assessed, both for ownership structure and for size class distribution. This resource was also assessed for accessibility, and potential proximity to end-users. It was found that Mataura and Invercargill are both good locations as destinations for wood energy resources, being well located to draw upon the regional forests and the major sawmills. The full breadth of the Southland forest resource would be required to supply a wood energy industry, reflecting the distribution of the corporate forests and the fact that corporate forest owners manage their dispersed estates as one whole, drawing upon forest resource from each area as a part of their harvesting strategy. As such, potential large users of wood energy would need to utilise log resource from across the region to meet their needs. This is similar to any other log market.

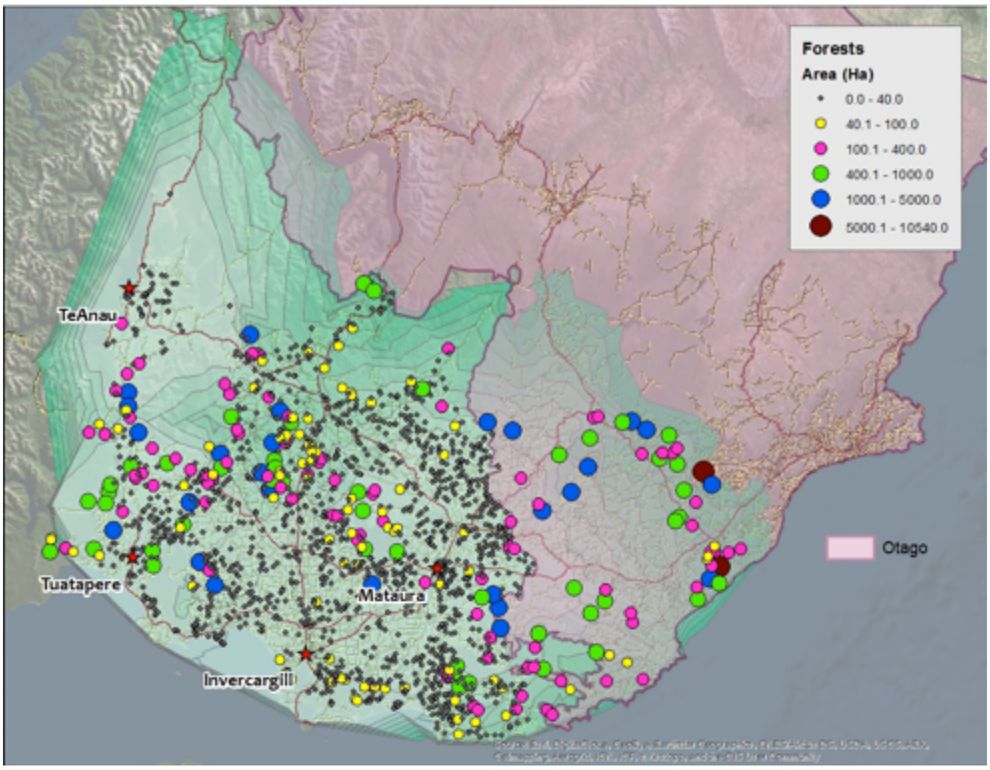


Figure 2 Forest areas within the Southland region

Provided with a stimulated domestic market in the presence of increasing harvest volumes, the development of an alternative domestic market for low-value residues would be positively greeted by forest owners in Southland. For the wood energy market to compete strongly with existing domestic and export markets for lower value residues, end users will need to pay $55 / tonne for a wood energy product of similar grade to chip logs. Wood energy end users will need to pay between $45 and $50 / tonne for billet wood-type log grades, reflecting the extra cartage costs associated with these smaller logs. These prices would need to be relatively consistent across the region, providing competitive prices to those forest owners who are proximate to existing markets such as the MDF plant (e.g.

forest owners in the Mataura and Invercargill forest areas) and providing viable prices for those forest owners who are distant to domestic markets. It is probable that higher prices would be required for forest owners sending these residues from the likes of Te Anau, or the more northern parts of the Clutha District. It is important to note that while export markets are volatile, and the stability of domestic markets for low value logs are valued by forest owners, any domestic market will also have to be able to fluctuate so as to shift with export pricing trends. The prices mentioned here would not be fixed, but are an indicative level of the pricing required to ensure consistent supply into the market.

Medium-term supply agreements should be negotiated with forest owners, ensuring stability of pricing for all parties, and consistent supply of product. At $50 / tonne (or $5.40 / GJ (GCV), or $7.00 / GJ (NCV) there is likely to be some interest from forest owners who are proximate to the end user. However, at this price a new wood energy market would not compete with a buoyant, or even average, export pulp market. During this assessment it has been demonstrated that for supply relationships to be robust, a base price of $55 / tonne (or $6.00 / GJ (GCV) or $7.70 / GJ (NCV)) is more realistic. Additional processing costs, management and overheads, add an additional $20 - $30 / tonne, providing a total estimated energy cost of $8.60 - $9.70 / GJ (GCV) or $11.20 - $12.50 / GJ (NCV). Both the end user and the forest owner will benefit from being proximate to one another, and being able to reduce the proportional impact of cartage cost. Negotiated commercial agreements will serve to refine these costs, and to reduce any excessive margins that may exist at the outset. These costs do not include the capital costs of chipping and handling infrastructure.

As is shown in Figure 3, at these prices green wood chip is more expensive than sub-bituminous coal and lignite, but is cheaper than wood pellets, diesel, electricity or LPG.

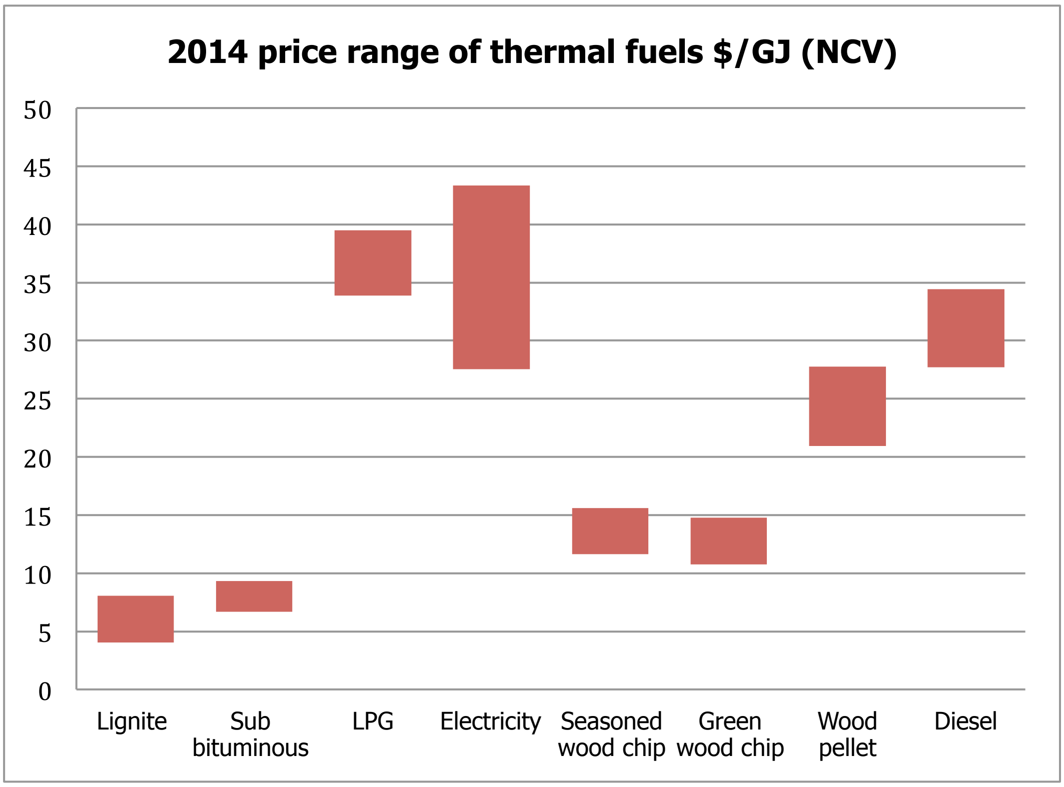


Figure 3 Price range of competitive thermal fuels, $/GJ (NCV).

When carbon costs $25 per tonne for GHG emissions the price of carbon-intensive lignite fuel approaches wood fuel cost but is still cheaper than wood fuels given the data used. Renewable wood chip and wood pellet fuels show the greatest resilience to an effective GHG emissions price and are the most resilient to international fluctuations in energy prices.

At this point in time, the most feasible way of utilising the log volumes for energy generation is for large-scale energy users to purchase log residue directly from the forest owners, or via a log trader, and to store logs at a central processing yard at the same site where the energy will be consumed and to then process these logs as and when needed. Maintaining a buffer supply on site, of both processed chip and of log residue, will be an important component of the supply chain. Use of the traditional log and load system is recommended as the best supply chain for log residue recovery from the forests. This wood chip supply pathway is consistent with current harvesting systems, with little deviation from current practice for harvesting crews and therefore will keep the cost of production as low as possible.

However, it has become apparent that there is a need to specifically evaluate the biomass recovery options from landings in Southland forests. This is still a relatively unexplored subject in New Zealand, particularly with regard to non-Central North Island (CNI) forests. It is strongly recommended that an evaluation of different supply chain systems be undertaken. This should include in-forest chipping, and the use of dump trucks to shift residues from operational skid sites to Central Processing Yards (disused skid sites), with specific evaluation in the context of the more scattered Southland forest estate. To give confidence to forest owners and potential energy users, it is important to validate this through field trials and extended time and motion studies. In their absence it will be very difficult to develop accurate estimates of delivered costs, to draw reliable comparisons between alternative systems, and to be definitive about the availability of volume of unrecovered residues within the forests.

Contents

1.0 Background

Wood Energy South has been set up to promote a shift in Southland to a cleaner, more sustainable fuel, improving air quality, and helping to support a new industry around the use of waste wood as an energy source. The project is being funded over three years (2014-2017) and aims to lower energy-related carbon emissions in Southland, improve air quality and demonstrate the cost and life cycle benefits of wood-chip and wood-pellet fuelled boilers utilising local waste wood. It will also provide local employment capacity building and business opportunities.

The Wood Energy South is primarily focused on overcoming market barriers to establish a regional cluster of wood energy end-use in commercial and industrial applications. Despite a proven economic case and technological maturity, renewable energy for heat faces several barriers including long technology 'lock-in' due to long asset life, perceived security-of-supply risks and a lack of price disclosure.

This report was commissioned so as to provide certainty to candidate industrial wood energy users within Southland about the ongoing availability of wood residue as an energy source. This assessment is focussed on Southland, but includes an assessment of parts of adjacent South and Western Otago. The inclusion of parts of Otago reflects the cross-regional wood flows that are a part of the forestry industry in New Zealand's deep south.

This assessment seeks to complete the following objectives:

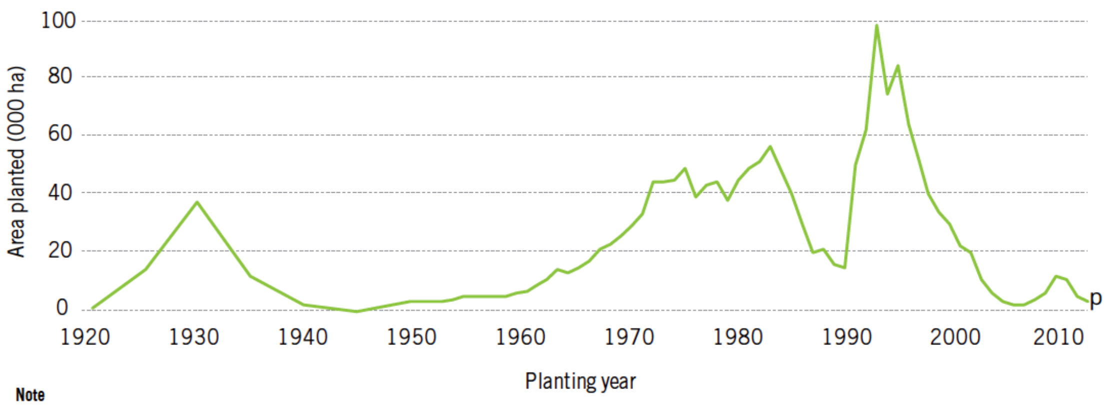
1. Evaluate the available woody biomass resources that are available to energy users in Southland.
2. Highlight the challenges and constraints to enabling a supply network, to identify solutions to overcome likely constraints, to identify the most profitable and effective supply chains, and to provide clear strategy to enable the sustainable delivery of wood fuel to potential industry users.
3. Evaluate forest owner's opinions and perceptions of a potential wood energy market for residues, and what is necessary to enable its success.
4. Investigate and assess the feasibility of supply chains for the recovery, transport, production, storage and distribution of green and dry wood chip.
5. Make recommendations for further research to better inform the development of an effective wood energy industry.

2.0 The Southland Forest Growing Industry

2.1 Forestry as a land use in Southland – history, current status and opportunities

Forestry has always occupied a strong place in Southland, though like other land uses has had its ups and downs over the decades. In the late 1980s a downturn in land values coincided with strong log prices, resulting in a significant prolonged spike in forest plantings. Between 1993 and 1996, new plantings rose over 15,000 hectares, with a diversification away from radiata pine to Eucalyptus species and Douglas fir. Between 1991 and 2005 the forestry estate expanded from 35,000 hectares to 89,000 hectares. The Eucalyptus species were planted on established farmland, and the Douglas fir was planted in the higher altitude catchments in the inland basins. Both species were contentious, the eucalyptus plantings for occupying pastoral land, and Douglas fir for the aesthetic impacts and risk of wilding tree spread (Ledgard, 2013).

Since 2005, the total exotic plantation forest area in Southland has declined by approximately 6,000 hectares. Forecasts indicate that both Otago and Southland are likely to experience further low-level deforestation, estimated at 3,900 hectares, between 2010 and 2020 (Manley, 2006). These trends are not unique to Southland, as demonstrated by Figure 4 below, showing annual plantings of exotic forests in New Zealand.



Note
1. This provisional estimate is compiled from a combination of information collected in a supplementary phone survey of selected large forest owners, known afforesters, and East Coast Forestry Project planting. The final estimate of new planting in the December 2014 year will be collected in the 2015 NEFD survey.
Symbol
p Provisional.

Figure 4 National forest plantings, by year (Source: National Exotic Forest Description, Figure 9.1, page 20. (MPI, 2014).

Today there is approximately 83,000 hectares of Southland land in forestry, the vast majority of which is considered plantation forestry (NEFD, 2014). 70% of the region's exotic forests occur in hilly country catchments on Land Use Classes 5,6 and 7 - where Land Use Class 1 is highly productive land and Land Use Class 8 is retired for non-productive uses. It has been predicted that the majority of land use changes in Southland will occur on higher land use classes, with changes between sheep and beef farming and dairying and vice versa. It is also expected that there will be some conversion from forestry into pastoral land (Ledgard, 2013).

2.1.1 Growing fast growing crops for wood energy – an opportunity?

Later sections of this report discuss the significance of the Southland Eucalyptus forest estate. Currently the existing Eucalyptus nitens resource is managed so as to produce chip for subsequent processing into paper. It is also a species that has good potential for bioenergy production. It has a basic wood density of 520kg / m3, compared to 420 kg/ m3 for radiata pine. Also, it possesses a relatively high wood density, has suitable chemical characteristics, exhibits low moisture content and can be easily harvested all year around using conventional machinery if single-stemmed growth form is maintained. Eucalyptus dries far more quickly than radiata pine, and as such provides the potential for less costly cartage.

Compared to radiata pine there is very little publically available information in New Zealand about Eucalyptus nitens. However, harvests of E.nitens in Southland have demonstrated final crop volumes crop volumes of 260 to 270 m /ha, at age 14 to 16. This indicates a mean annual increment (MAI) of 17 to 18 m3 per ha. As a comparison, Pinus radiata would have an MAI of 22 to 26 m3 per ha at age 28 to 30 and at age 15 the MAI would likely be similar to that of the E.nitens, though this is dependent on the stocking (Nicholas and Hall, 2010).

In order to expand the supply of biomass resource forest, there could be an opportunity to grow fast growing eucalypts for on an intermediate length rotation (10 to 15years). This would complement the existing volumes arising from the low value residues and existing unused residues from the predominately Pinus radiata / Douglas fir Southland forest estate.

Growing costs are similar to those for longer rotation softwood plantations. Whilst the rotation is much shorter the establishment costs of the first crop are higher due to higher planted stockings, and the harvest volume is reduced (ibid, 2010). Second rotation crops are less expensive to establish, due to the ability of the eucalyptus trees to coppice after harvesting. Harvesting costs are also expected to be similar to those for current conventional logging and transport costs will also be similar.

A major element of biomass productivity is species selection and site matching. Eucalypt species tend to be favoured because of their fast initial growth rate and ability to generate high stem wood volumes at an early age. However, more research is required to match species to site specifically for energy production (ibid, 2010).

Probably the biggest limitation to a dramatic development of a specific short-rotation wood energy forestry crop is the availability of suitable land at an appropriate cost. As discussed in later sections of this report, distance to market plays a significant role in the viability of carting wood residues for energy. Therefore any new wood energy forests – where energy is the primary product being sold from the forest - should be located within 50-80km of the end user. As this report describes, most of the large users of heat energy are located in areas surrounded by highly valuable agricultural land. Though small pockets of new forestry could be integrated into these landscapes, the extent will be limited. Greater opportunities exist further afield, in the hills to the west and east of Invercargill.

A specific evaluation of the profitability of growing short rotation energy crops in Southland would be required as the first step in developing a better understanding of this opportunity.

2.1.2 Southland Forestry and the Emissions Trading Scheme

Government emissions trading scheme initiatives, such as the Permanent Forest Scheme Initiative and the Afforestation Grant Scheme, appear to have made no obvious difference to the region's net exotic forest area (Ledgard, 2013). The stop-start nature of these initiatives, the lack of coherent government policy regarding climate change and emissions trading, and the dramatic downturn in carbon prices has stymied any carbon-related forestry investments in the region. Offset against relatively strong performances from both the dairy and red meat sectors, this has served to reinforce the predicted decline in net forest area.

Between 2013 and 2015 carbon prices dropped from $25/tonne to $3/tonne over a matter of months, settling at $6-$7/tonne in more recent times. A lot of this has been as a result of Europe's economic woes, but also due to a reduced Emissions Trading Scheme (ETS) that sees the delay of the introduction of other sectors into the regime, and an indefinite reprieve for agriculture. The ETS has also resulted in perverse outcomes such as large polluters (such as fuel companies and energy companies) making large windfall profits by buying cheap offshore credits to fulfil their obligations whilst still charging consumers for the full carbon price. The result to date is disillusioned forest owners and cynical investors who have little trust in the ETS and its intentions. As such, rather than achieve net afforestation New Zealand has experienced a fairly constant deforestation trend over the last seven years. It is hard to envisage a modified ETS being able to restore any trust in the short term, and therefore is unlikely to have any significant impact on new plantings.

2.2 Forest ownership breakdown for Southland

To understand the extent of forest ownership in the region, data was collected from a variety of sources. Existing sources included Ministry for Primary Industries (MPI) data, as well as regional information collected by the Southern Wood Council (SWC). This information was complemented by confidential information that was provided by all of the corporate forest owners within the region. Forest data was obtained for Council owned forests, but the managers of these forests were unable to participate in the interviews.

Lastly, as a part of this project, considerable time was spent in mapping all forest block across the Southland region. This exercise alone provides an accurate and up to date assessment of the Southland forest estate.

The following graph shows the proportion of forest area (in hectares) within each size class.

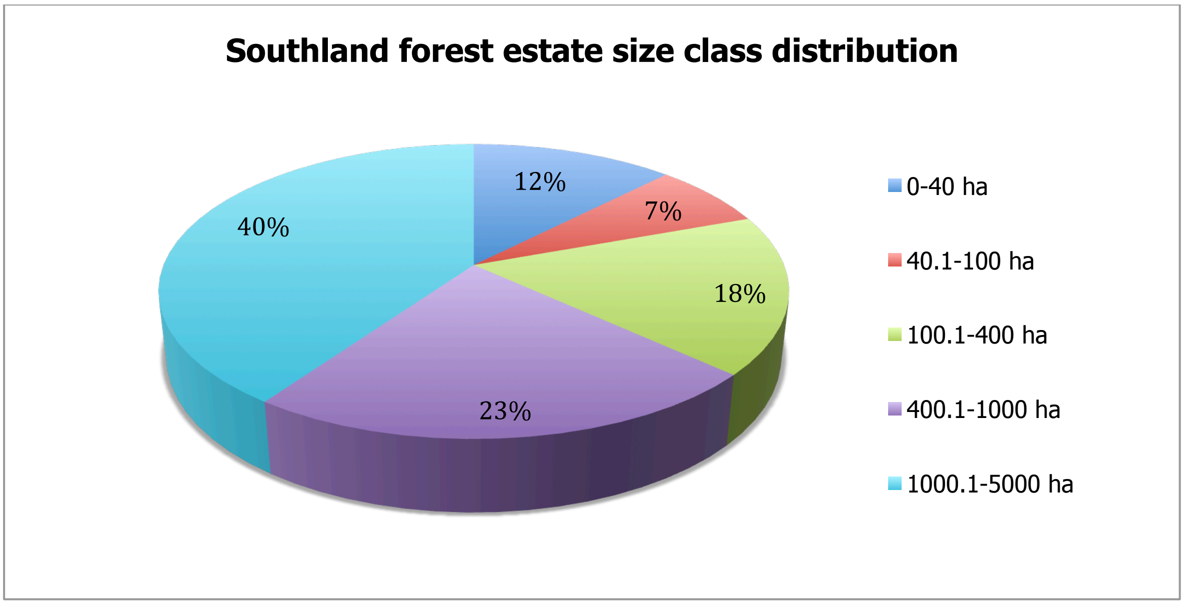


Figure 5 Forest size class, as a proportion of overall forest estate

The graph (Figure 5) above shows the distribution of forest size classes within Southland. It is important to note that these areas are based upon GIS mapping that was completed for this project, and represent physical forest stands across the region. The same owner, as described below, owns many of these stands.

2.3 The Large Forest Owner Estate

As described above, the corporate forest within the project area is significant, providing the backbone of the Southland forestry industry, and providing reliable woodflow supply to the downstream processing industry. The major forest owners are described in Appendix 1.0.

The corporate forest owners all have permanent harvesting contractors working within their forests, year round. At key times – such as buoyant log markets – additional, temporary, harvesting contractors, sometimes supplement their permanent forest harvesting capability. Much of the large corporate forestry estate is into its second rotation of forest crops, and as such has well-developed infrastructure. The established roading network lowers the overall cost of extraction in second rotation forests. In contrast, the smaller forests typically do not have established internal roading and are instead harvested in a piecemeal manner that incorporates forest roading as the harvesting activity progresses. For a proportion of smaller blocks this capital cost may make extraction uneconomic, or only viable during a log price spike.

3.0 Processing, Infrastructure, and Markets

3.1 Forest Harvesting and Infrastructure

The considerable forestry estate in Southland is characterised by good forest infrastructure, and a medium-scaled forest processing industry.

The Craigpine sawmill at Winton is the largest log processor within the Southland area, processing 200-250,000 tonnes of logs per annum into sawn timber. Niagara sawmill, in Kennington, is another large sawmill, processing between 180-200,000 tonnes of logs per annum. Other sawmills within the region include Pankhurst sawmill (40,000 tonnes of logs / annum) and a number of sawmills processing less than 20,000 tonnes logs / annum including Stuarts sawmill, Ngahere sawmill, Lindsay and Dixon, Findlater Sawmill, and Beven West milling

The medium density fibreboard (MDF) factory at Mataura is the other major processing facility in the region. Owned by Dongwha New Zealand, this processing facility has typically consumed between 350,000 tonnes and 390,000 tonnes of chip volume to produce the MDF product. Approximately two-thirds of this consumption is derived from logs, and the remainder as chip residue from sawmills.

South Wood Export Limited operates a stand-alone chipping facility at Awarua, 10 km south of Invercargill. Logs are chipped for export to Japanese pulp and paper manufacturers, chipping around 200,000 tonnes per annum of hardwood eucalyptus.

3.2 Port Infrastructure

The Port at Bluff – SouthPort - provides an essential component of the required infrastructure for the Southland forestry industry. Export volumes have increased significantly in recent times, as shown in the table below.

Table 1 Export volumes through SouthPort. (Source: MPI Quarterly Trade Statistics)

Year end March	(m^3) export logs	(m^3) sawn timber	BDU hardwood chip
2006	74,183	110,872	40,727
2007	91,816	70,027	59,208
2008	103,435	59,981	60,808
2009	101,371	81,169	39,009
2010	269,488	102,433	72,432
2011	301,357	115,261	90,132
2012	208,938	140,515	80,630
2013	314,743	123,455	81,943
2014	395,503	110,050	78,872

The relative consistency of export sawn timber volumes and export hardwood chip volumes are apparent in the graph below. Likewise, the significantly increasing log export volumes are shown in the graph below. Log export volumes have increased from volumes in the vicinity of 100,000 m^3 / annum between 2006 and 2009, to between 250,000 m^3 and 400,000 m^3 in the years 2010-2014.

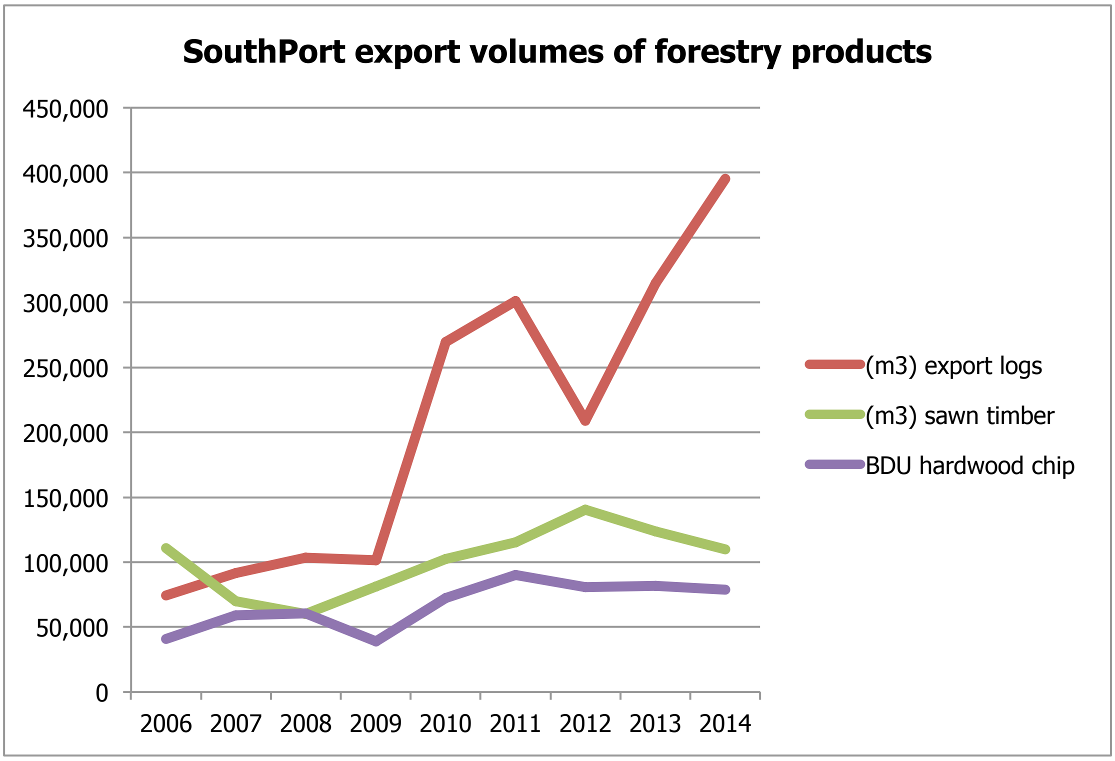


Figure 6 Volumes of exported forestry products, from South Port

4.0 Wood Availability Forecasts for Southland

The primary objective of this study is to understand the future security of supply of log residues in the Southland region. As such, considerable attention has been paid to assessing the forest biomass resource within the project area. In producing this report we have collected information from a variety of sources, including national databases, council databases, project-specific mapping of local resources, and from targeted interviews with corporate forest managers.

4.1 Background

In 2014, the forestry consultants Indufor Asia Pacific Limited (Indufor) completed wood availability forecasts for the Ministry for Primary Industries (MPI). The regionally focussed forecasts were developed to inform local industry, councils, infrastructure and service providers to assist in their planning needs. These forecasts for Otago / Southland (2014) have been used as the basis for discussion of the availability of wood at a regional level and as such, the potential availability of woody biomass.

Indufor prepared four production scenarios for radiata pine potential wood availability, one for Douglas-fir availability, and one scenario that combined radiata pine and Douglas fir. The scenarios demonstrate possible scenarios for harvesting the Otago-Southland forest resource in the period 2014-2050. The scenarios are based on the available resource in each region, alongside a series of forecasting assumptions (Indufor, 2014).

The forecasts are generated from the harvesting intentions of the region's large-scale forest owners, being those with greater than 1000 hectares. The scenarios were then used as the basis for consultation with forest managers and consultants, ensuring they provided realistic representation of the industry. A high degree of confidence is placed in the harvest intentions of the large forest owners, due to their consistent harvest programmes.

The intentions of the small forest owners are less obvious, with the timing of harvest being influenced by a range of factors. These factors include: individual forest owner objectives, forest age, log prices, current demand by proximate wood processors, and perceptions about future log prices (Indufor, 2014).

4.2 Southland Wood flow availability forecasts

In Figure 7 below, the large-scale owners resource is shown as the "base" volume, in blue. The fluctuations in the total annual forecast volumes reflect the variations in the areas of the small-scale owners estate, and the assumption that all radiata pine is harvested at age 28. This base scenario is incorporated simply to provide an overview of the fluctuations in the forest estate.

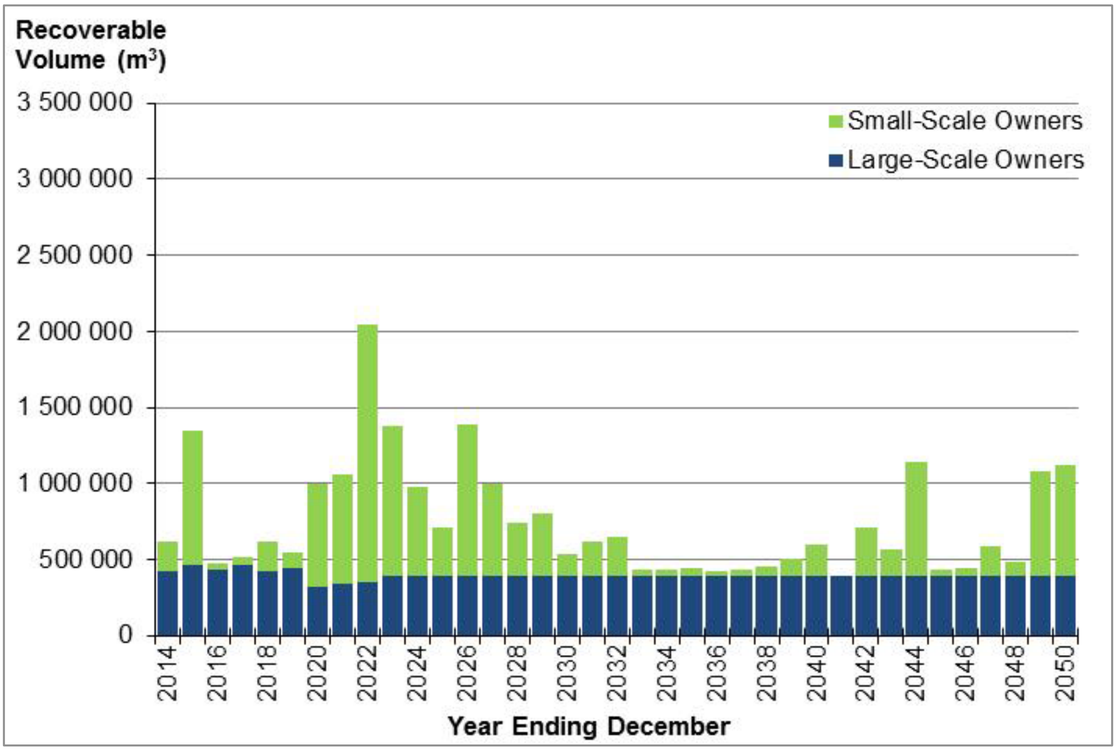


Figure 7 Southland Region's Radiata Pine availability, under scenario 1, harvest occurring at age 28 (Indufor, 2014: 22)

The large increase in harvest volume after 2019 reflects the maturing of the small-scale owners' estate. For example, the increase in 2020 is a consequence of the 1,313 ha planted by small-scale owners in 1992 being harvested at age 28 years.

Fluctuations in harvest volumes of the magnitude shown the figure above would be impractical due to operational constraints (for example: availability of harvest machinery, harvesting crews and transport operators) and market absorption constraints (for example: limited domestic wood processing capacity, levels of export demand), (Indufor, 2014:22).

4.3 Douglas-fir & Radiata Pine Combined, across Southland.

Feedback from major forest owners in the region suggested Douglas fir was often used to fill gaps in the radiata harvest profile. In the figure below, a non-declining yield constraint is modelled at a combined level for the radiata and Douglas-fir estate. The results suggest that from 2029 a sustainable harvest of 1.00 million cubic metres per year (1.2 million tonnes) is possible from the combined radiata and Douglas fir estates, with the Douglas-fir harvest increasing in significance from 2029 onwards (Indufor, 2014:28).

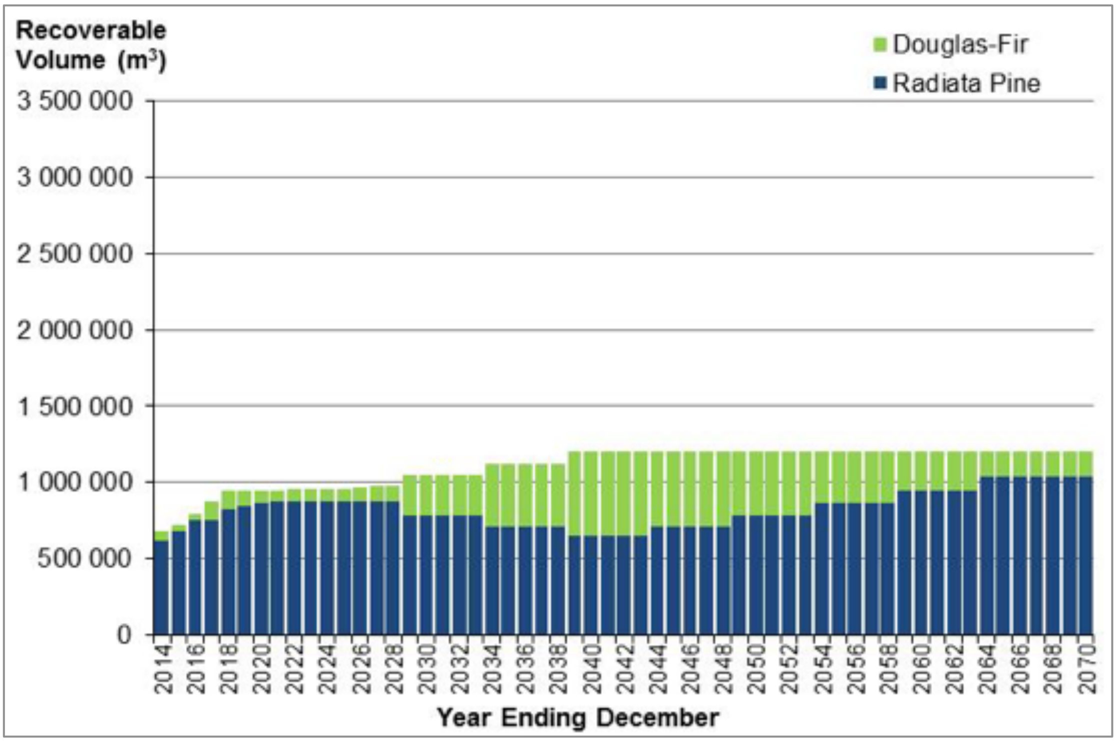


Figure 8 Southland Region's Combined Availability of Douglas-fir and Radiata Pine, including volumes from Douglas fir production thinnings (Indufor, 2014:28)

One of the impacts of combining the radiata pine and Douglas-fir harvests is that the Douglas-fir harvest tends to be delayed to boost the total volumes once the radiata pine planted during the 1990s has been harvested. However, an analysis compared the rotation ages from the Douglas-fir only scenario, and the combined Douglas fir and radiata pine scenario. It was found that there is little difference in terms of harvest age between the two scenarios, meaning that the Douglas fir can be typically harvested close to target rotation age (ibid, 2014:17).

Most of the potential increase in wood availability from 2015 onwards will come from the region's small-scale forest owners who established forests during the 1990s. Market conditions and logistical constraints will determine the actual rate of harvest increase, and to what level is reached.

4.4 Eucalyptus forest estate

It should also be noted that the significant-scale short rotation eucalyptus resource is not included in the wood availability forecasts (ibid, 2014:35). The eucalyptus estate adds an estimated additional 200,000 tonnes per annum of harvest volume. Currently all of this 10,500-hectare eucalyptus forest estate is export-focussed, but if domestic pricing is competitive there is an opportunity to divert portions of the annual 200,000 tonne of chip production into the domestic energy market.

Southland Plantation Forest Company of New Zealand Limited (SPFL) appointed Southwood Export Limited (SWEL) to manage this plantation. The SPFL estate is comprised of forty individual forests where planting began in 1992. These forests are located within Southland/ Otago and are grown on a renewable basis.

5.0 Assessment of specific forest areas within Southland.

Proximity to the end user is important for the viability of a successful wood energy market, due to the impact that cost of cartage has on the profitability for the forest owner. As such, this report has sought to provide a more refined analysis of the forest estate in specific parts of Southland.

For the purposes of this assessment the Southland region was divided into four portions, each including a specific end user point. The end user points were generated from "demand scenarios" provided by Venture Southland, each of them depicting potential scenarios for industry uptake of wood fuel. The end user destinations are Te Anau, Tuatapere, Invercargill and Mataura, as shown in Figure 9 below.

Within each forest area the forest areas have been mapped, size classes derived, and proximity of end user to forest estate categorised. Lastly, the age class distribution for the forest areas managed by corporate forest owners was evaluated, using the age-class stand data that they kindly provided. Given the dominance of the corporate forest owner estate, the age-class distribution of the corporate estate provides a very good indication of the reliability of the forest resource in each of the four areas.

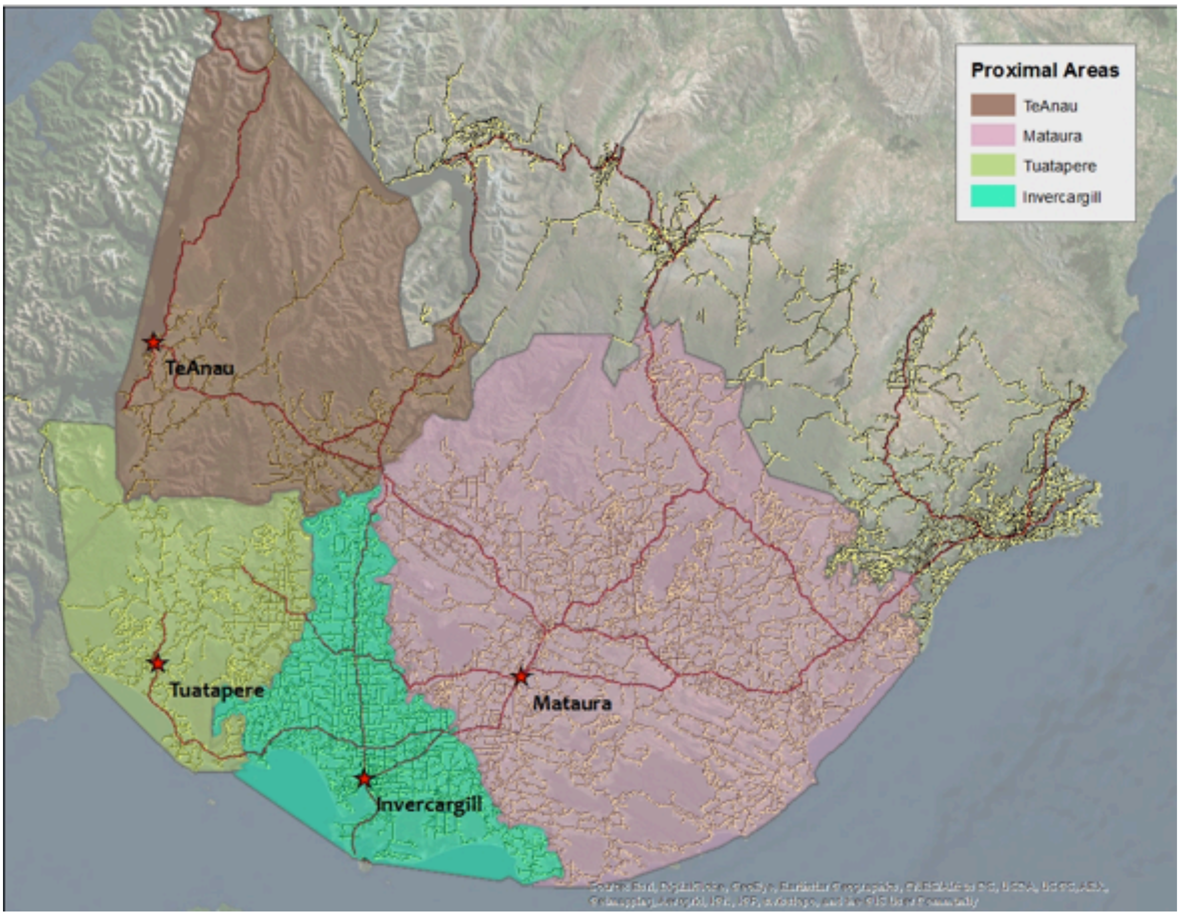


Figure 9 End User Destinations and Forest Catchments in Southland

Figure 10 below shows the extent of the Otago region that has been assessed in this project.

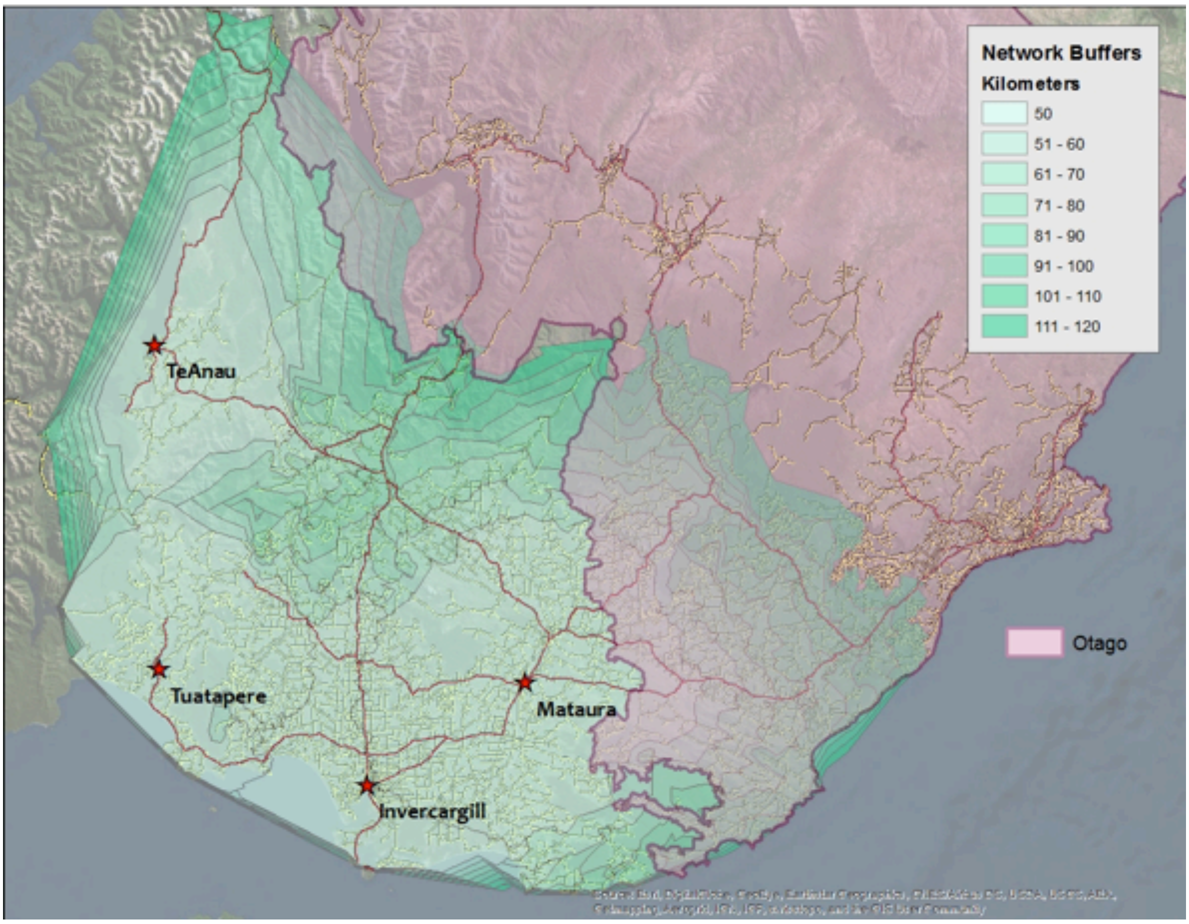


Figure 10 Extent of forest assessment areas, including portion of the Otago region

5.1 Distribution of forests within the study area

As discussed, the forests across Southland were mapped and then categorised into size classes. To reflect the realities of cross-regional log flows, an additional area in Otago was subsequently mapped but was limited to forest areas greater than 100 hectares.

Figure 11 provides an overview of the distribution of the forest estate across Southland, demonstrating the areas of the region that are densely populated by forests, and those that are less so.

GIS mapping was used to assess the proximity of forest areas to the four destinations, incorporating all forests greater than 0.5 hectares. This process involved establishing polygons in a 50km radius of the end destination, then increasing in 10km intervals until a 120km radius around the end destination is achieved. 120km was chosen, after consultation with Forest Managers, to reflect the outer limits of feasibly economic cartage of low value residues. The radiuses are generated from the roading network, thus reflecting true distant to end point rather than a straight-line radius.

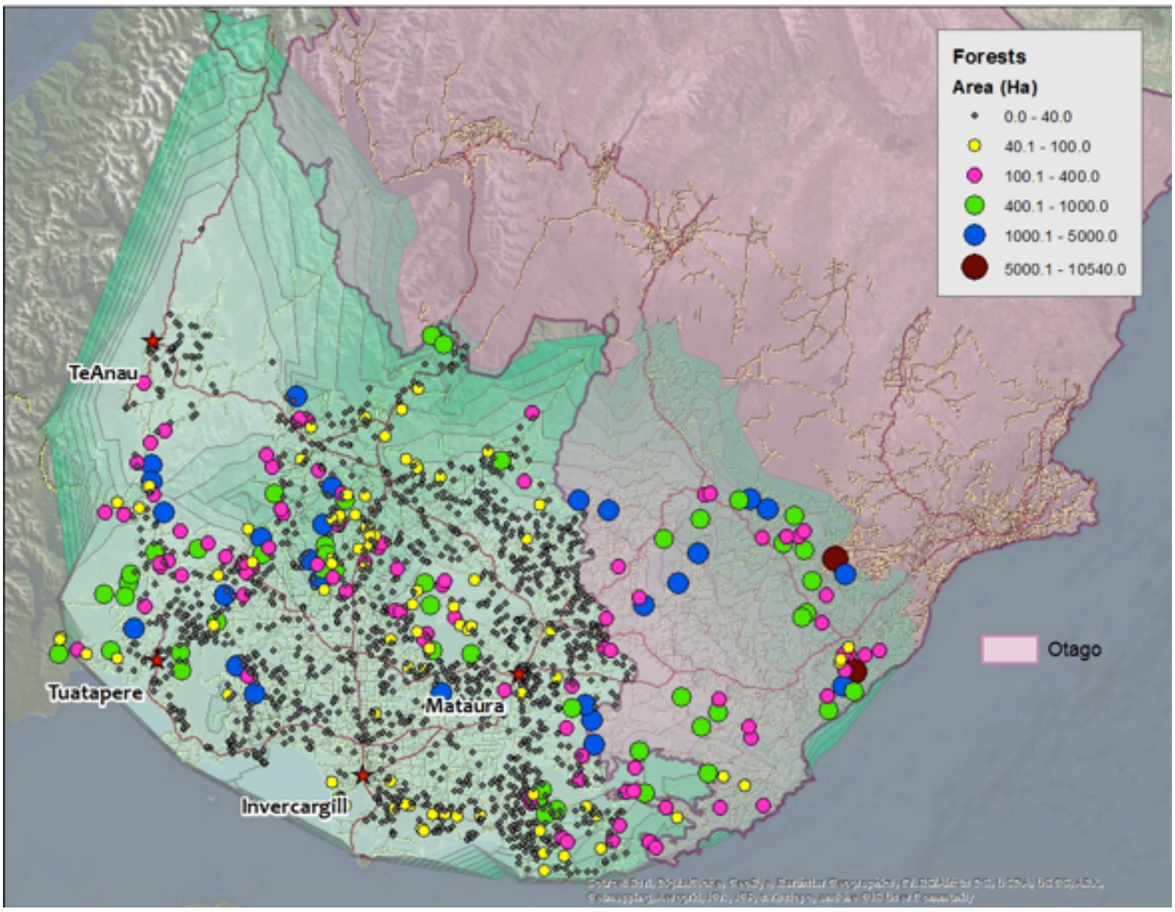


Figure 11 Distribution of forests across Southland, and larger forests within part Otago

Figure 12 below provides a graphical summary of the area of forests that are within various distances of the end user destinations. It shows that Mataura is the best-positioned site for capturing existing wood flow, followed by Invercargill, and then Tuatapere.

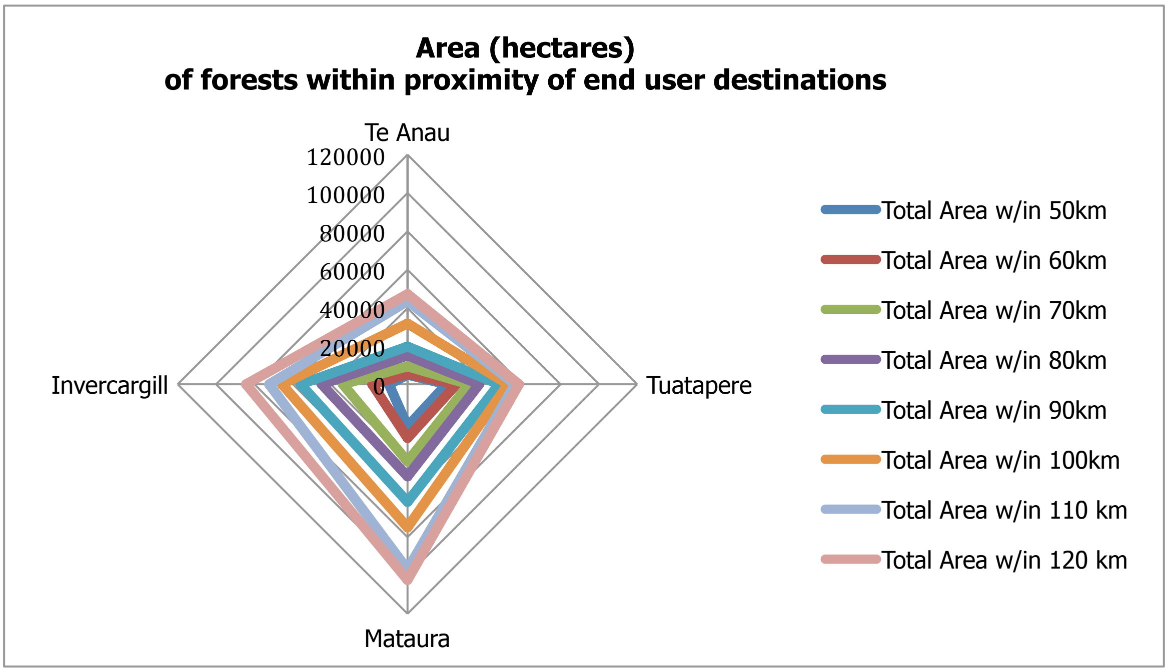


Figure 12 Area of forests within proximity of the end user destinations

5.2 Tuatapere Wood Catchment

A well-known area for forestry in Southland, Tuatapere was selected as an example of a small Southland town that could potentially generate its energy from wood residue. Though this is not a likely situation, it never the less provides another lenses through which to evaluate the local availability of wood residue.

Shared by three corporate forestry companies, some large plantations exist within the Tuatapere area, though some are now on the low side of the supply yield. The combined Douglas fir-radiata pine resource is lumpy, reflecting recent large-scale harvesting activity across this area. The eucalyptus plantation resource is significant, and being over 6000 hectares in size, is a considerable short-rotation forestry resource that will provide regular yields into the future. Owned by the Southern Plantation Forestry Company, these forests located in the west of the region are the most remote of its forests and are the most distant from the chipping facility at Bluff.

The Tuatapere area is well stocked with smaller forests, typically larger farm forestry blocks, or private syndicate forests. These forests will help to "fill in" gaps in the corporate estate, providing some potential to smooth out wood flows.

The sawmills in the area all supply existing outlets, primarily dairy farms, with their existing sawdust, and wood chip.

Figure 13 and Figure 14 below provide graphical descriptions of the forest resource within distances of Tuatapere. These figures demonstrate a considerable resource, growing steadily as distance from Tuatapere increases.

For wood energy to compete as a log grade against existing chip logs (to Mataura) and pulp logs (to Bluff), their gross value (at end user) would need to be $50-$55 / tonne. Billet wood type energy logs would also need to be valued at $50 / tonne, reflecting the extra cost associated with carting this product.

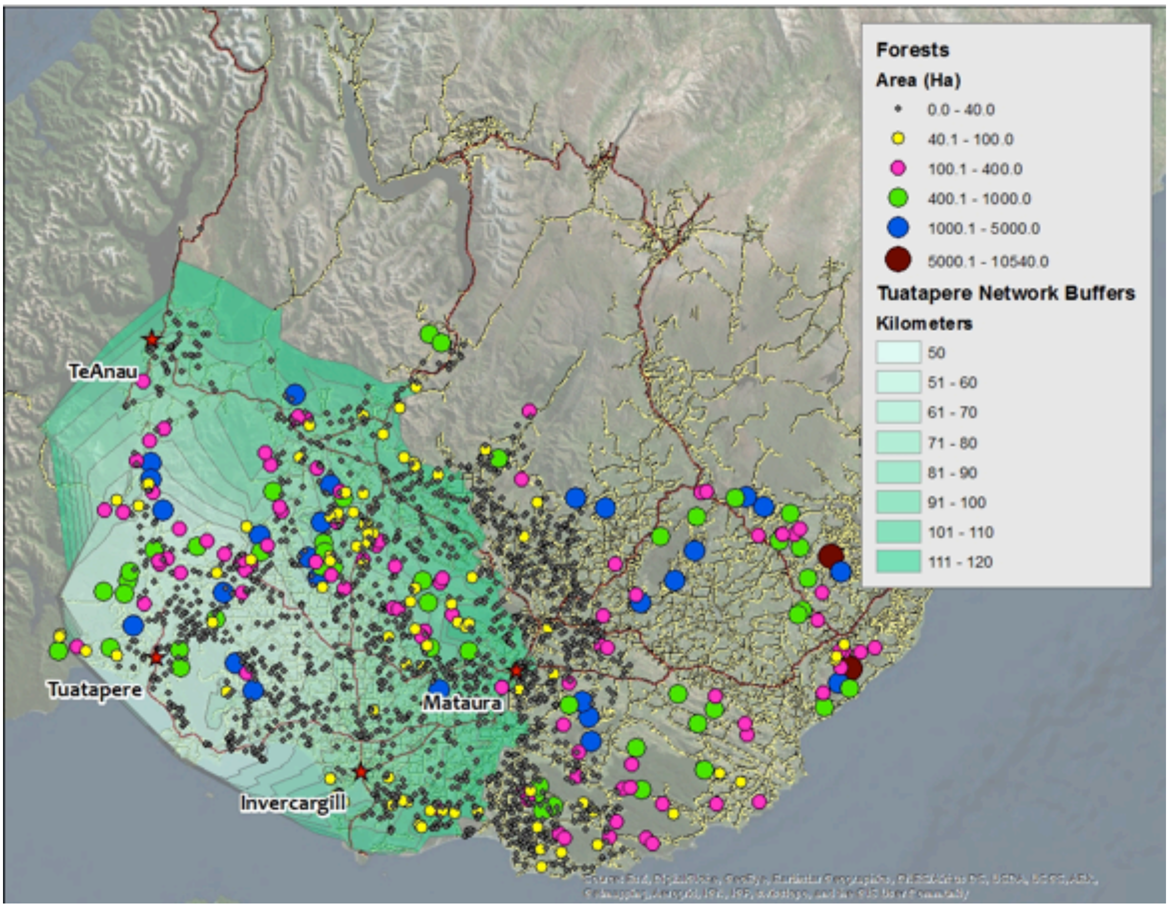


Figure 13 Forests in proximity to Tuatapere

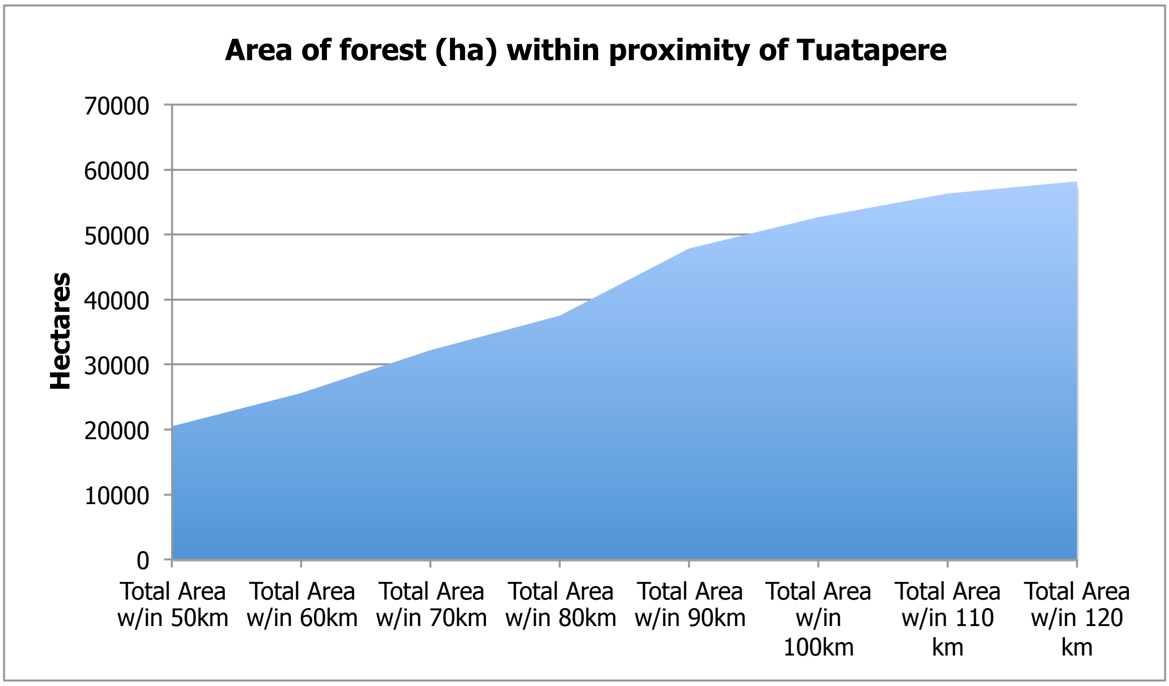


Figure 14 Hectares of forest within proximity of Tuatapere

5.3 Te Anau Wood Catchment

Te Anau, located in the northwestern corner of Southland, is a growing and dynamic corner of the region. Predominately a rural service town, it also has a well-established tourism sector, but is lacking any processing industry of scale and as such, any large-scale energy consumer.

Reflective of the higher-altitude of the Te Anau basin and surrounding area, forestry in this area is a less-established land use sector than other parts of Southland. As can be shown in Figure 15 and the corresponding Figure 16, there is only a small amount of forest area within 50 km of Te Anau, and this is a mix of small farm forestry blocks, and a mid-scale Douglas fir plantation that has a narrow age class distribution. It is not until a large 100 km – 110 km forest catchment is mapped that the forest resource becomes of scale, incorporating some of the larger corporate forests to the east and the south of the Te Anau basin. Three corporate forestry companies have interests in this area, with the three key species of eucalyptus, Douglas fir and radiata pine dominating. Individually, none of the three companies provide consistent or even wood flow from the Te Anau forest area. However, as a collective, their age class distributions provide a reasonable consistency of wood flows from this area.

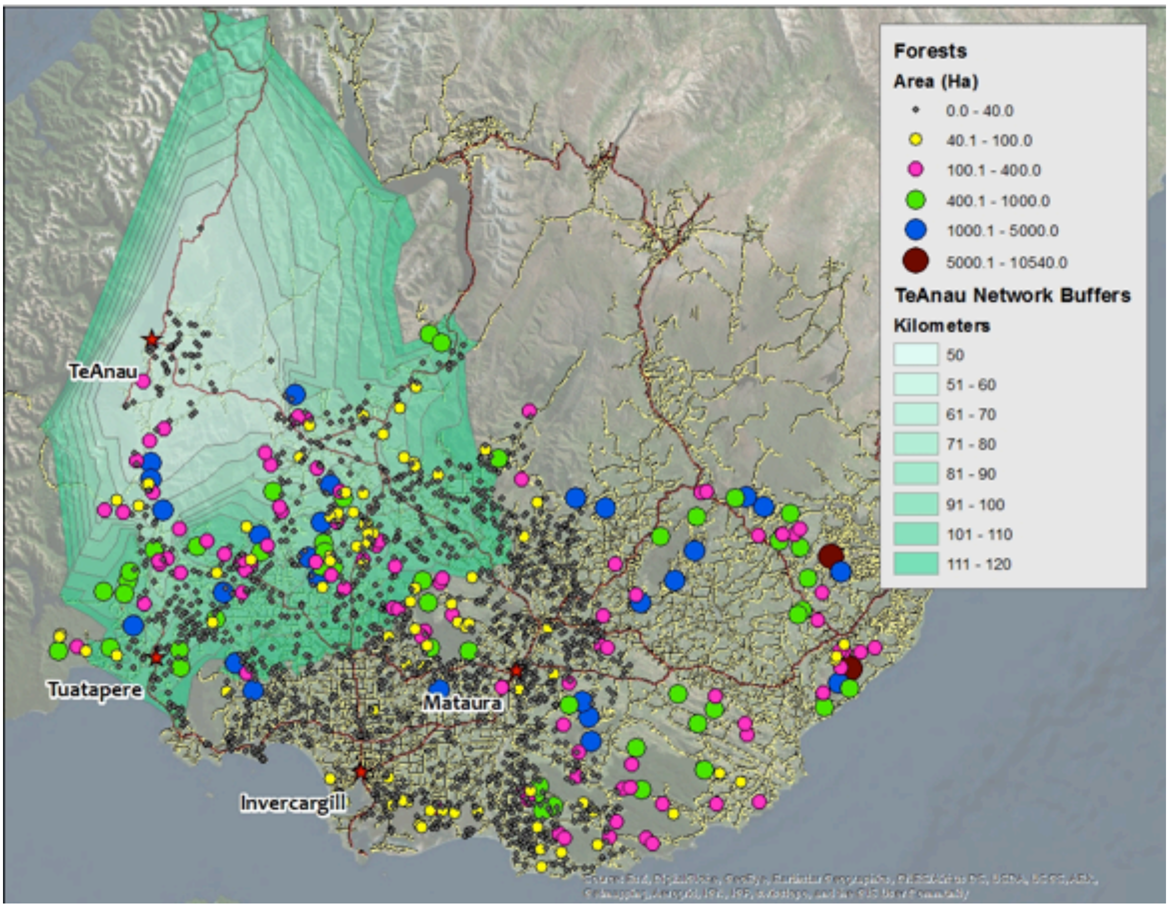


Figure 15 Forests in proximity to Te Anau

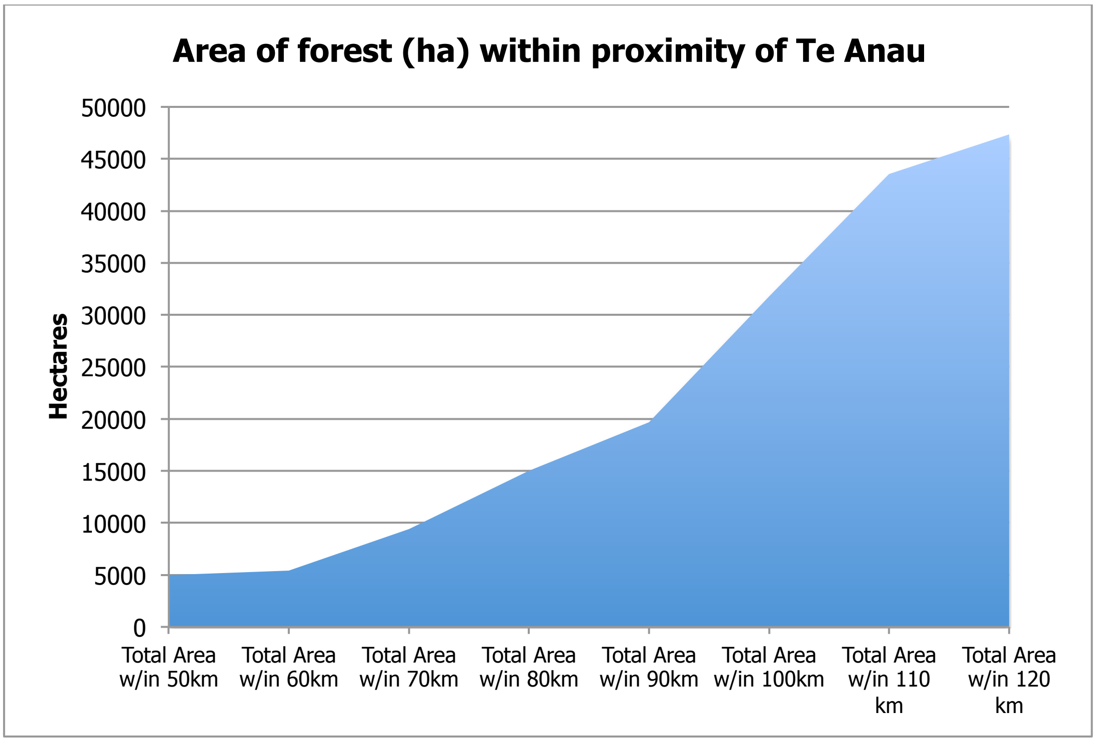


Figure 16 Areas of forest within proximity of Te Anau

Due to Te Anau township's distance from the forestry resource, and its relatively isolated location, any wood energy industry based in Te Anau would be reliant on the importation of either the processed energy product or logs for consistent energy flows. For most cartage operators a delivery into Te Anau would be a one-way cart, without prospect of return backloads, thereby adding to the cost of the delivered energy.

Corporate forest owners to the east of Te Anau, in the Lumsden and Garston area, are relatively proximate to Queenstown. The rapid development within Queenstown and surrounding environs provides good opportunities for a wood energy industry to be established in Central Otago, and though this will also often require a one-way cart, is more likely to provide the scale of demand necessary to establish long-term relationships with the forestry sector. By contrast, Te Anau is of small-scale, and is unlikely to provide the scale of demand for wood energy to become a reliable and cost effective means of delivering energy.

For Te Anau-based forest owners to viably supply the wood energy market in Invercargill or Mataura, the price paid for the chip-type log would need to be a minimum of $50-$55 / tonne. At $50/tonne it would compete favourably against domestic markets at Mataura, and at $55/tonne will compete against the longer-term average for export pulp. It is important to note that for any of these markets, forest owners are breaking even on these lower grade logs. The distance from market creates higher cartage cost which diminish prospects of profitability.

5.4 Invercargill Wood Catchment

A number of large scale processing industries, such as the Alliance meatworks at Lorneville and Open Country Dairy processing factory at Bluff, are located close to Invercargill. In addition, some Invercargill-based public services (such as hospitals) operate from Invercargill. As well as the Port at Bluff, there are other large wood processing facilities located close to Invercargill, most notably the Niagara sawmill.

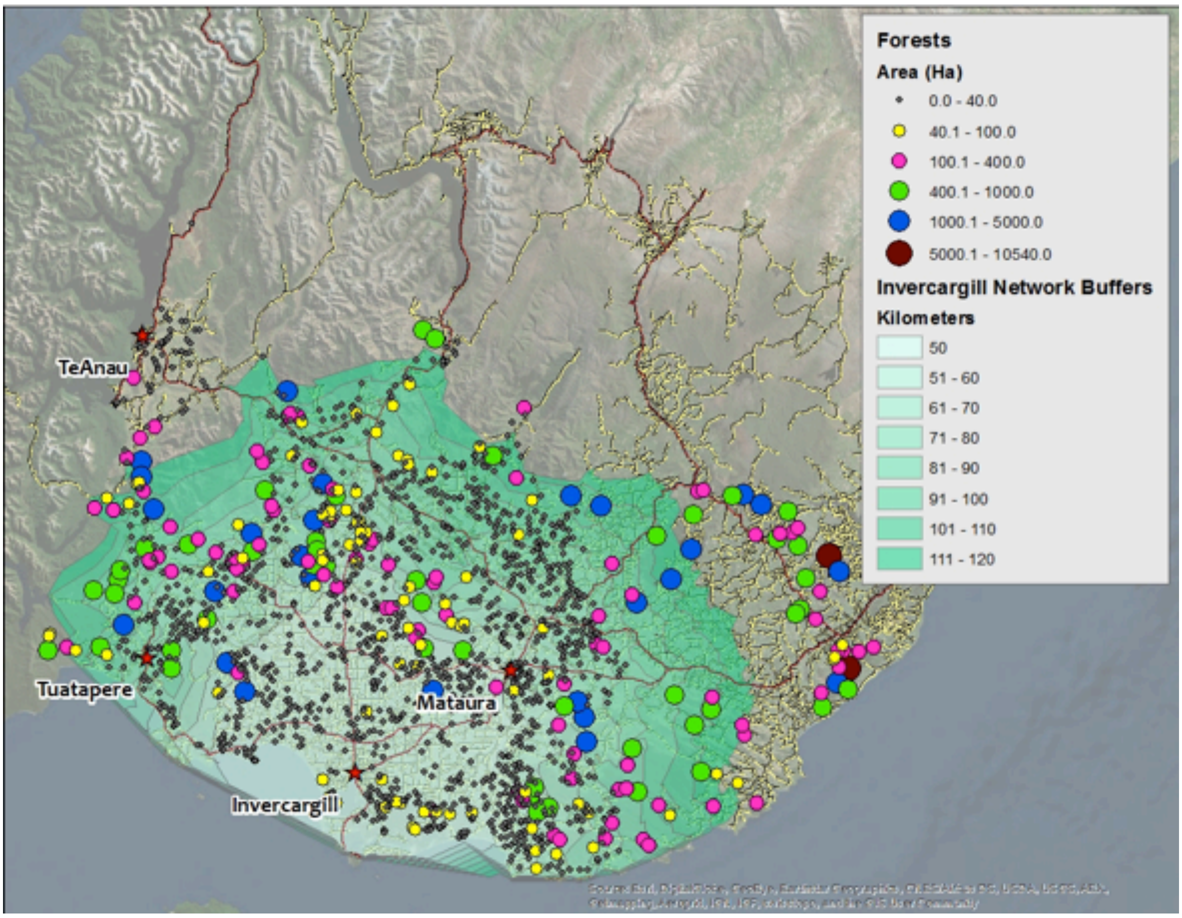


Figure 17 Forests in proximity to Invercargill

As shown in Figure 17 the fertile plains that surround Invercargill are devoid of larger plantations, with the odd exception on the south coast, and are instead littered with small-scale woodlots and shelterbelts. Many of these smaller forest areas have been harvested in recent years, and have not been replanted. As such, a declining forest resource is probable in this part of the region.

In areas between 60km and 70km from Invercargill (beyond the likes of Mataura), as the landscape becomes increasingly hilly, there is a marked increase in the presence of mid-large scale forest stands. Corporate ownership of forests is interspersed with larger privately owned forests, and a continuation of smaller scale farm forestry. The potential for the Otago forestry resource to contribute to Invercargill's consumption is demonstrated in Figure 18 below.

The proximity of the MDF processing plant at Mataura, and the relative proximity of the port at Bluff means that the price paid for wood energy logs, at a chip-grade specification, needs to be at $55 / tonne for it to compete against these other existing markets. Billet wood also needs to be at $48-$50 / tonne for it to compete.

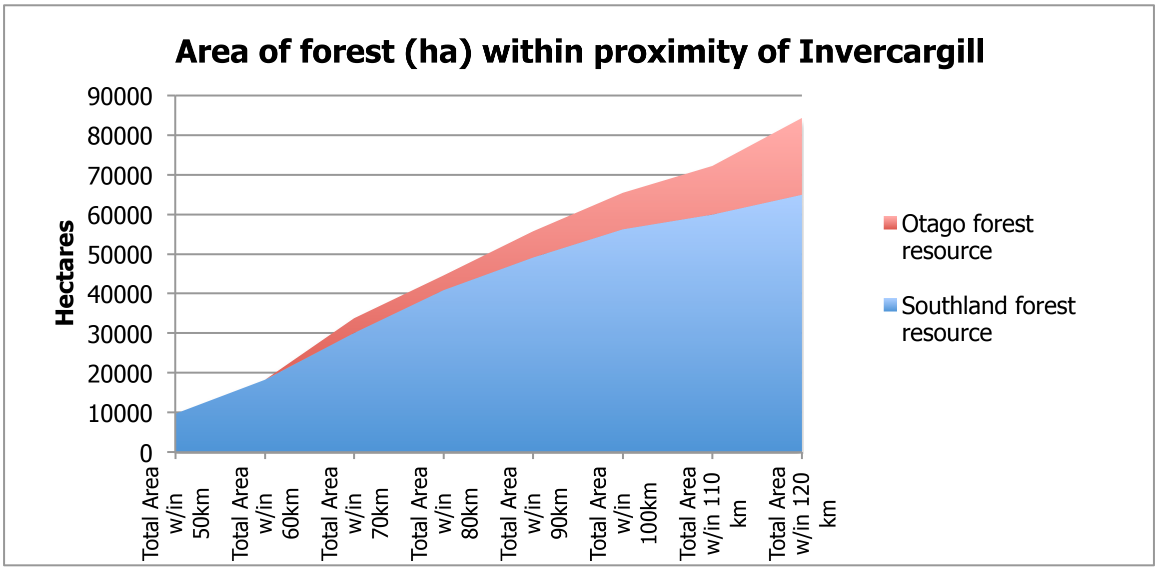


Figure 18 Area of forest within proximity of Invercargill

5.5 Mataura Wood Catchment

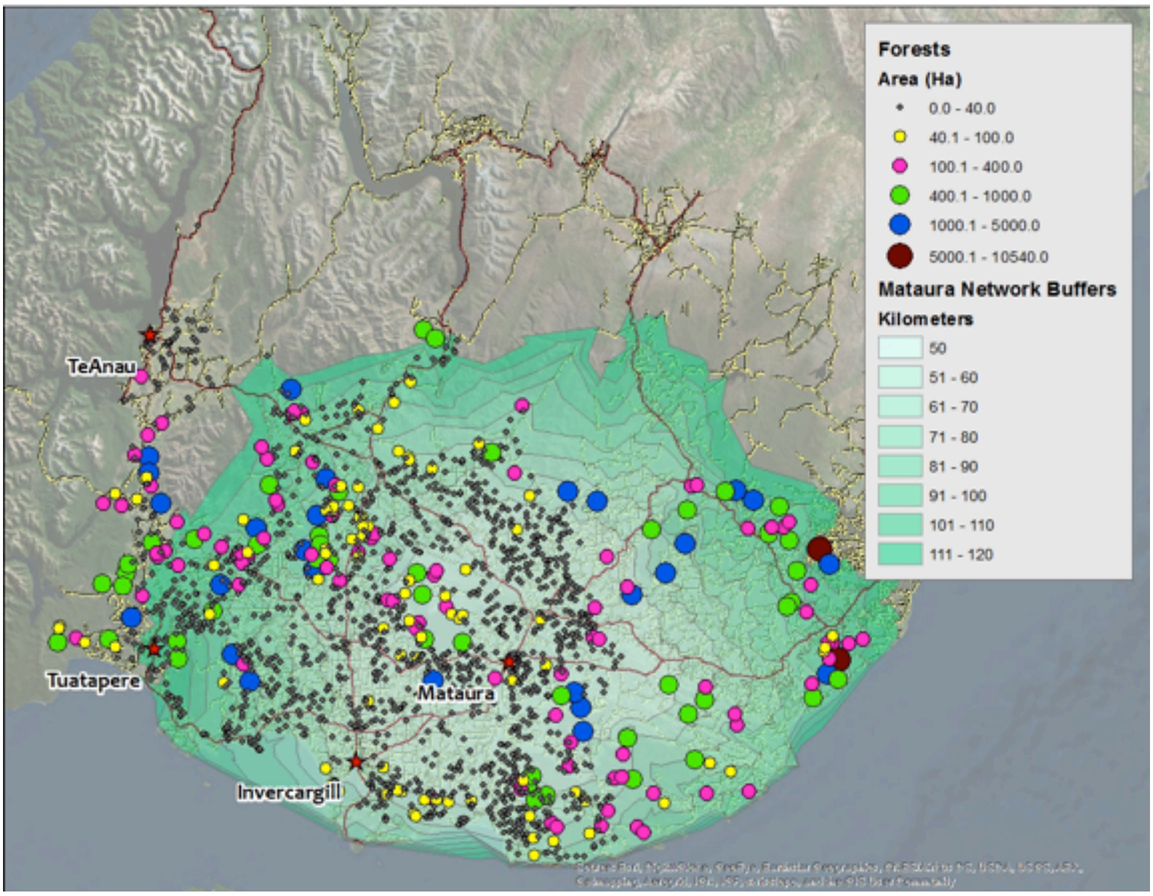


Figure 19 Forests in proximity to Mataura

Figure 19 above clearly shows that Mataura, located 50km north of Invercargill, is in the heart of a combined Otago / Southland forestry resource. The positioning of the MDF processing plant here speaks of its proximity to forest resources, and also to the port facility at Bluff. As shown above, there are a number of larger forests within a short distance of this area. This is reinforced in Figure 20 below.

Four major corporate forest owners manage sizeable portions of their estate within this area, three of which are predominately radiata pine / Douglas-fir forests, and one is growing eucalyptus. Collectively these corporate forest owners provide a consistent and increasing wood flow into Southland sawmills and export markets.

The considerable South Otago forest estate is close by and provides much of the wood flow into the Southland region. Being underpinned by corporate forest owners, the South Otago forest estate is forecast to provide consistent supply, as well as much of the forecast growth of forest volume in the south.

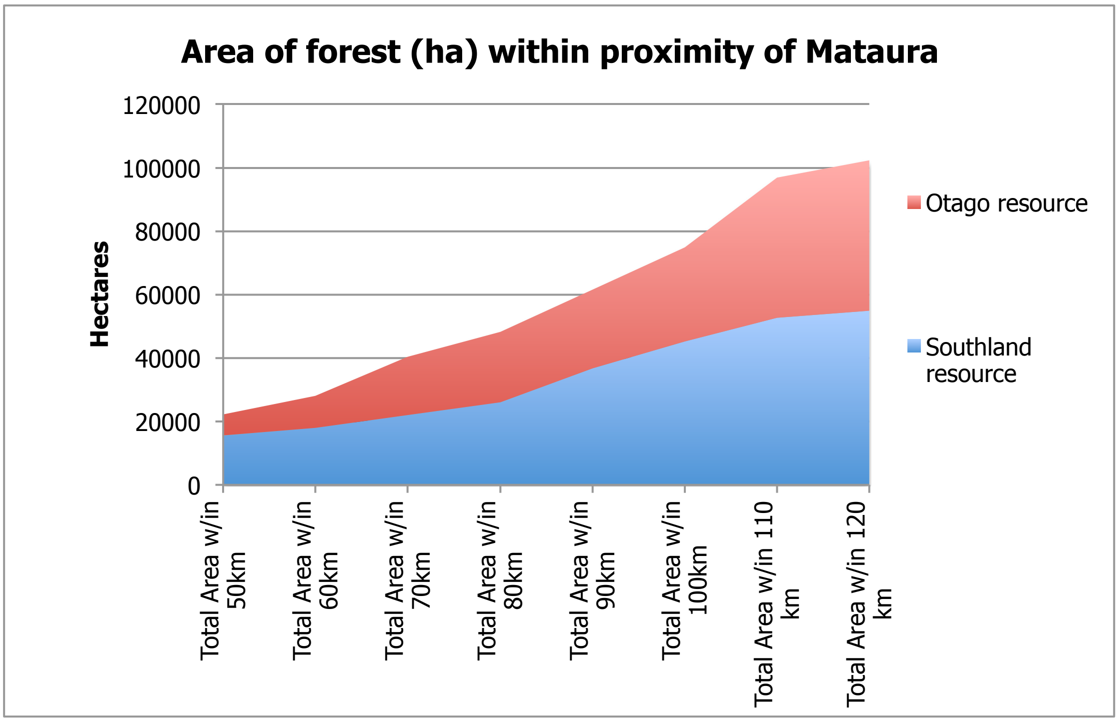


Figure 20 Area of forest within proximity of Mataura

The proximity of the MDF processing plant at Mataura, and the relative proximity of the port at Bluff means that the price paid for wood energy logs, at a chip-grade specification, needs to be at $55 / tonne for it to compete against these other existing markets. Billet wood also needs to be at $48-$50 / tonne for it to compete.

5.6 Summary

Beyond the Southland Plains themselves, there is a strong band of forests present across the hill country to the north, east and west of Invercargill. Of the four forest areas described in this section, only the Mataura forest area could feasibly stand alone as a supply catchment for proximate end users such as the Alliance meatworks at Mataura, the

Silver Fern Farms processing plant at Waitane, or the Fonterra Dairy Processing Plant at Edendale.

Invercargill, as the other major point for energy demand, requires supply from each of the assessed forest areas so as to ensure consistency of supply. This reflects the distribution of the corporate forests and the fact that corporate forest owners manage their dispersed estates as one whole, drawing upon forest resource from each area as a part of their harvesting strategy. As such, large energy users, such as Alliance meat works (Lorneville), Open Country Dairy (Bluff) and the Southland hospital, would need to utilise log resource from across the region to meet their needs. This is similar to any other log market.

The Tuatapere and Te Anau forest areas contribute to the regional resource, providing important volume to the overall Southland estate. As end user destinations they are not of high importance, though do have the potential to become independent and resilient energy users.

For the wood energy market to compete strongly with existing domestic and export markets for lower value residues, end users will need to pay in the vicinity of $55 / tonne for a wood energy product of similar grade to chip logs. Wood energy end users will need to pay between $45 and $50 / tonne for billet wood-type log grades, reflecting the extra cartage costs associated with these smaller logs. These prices would need to be relatively consistent across the region, providing competitive prices to those forest owners who are proximate to existing markets (e.g. forest owners in the Mataura and Invercargill forest areas) and providing viable prices for those forest owners who are distant to markets (e.g. Te Anau and to a lesser extent, Tuatapere). These prices will need to fluctuate, particularly in response to export log market prices. As such potential users of wood energy will need to allow for price increases, beyond those of inflation adjustments.

6.0 Assessment of wood energy resource availability in Southland.

As well as evaluating industry forecasts of expected harvest volumes, this study has sought to ground truth the forecast information with the most recent data on actual log and wood volume trade. Export data has been collected from log traders, and sawmill consumption data collected from sawmill managers. In addition forest managers from each of the large forests participated in this assessment by taking part in one-on-one interviews.

The Indufor report forecasts a combined Radiata pine / Douglas fir Southland harvest volume of 700,000m3 for the 2014-15 year, or 825,000 tonne. With the addition of the forecast eucalypt harvest of 200,000 tonne, it is anticipated that in the 2014-16 years an annual harvest of 1-1.1 million tonnes is likely. Based upon the ground-truthed data, interviews with processors and log traders, estimates of the log flows in Southland have been created, and are shown in Figure 21 below.

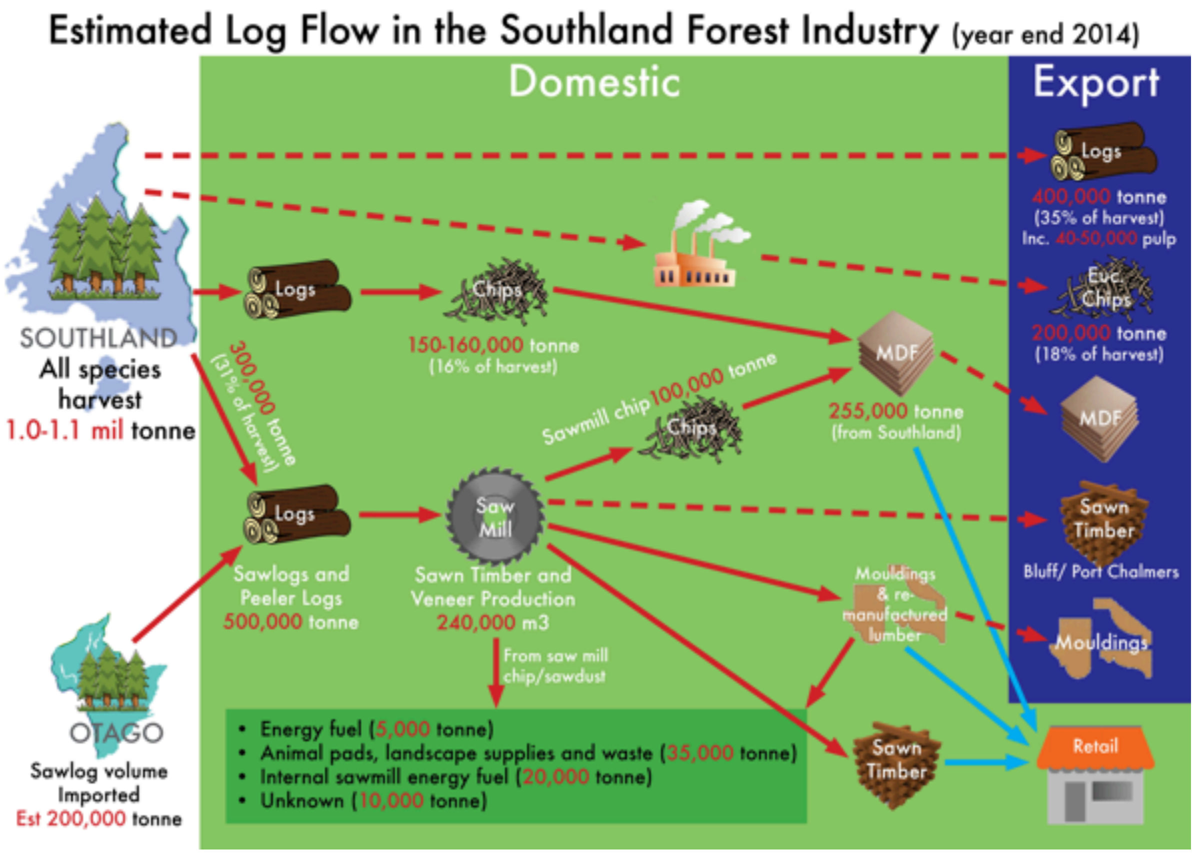


Figure 21 Estimated woodflows in Southland, for the 2014 year

Current harvest volumes in Southland are in the vicinity of 1.0 million tonnes / annum. This includes 200,000 tonne of eucalyptus, specifically harvested for the export chip market. 400-450,000 tonnes of logs are being exported, of which 40-50,000 tonne is the export pulp grade. 150-160,000 tonnes of logs are supplied to the MDF plant at Mataura, including 10-20,000 tonne of billet wood. The remaining logs are processed locally, complemented by log imports from Otago. The sawmilling process produces an estimated 170,000 tonne of wood chips, of which 100,000 tonnes is destined for the MDF plant.

30-40,000 tonne of woodlots and shelterbelts are harvested and chipped on site by portable chipping operators. This wood chip supply is currently for the dairy herd home market.

6.1 Estimated annual volumes of low-value residues produced in Southland

Woodflows from across Otago and Southland are planned to increase significantly in forthcoming years. Already a considerable industry in the southern regions, forestry is soon to become even larger and significant as a contributor to the regional economy. Over the next decade there will be an increase in the expected harvesting across the Southland region, increasing in steps from the current harvest of 1,000,000 tonne, through till 2040 when a new sustainable harvest yield of 1,500,000 tonne will be reached.

Currently the lower value logs from the Southland regional forest estate (chip / pulp) are sold to a mixture of local markets, clearly dominated by the Dongwha MDF plant at Mataura, and the balance heading across the Port at Bluff to the export pulp market. The proportional split of destinations for these markets is dependent on the forest owner, their market agreements, and their proximity to the markets. However, in Southland it is common for 60-75% to be sent to the domestic market, and the balance exported. Forest owners closer to the MDF plant shift greater proportions of their product to the domestic market. All major forest owners have contractual agreements with Dongwha, and view this outlet as a cornerstone component of the domestic market.

Forest owners generally agree that the current price paid for chip logs at Dongwha is moderate, but recognise the value of the consistent outlet and the relatively stable pricing. The volatile pricing of the export market is well known, and though not limited to the forestry industry, is an attribute that is often associated with it. The volatility of the export log market has been suitably demonstrated over the last three years, shown in Figure 22.

Though forest owners appreciate the periodically high prices of the export market, they also appreciate the stability of the domestic market. Forest owners recognise the need to support the domestic market, even in times of buoyant log prices, so as to ensure the continuity and viability of a domestic market for lower value logs. However, all of the forest owners spoken to expressed support for an additional competitive market for low value residues. The location of the end user market will dictate its importance to the forest owner, just as the MDF plant does now.

The increasing regional forest volumes will provide forest owners with the ability to service existing domestic markets, as well as new markets. Proximity to market place is critical, as is the provision of a stable log price which can provide consistency to forest owners in periods of fluctuating export commodity prices and concurrently continue to be a competitive market when export prices are buoyant. Given the steady-state demand from Dongwha for chip logs, there will be an increasing proportion of the lower value logs available for sale to markets beyond the Dongwha MDF market as the regional forest harvest volumes increase.

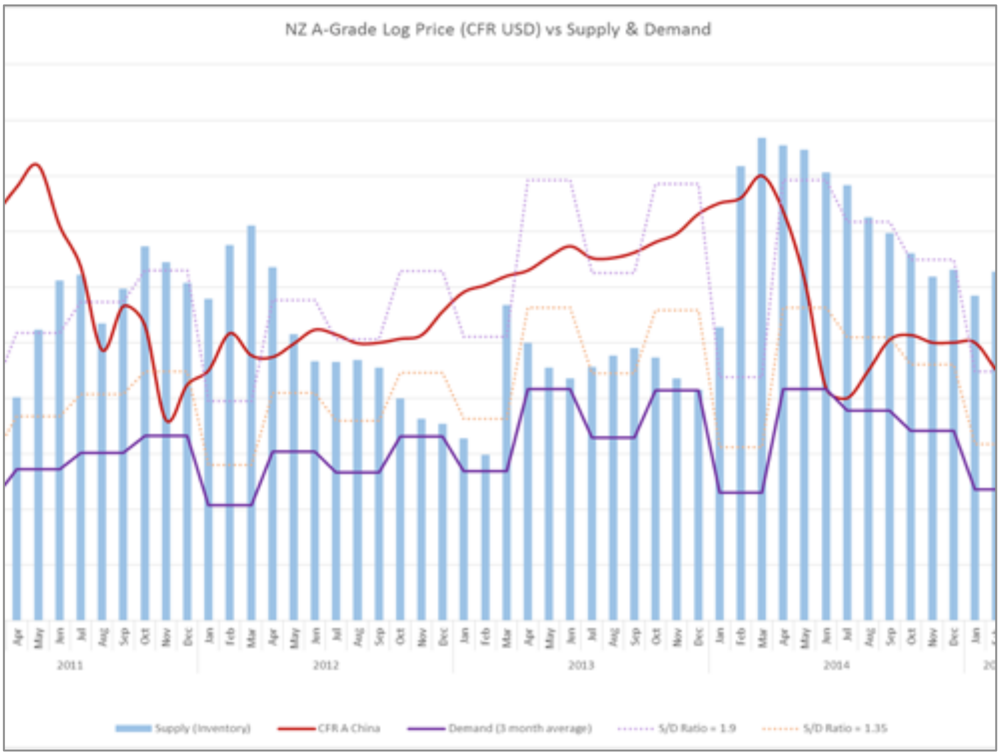


Figure 22 Snapshot of export price fluctuations over time

The expected woodflows from the Southland are shown in Table 2 below. After the year 2025, it is anticipated that wood flows will stay relatively constant until another increase around 2040. Estimated wood chip, pulp, and billet wood volumes are also shown. This analysis demonstrates the increasing availability of lower-value log products within the study area that are available for use.

Table 2 Estimated woodflow volumes from within the Southland region

	2015-2018 (per annum)	**2019-2028** (per annum)	**2029-2033** (per annum)	**2034-2039** (per annum)	**2039-2045** (per annum)
Total Harvested Volume	1,000,000 tonne	1,200,000 tonne	1,350,000 tonne	1,425,000 tonne	1,550,000 tonne
Estimated Chip (MDF) volume / annum	160,000 tonne	160,000 tonne	160,000 tonne	160,000 tonne	160,000 tonne
Estimated additional low-value logs / annum (eg.pulp)	50,000 tonne	60,000 tonne	123,500 tonne	139,000 tonne	165,000 tonne
Estimated billet wood volume / annum (MDF)	20,000 tonne	20,000 tonne	20,000 tonne	20,000 tonne	20,000 tonne
Estimated additional recoverable residue wood / annum	45,000 tonne	56,000 tonne	75000 tonne	80,000 tonne	87,000 tonne

Estimated wood chip from portable chippers	35,000 tonne	35,000 tonne	30,000 tonne	25,000 tonne	25,000 tonne
Total produced chip / pulp / billet wood / annum	310,000 tonne / annum	331,000 tonne / annum	408,500 tonne / annum	424,000 tonne / annum	447,000 tonne / annum
Total volume energy equivalents (GJ) / annum (Net Calorific Value)	2,216,500 GJ / annum	2,366,650 GJ / annum	2,920,775 GJ / annum	3,031,600 GJ / annum	3,196,050 GJ / annum

To summarise, an estimated 1-1.1 million tonne of logs is currently being harvested. Of this, an estimated 160,000 tonne is sent as chip logs to the MDF plant at Mataura, and 50,000 tonne as pulp, exported through Port South. An additional 20,000 tonne logs is supplied as billet wood to the MDF plant, with an estimated additional 45,000 tonne of residue currently unrecovered. Total volumes are expected to increase as described in the table above.

It is estimated that there is between 30,000 and 40,000 tonne of woodlot and shelterbelt logs being chipped annually, in Southland. This yield is likely to be unsustainable, as it is being generated from existing shelterbelts, many of which are not being replanted. The entire chip from these in-situ operations is being used as bedding for dairy farm herd homes.

The estimated woodflow volumes shown in the table above have been generated from an assessment of various datasets, including data from large forest owners, and regionally focussed MPI wood flow data. The estimated volumes of chip, pulp and billet wood are averages, and should be treated as guiding figures only. Again, these figures have been generated from discussions with local forest managers, and using MPI regional yield data.

A further, unique aspect of the Southland forest estate is the high proportional volume of eucalyptus forest grown specifically for chipping. Currently all of this 10,500-hectare forest estate is export-focussed, but if domestic pricing is competitive there is an opportunity to divert portions of the annual 200,000 tonne of chip production into the domestic energy market. This considerable eucalyptus resource has the ability to significantly bolster consistent supply into the local energy market.

6.2 Estimated available sawmill wood chip

Currently there is an estimated 170,000 tonne of wood chip produced from sawmills in the region. The majority of this – approximately 100,000 tonnes – is supplied to the MDF plant at Mataura. The balance is sold to dairy farmers for animal bedding, used for internal energy demands within the sawmills, and a small amount sold to existing energy markets.

As the volume of forest harvesting increases, we expect to see an increase in domestic wood processing. However, being able to predict that level of expansion is difficult. The wood processing industry is notoriously challenging, as demonstrated by the closure or scaling back of several processing plants in Southland in recent years (e.g. Brightwood and SVL). Whilst there are a number of sawmills in the region that are demonstrating longevity and stability, it is difficult to evaluate the potential for expansion.

It is considered that there will be some expansion in processing capability from the larger sawmills, with overall regional processing increasing to 700-750,000 tonnes of logs. Assuming that existing markets for chip products (e.g. MDF, bedding) will continue to be supplied as status quo, it is estimated that 90-120,000 tonnes of sawmill wood chip will be available for wood energy by 2040.

6.3 The "South Otago" effect

Section 5.0 of this report demonstrates the significance of the South Otago forest estate to the Southland wood-processing sector, and also to the potential for a thriving Southland wood energy sector. For both the Mataura and Invercargill wood catchments, the South Otago forest estate contributed significantly to wood flows. For example, using Mataura as the end destination, there is an estimated 55,000 hectares of Southland forests within 120km of Mataura, and 47,500 hectares of South Otago forests within 120km of Mataura.

A 2015 report entitled "South Otago wood residue supply assessment" (Millar, 2015) was prepared in conjunction with this report. It found that the corporate forest estate within the South Otago area is significant and stable, providing the backbone of the wider Otago forestry industry, and providing reliable woodflow supply to the downstream wood processing industry. Currently there is an estimated 800,000 tonne of logs annually harvested in the South Otago areas, expected to rise to 1,100,000 tonne by 2019, and 1,300,000 tonne by 2025. The South Otago forest industry is of equivalent size to the Southland forestry industry, each estimated to be 82-83,000 hectares in size.

Of the existing 2014-15 South Otago total harvest volume an estimated 225,000 tonne of lower-value log products will be produced from these forests. Of this, an estimated 65,000 tonne is committed to the Dongwha-owned Medium Density Fibreboard (MDF) processing plant in Mataura. An additional estimated 20,000 tonne of billet wood is sold to either existing Dunedin-based energy markets, or to the MDF plant. The remaining 105,000 tonne of lower-value logs are sold to export markets, usually via Port Chalmers wharf. The proportional split of destinations for these markets is dependent on the forest owner, their market agreements, and their proximity to the markets. Unlike the Southland industry – which favours supply to the more proximate MDF plant at Mataura - it is common for just 30-35% of South Otago lower value logs to be sent to the domestic market, and the balance exported. Forest owners closer to the MDF plant shift greater proportions of their product to the domestic market. It is estimated that an additional 40,000 tonne of unrecovered residue is left in the forests, remaining there due to the lack of profitable markets for these logs.

It was estimated in the South Otago study that 80% of the forest owners in the South Otago / Clutha District would benefit from a wood energy market which centred on Balclutha and Clydevale as its end destination. The 20% of forest owners that would find a market less beneficial were those located in the South Catlins, and in Tapanui. Both of these areas are, of course, close to Mataura and Invercargill and would be in an excellent position to service a Southland wood energy sector.

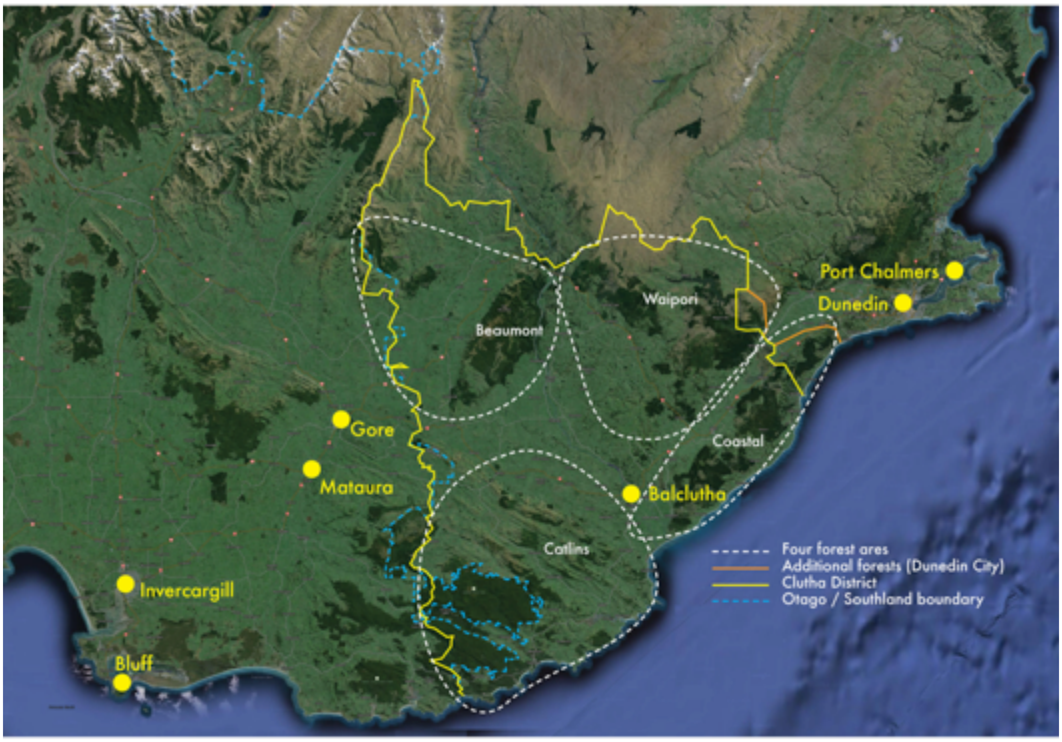


Figure 23 Core forest areas assessed in the South Otago wood residue supply assessment.

All of the South Otago forest owners could feasibly supply a Southland wood energy sector, but the increasing distance from market would direct impact on the viability of the more northern coastal and Waipori forests supplying such a market. However, if the price was appropriate then these markets become viable. A price point for these northern forests would need to be in the vicinity of $60 / tonne. The South Otago / Clutha forests that are more proximate to end-users would be viable at a $50 - $55 / tonne delivered price.

7.0 Sources of forest biomass for energy

Understanding what resource is available as a viable and consistent supply of raw resource to enable the production of wood energy is a primary objective of this project. The raw resource could arise from three main sources, namely:

1. Use of existing local low-value log products that are currently marketed and sold into alternative markets;
2. Use of existing by-product and arising's from sawmills;
3. Capturing wood residue that is not currently recovered or sold from the forest site.

7.1 Use of existing local low-value log products

7.1.1 Domestic chip log market

Large forest owners typically supply a number of markets with their lower-value log products. Chip logs, with a minimum length of 3.0 metres and a 30cm Small End Diameter (SED) are sold either as export pulp logs, as chip for the export market, or as chip logs for the Mataura-based Dongwha medium density fibreboard (MDF) plant.

Prices paid for the chip logs can differ between clients, often depending on the distance from forest to MDF plant. There has historically been an additional premium paid for chip logs that are further afield, so as to offset the additional cartage cost. As at the time of this assessment, prices range between $46 / tonne and $49 / tonne, for chip logs landed at the MDF plant. Historically, prices have ranged between $46 / tonne and $52/tonne. The occasional peak price occurs, often for periods where supply into the MDF plant is uncertain (for example over Christmas) and normally for a very short time. As previously discussed, the Dongwha plant consumes between 350,000 tonnes and 390,000 tonnes of chip per annum, with approximately two-thirds of this consumption derived from logs, and the remainder as chip residue from sawmills.

7.1.2 Export pulp log market

New Zealand's core export log markets in China, India and Korea provide fairly consistent demand for pulp logs. The export pulp logs are cut to a better specification than domestic chip logs, usually being straighter and longer logs. Rather than being converted into chip at the point of sale, they are often cut into low-grade sawlogs and used as temporary building materials (e.g. boxing-grade timber).

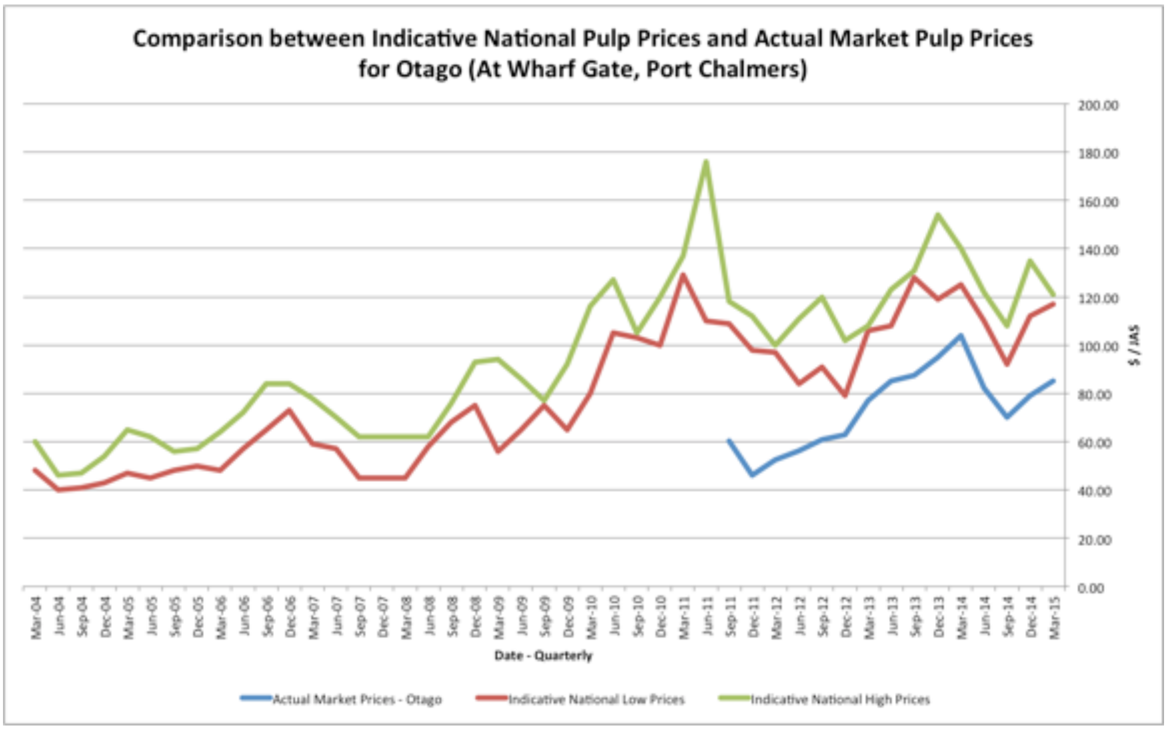


Figure 24 Comparison between indicative national pulp prices and actual Otago and Southland pulp prices

Historic export prices are shown in Figure 24 above, for Otago and Southland. The indicative national market prices for pulp were obtained from the Ministry for Primary Industries, and represent the low and high price range from across their national database[1].

The Otago / Southland market prices are actual prices that have been received, at wharf gate, over the last four years. The trends are noticeably similar, showing a steady but unpredictable increase in export pulp prices over time. The rise of the Chinese log market as the dominant purchaser of New Zealand log products contributes strongly to this upward price pressure.

In Otago / Southland the average wharf gate price for pulp logs over the four years to March 2015 is $74 / JAS. A typical log conversion of 0.8 JAS to tonne, equates to an average rate for pulp logs of $59.20 / tonne.

7.1.3 Domestic billet wood market

Billet wood is woody residue of lengths between 1.0 and 3.0 metres, and usually arises as a by-product from harvesting operations. This product is sold to the Mataura-based Dongwha Patina Medium Density Fibreboard (MDF) plant for a sale price that effectively provides the harvesting contractor with some cost recovery value, and the forest owner (CFL) with a small financial return which contributes to the maintenance of roads and overheads. A significant benefit to forest owners of selling billet wood is the 'clean' forest landings that result, requiring less post-harvest management to rehabilitate these sites. The ability to pay the harvest contractors a fee for their handling of this product is also of

[1] "These log prices are historical and indicative only and may not correspond to actual prices paid, or grades

importance. At the time of this assessment prices paid for billet wood varied between forest owners. The customer, Dongwha, pays the cartage for billet wood, and as such is prepared to pay more billet wood that is in closer proximity to their plant. Prices paid for billet wood have varied between $11 / tonne and $18 / tonne (on truck). Cartage to the MDF plant can be as high as $30 / tonne, resulting in a delivered price to Dongwha of $30-$45/tonne.

Unfortunately the billet wood market is not so viable for forest owners that are less proximate to the MDF plant, due to the increasing transportation costs that are paid for by the purchaser. It has been found that providing billet wood is not viable in forests that are over 100 kilometres from Mataura, though collection does occur occasionally.

7.1.4 Domestic firewood market

The sale of firewood is another potential outlet for the low-value logs arising from Southland forests. Radiata pine is not normally demanded by firewood outlets, but Douglas fir, eucalyptus and macrocarpa is consistently sought at prices in the vicinity of $40 / tonne on truck (i.e. cartage is paid by the purchaser). The domestic firewood markets provide consistent outlets for these minor species that have few alternative markets for logs that are out of round wood specification.

Some firewood is sent to Central Otago from Southland, but is considered to be nominal amounts. Cartage operators interviewed during the course of this assessment described the transfer of firewood logs from Southland to Central Otago and Queenstown Lakes as being limited.

7.1.5 Export softwood chip markets

Until 2013, chip logs were commonly sold to local chipping processors who processed the raw log into chips, and then sold into export chip markets. In 2013, however, only 25,500 Bone Dry Units (BDU) were sold from Bluff (MPI, Quarterly Trade data, 2015). Since then, there has been no export of softwood chip from Bluff or Port Chalmers. This is primarily driven by the reduction in global paper manufacturing. There is general agreement by those in the industry that is unlikely to change into the future.

7.1.6 Export hardwood chip markets

The export hardwood chip market is a consistent one, due to the presence of SPFC in Southland. SPFC are owned by paper manufacturers in Japan, and as such, have consistent outlets for their product. In 2013 and 2014, 79,000 BDU and 81,000 BDU were exported from Bluff, respectively (MPI, Quarterly Trade data, 2015).

There is an opportunity for a portion of Southland’s wood energy to be provided through the eucalyptus estate. However, at this point in time this can only be considered a theoretical statement and any commercial prospects would need to be developed over time. Currently the vast majority of the eucalyptus estate is owned by entities that are vertically integrated paper manufacturing companies.

7.2 Use of existing sawmill by-products

As a part of this assessment, managers of sawmills were interviewed so as to get an understanding of the availability of residues from existing operations. All of the sawmills within the study area have committed their supply of by-products to either their own internal energy use, or to existing customers.

For the smaller sawmills the primary outlets for their woodchips and shavings included meeting their own fuel needs, often to fire their internal boiler systems for heat generation. There are a couple of exceptions where the heat produces energy for electric generation

Almost all the smaller mills are supplying their wood chips to the animal bedding market on informal agreement with invoicing for 20th following month payment. All sawmills were happy with their existing situation, appreciating that they were now being paid for a by-product that was traditionally a waste product that was often difficult to deal with. Some can recall when they bulldozed the sawdust into landfill and burnt the wood waste to get rid of it. To have an existing market and someone prepared to pay for the product was acknowledged, with several people expressing that an improvement in price would be secondary in importance to having the waste wood moved off site quickly and efficiently as possible

The larger sawmills have committed a significant portion of their supply of woodchip by-product to the Dongwha MDF plant for the short-medium term, as well as using some of the residue for their own energy needs. The larger sawmills are also supplying dairy farms. These larger mills generally expressed a desire to earn more from the wood waste they produced, and are very interested in the wood energy market.

7.2.1 Wood energy markets

One large sawmill is currently supplying the small-boiler wood energy market in Southland with dry chip from their remanufacturing plant. Currently 250 m^3 of dry chip is produced weekly, with capacity to quickly double that production by converting existing firewood by-products into wood chips. It is expected that this volume will double again in the next five years, as the volume of logs being processed increases.

When considering the potential to supply wood energy commercially, sawmill managers were interested in the idea but few actually had given it any thought to do so on a commercial basis. A normal response is that the primary objective is to produce sawn timber or post wood and that arising's simply need to be moved on with the least fuss. The larger sawmills did consider this differently, and had considered the potential opportunities that a wood energy market could provide their businesses.

When sawmill managers were asked what would attract them to diverting residues and arising from their existing markets, almost all quickly came to the answer, "Price". However, upon reflection they would not easily give up a stable customer base that most have. The stability of a customer base was a strong priority, with the exception of the larger sawmills where more market diversity was desired.

7.2.2 Dairy Herd Homes

Woodchip bedding systems are predominately a cow standoff facility used to house the dairy herd away from pasture in a duration controlled grazing system. An untreated woodchip based product is used as soft floor bedding for cows in which effluent is captured and absorbed.

A clear roofing system protects both cows and the bedding product from moisture and allows sunlight to enter the shelter enabling drying of the flooring product. Further, sunlight encourages micro - organism activity to break the effluent down. Woodchip flooring is replaced between one and three years of use allowing the farm to distribute the current high carbon, nutrient rich bedding as fertilizer (MacDonald et al., 2014). Other options for dairy herd homes are also being used, including concrete slate systems and rubber mats. However, the use of wood chips seems to be a well-established and well-regarded method of housing dairy cows.

Chip for herd homes comes from two main sources. Firstly, as wood chip from sawmills. Interviews with sawmill managers demonstrated that this was a significant market for them, and one that they considered was growing. Secondly, chip is commonly produced by a handful of portable wood chipping operators in Southland. Four contractors were spoken to as a part of this study, and it was estimated that they collectively harvest and chip 30-40,000 tonne of logs from small woodlots and shelterbelts. All of this resource is destined for dairy farms, either lane ways or herd homes. The sustainability of this resource was questioned, as many farmers who are commissioning these operations are not replanting the harvested trees.

7.3 Capturing wood residue that is not currently sold from the forest site.

In this study, forest residues are defined as the unused portions of plantation trees that have been felled by logging, but remain in the forest unused. These forest residues have some potential to be used as an energy product, if they can harvested and processed at a cost that justifies the return.

Forest biomass supply for energy is typically generated from logging residues. When this material is "green" - immediately after harvesting - the moisture content (MC) is typically 55% MC wet basis (wb), rising to a maximum of 60% MC wb. This material occurs at two key locations within the forest: at landings (roadside skid sites) and at the stump (cutover).

Currently, the standard operating practice within most commercial forests throughout New Zealand is to push the 'waste' residue back into the forest, or to leave it in a pile on the edge of the landing. In both circumstances, the residues are left to decay.

7.3.1 Forest residues generated on the cutover

The amount and type of residue left on the cutover site will differ from site to site, depending on the type of extraction system used and the quality of the trees being harvested. Ground-based harvesting systems (either skidder or forwarder) will typically mechanically de-limb the branches on the cutover site, thereby leaving significant woody residue behind. Whether recovering the stem residues is cost effective or not will be determined by two factors - the quality of the forest itself, and the presence of a market that adequately demands stem-residue product. Additionally, forest owners value the decaying residues as part of the nutrient recycling for the next crop.

Markets must place a suitable value on the existing waste stem wood to enable the recovery of these cutover residues. The small piece size of stem wood being recovered, the relatively low volumes of remaining residue, and the relatively large travel distance between stem pieces, mean that recovery is comparatively expensive. After significant consultation with forest managers as a part of this study, it has become clear that forest managers will not contemplate retrieving wood residue from the cutover site if the net revenue obtained is similar to billet wood. Quite simply, the current returns from billet wood do not justify the extra cost and time associated with the retrieval of this product.

7.3.2 Forest residues generated at forest skid sites.

The forest landing, or skid site, is the main point of woody residue accumulation in the forest. It is at the skid site that the greatest potential exists to recover woody residues for downstream uses.

The amount of residue that accumulates at the forest skid site is influenced by the harvesting system used and the quality of the forest crop being harvested. The residue that accumulates at landings is of a higher priority than the residues accumulating on the forest cutover because of the following reasons:

1. There is a condensed, cumulative volume.
2. The volume of residue is located within a processing site that is well positioned to make use of forest processing equipment that is in place.
3. The harvest contractors have already expended cost and energy harvesting the logs, and need to recover value from it.

As a result of the above, there is a much higher potential for cost-effective recovery of a wood product.

Figure 25 Stem residue accumulations at a typical forest landing

For the purpose of this study, woody residue that can be potentially used for wood chip is no smaller than the billet wood grade (1.0m – 3.0m lengths). Numerous studies provide evidence as to the inefficiency of handling very small pieces of residue, and as such these small residues have been discounted.

However one operation that should be considered by Wood Energy South, is completing a time-efficiency study of the use of shredders (rather than chippers) on forestry skid sites. Such an assessment should aim to understand:

- The cost of processing skid site residues with a shredder.
- The quality of the product that results, and its suitability for boilers.
- The ability of the forest infrastructure to accommodate chip liners, or similar trucks.
- The most effective method of handling the wood chip, and the machinery and infrastructure required to do this.
- The costs and benefits to forest owners (e.g. clean skid sites for replanting).

7.3.3 Estimated unutilised available wood residue.

During this project assessment we have asked forest managers what their assessment is of the available wood residue that remains on the skid site after the completion of the forest harvesting operation. Estimations from forest managers were similar, but spread over a range. For all of the forest managers, the quality of the forest and the distance to market will determine the volume of unutilised wood residue that remains after a harvesting operation.

Previous site assessments of forest skid sites in a suite of Dunedin forests (Millar, 2009) provided the following information regarding the levels of wood residue that accumulate on skid sites. This information has been updated during this assessment, during the course of interviewing forest managers. In the table below, a "poor-quality" site refers to forests which have not been well maintained or are growing in exposed sites, and as a result, produce a greater than average amount of bent, overly-branchy, or lower quality, nonmerchantable logs. Conversely, a "high-quality" site refers to forests of high productivity that have been well maintained and are situated in high-productivity sites that grow high-quality logs. In these instances, the proportion of lower quality logs is less.

There is, of course, a large range of sites and conditions. The figures in Table 3 should be treated as a guide only. The figures in this table summarise the expected average log stem residue volumes as a proportion of total harvestable volume that can be expected to be harvested from different quality sites within a normal corporate forest. The usable proportion of the residue is the billet wood grade, or non-saleable chip log grade that has been discussed above.

Table 3 Estimated recoverable wood residue from forest sites, that is not currently recovered

	Poor-Quality Site	Average-Quality Site	High-Quality Site
Total woody residue as proportion of total recoverable volume	30%	10%	4%
Usable woody residue as proportion of total recoverable volume	15%	4%	2%

These findings are in keeping with other New Zealand studies on wood residue evaluation, and suggest that on an "average" skid site, 350-450 tonnes of usable wood residue would remain after a harvest operation. It is important to note that "average" skid sites are difficult to determine, as there are so many variables in each harvesting operation.

Determining the quality of the fuel required will have a significant impact on the amount of residue available. The figures above are to provide a higher quality wood chip, clean and free of any green matter. If the required wood chip is not of such a high quality, and is more of a hog fuel, then considerably more volume (potentially double the figures in the table above) may be available. This research should be completed, specifically with regard to Southland forests, so as to confirm the availability and quality of this resource.

8.0 Establishing the price for wood energy

To evaluate the price that forest owners would need to be paid to gain their commitment to an emerging market, an analysis was completed that assessed the gross prices, associated costs, and net returns for forest owners in a variety of locations across Southland.

The price that prospective energy users will need to pay for log product is largely determined by the opportunity cost for forest owners of selling log products in to competing, alternative log markets. The lesser the value of the logs, the greater will be the proportional impact of the cost of production on the net return to forest growers. Proximity to the end market is the biggest single variable cost, creating a significant range of net returns to forest owners, dependent on the forest location.

If prices for wood energy are set at levels that are competitive with existing log products of similar quality (chip and billet wood), then it provides an alternative market for forest owners. At $50/tonne, a new wood energy market will provide some competition for an averagely performing export pulp market. Southland forest owners have a reliable domestic option for their lower value logs already, and though most people express an opinion that competition would be a good thing for the industry, they also recognise the benefit the MDF plant provides. For forest owners around Southland, a consistent wood energy market paying $50/tonne will provide another outlet option for their low value logs, which will be a preferential market for some harvesting operations but not for others. As described earlier, a price of $55/tonne (at end user) is necessary to be more strongly competitive with existing products.

8.1 Cost breakdown of wood energy

The various cost components of wood fuel, for end users in Southland, are outlined as follows:

1. Logs, delivered to site: $55-$60 / tonne.
2. Chip to fuel pile, on site (end user): $15 - $20 / tonne.
3. Load to hopper, as required: $5/ tonne.
4. Management and overheads: $5 / tonne.

Total cost $80 - $90 / tonne, or $8.60 - $9.70/ GJ (GCV), or $11.20 – 12.50 / GJ (NCV).

The Gross Calorific Value (GCV) is the total energy in the wood, and is often the conversion figure used when considering the cost of delivered fuel, prior to combustion. A GCV of 9.28 GJ / tonne has been used in the calculations in this report.

Net Calorific Value (NCV) is the net energy content of the wood fuel, including the energy required in burning off the moisture. The NCV reflects the true cost of energy. A NCV of 7.15 GJ / tonne has been used in the calculations in this report.

(http://www.eecabusiness.govt.nz/wood-energy-resources/biomass-calorific Accessed on 15 July 2015).

The range of prices paid for the logs reflect previous discussion within this report. $55/tonne is a recommended market price to be paid for full-length log product. Depending on the distance to the end user, a billet wood log price of $45-$50 / tonne is likely. The smaller piece size of billet wood means that processing and handling costs will be higher, and as such, will result in a similar end price to the user.

The chipping cost differs too, and will ultimately be determined by the productivity requirements, the infrastructure in place to support that productivity, and the efficiency of the utilisation of that infrastructure. The quality of logs secured will also impact upon the productivity of the chipper, and the cost of chip production. The quality of logs secured will, in part, be determined by the price paid.

9.0 Evaluation of competing thermal fuel prices.

If a business is replacing or installing a heating system, thermal fuel price forecasts are one consideration in calculating the running costs of the heating plant. Maintenance and capital costs are the other major cost consideration, though these are very dependent on the specifics of the site.

As a part of this assessment, historical, current day and predicted future prices for thermal fuels have been compared. For imported fuels, the long-term price range can be projected out using the 2020 range as an indicator. History has shown that the price of imported fuel is notoriously hard to forecast and the future is likely to be at least as changeable. Emissions costs may also have a significant impact in the long term and as such, possible emission costs were included in the 2020 price forecast range.

Prices are for delivered price excluding GST. Prices are all 2014 real price unless otherwise stated. Background data and methodology for this section are described in Appendix 2.0.

9.1 Coal

Coal is generally classified lignite, sub bituminous and bituminous. Lignite is the lowest grade coal with a moisture content of 30-70% and has the lowest energy content per weight. Sub bituminous coal is the mid-range coal with less moisture and more carbon content than lignite. Bituminous is high-grade coal with the lowest moisture content and highest carbon content and is not mined in Southland.

Lignite is mined in the New Vale mine in Southland and also in the Kaitangata, Kai point mine in Otago. The lignite resource in Southland is vast. Sub Bituminous coal is mined in the Ohai area located in western Southland. When the Ohai coal mine closes, sub bituminous coal will need to be imported from outside the region which will increase the cost. Bituminous coal is brought in from outside the region.

Southland lignite is typically not cost effective to transport over significant distances. It is assumed prices will always be set domestically based on costs of supply (COVEC, 2014). For modelling it is useful to assume sub bituminous international prices have a small influence on domestic price.[3]

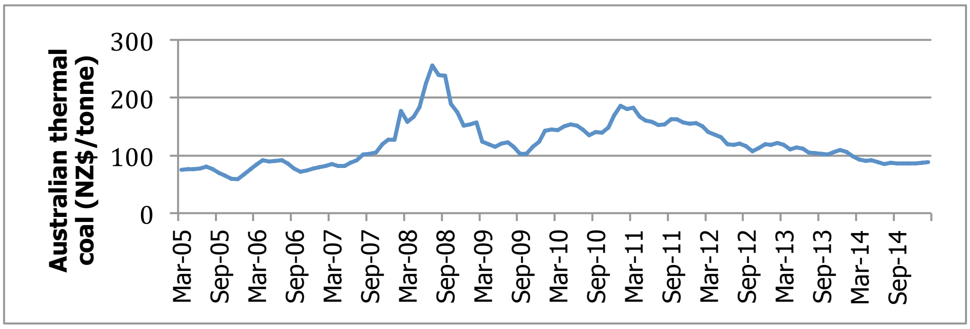


Figure 26 Historic Australian Thermal Coal price in $NZ per metric tonne (Index Mundi 2014, 29/5/2015)

In 2015 international thermal coal prices declined to the lowest price since 2007. This is due to oversupply and contributing factors. Prices are expected to increase moderately over the next decade (IEA, 2014).

The largest lignite user Fonterra lies outside the price range given and was not included in the table as the Fonterra price is not relevant to a typical industrial boiler.

Table 4 Coal price forecast ($/GJ)

($/GJ)	2014		2020	
	Low	High	Low	High
Lignite	4.1	8.0	4.1	8.0
Sub bituminous	6.7	9.3	8.6	10.9

9.1.1 The use of coal in the context of changing Air Quality standards

The Government's National Environmental Standards for Air Quality (NES), aims to provide a guaranteed level of protection for the health of all New Zealanders. As a consequence, Environment Southland is legally obliged to make sure that air quality in Southland meets those standards through management options determined in consultation with the community. That process is underway with the review of the Regional Air Quality Plan for Southland (1999), which needs to be updated to reflect new legislation and community health values.

The NES have a minimum standard for the pollutant PM_{10}, which is highly concentrated in smoke. The standard is exceeded when more than 50 micrograms of PM_{10} is measured as a 24-hour average. Far and away the biggest contributor of PM_{10} in the built up areas of Invercargill and Gore is the burning of coal and wood in home fires.

An emission inventory undertaken for Invercargill and Gore found that domestic heating is the main source of PM_{10} emissions in both areas and accounts for 92% and 96% in Invercargill and Gore respectively. Other sources include motor vehicles (2% and 1%), outdoor burning (<1% and 1%) and industrial and commercial activities (6% and 1%).

As a result, from 2015 Environment Southland is beginning to phase out high sulphur-emitting coals in household burners. It is also phasing out open fires. These two changes signal ongoing changes to address air quality in Southland.

9.2 LPG

LPG is produced in the North Island and transported to Dunedin via ship and then overland to Southland. LPG can also be supplied from the international market, though from 2010 to 2015 New Zealand produced enough LPG to meet domestic needs. However between 2006 and 2010 up to 50% of New Zealand's LPG was imported. New Zealand may again need to import LPG to make up for domestic shortfall (Geest, 2014). Longer term the need to import will be determined by availability of LPG feed stocks. LPG prices were set domestically prior to 2008 (MBIE, 2014). LPG is now priced according to the Saudi Aramco contract price, though domestic sales are not always tied to the Saudi price (AA, 2014).

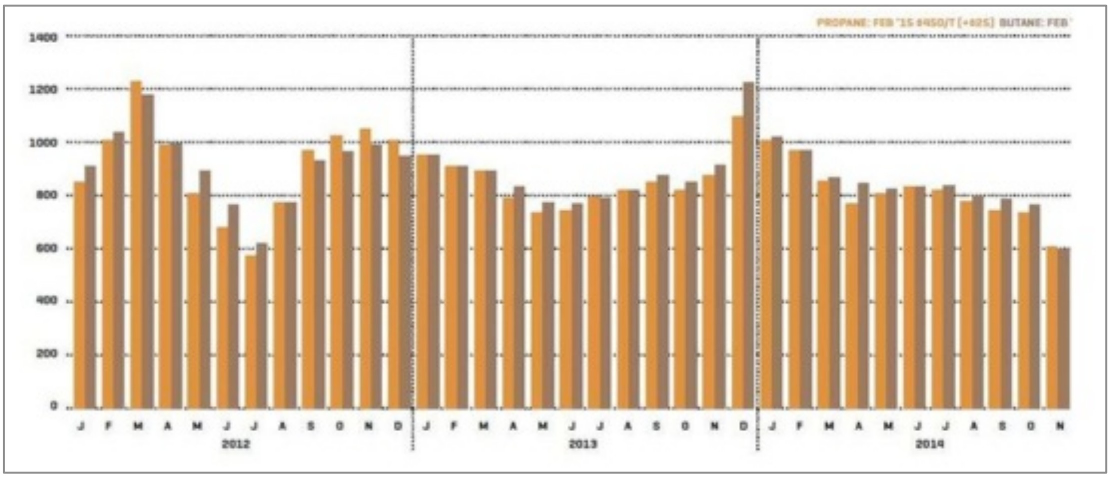


Figure 27 Saudi aramco contract price LPG exports (US$/tonne) (Mees, 2015)

International prices recently dropped from around $800/tonne in 2014 under $400/tonne in 2015 (CME Group, 2015).

LPG suppliers that were contacted did not give LPG prices for Southland. There was however a recent study completed in Queenstown where prices were collected by surveying LPG users. Given LPG transport distance to Queenstown and Invercargill are similar, both centres should have similar prices. The study surveyed commercial users and found LPG delivered cost was 12-14c/kWh in 2013 (Millar and McGinty, 2013). Inflating to 2014 prices and converting to $/GJ, gives a price range of 33-39 ($/GJ).

The prices above are set according to domestic supply model where international LPG prices have been relatively high until very recently. To include all scenarios the price of imported LPG based on the current low international price outlook was included.

Table 5 LPG price forecast ($/GJ)

($/GJ)	**2014**		**2019/2020**	
	Low	High	Low	High
LPG	34	40	16	45

9.3 Electricity

Electricity is produced domestically from renewables, domestic gas and coal. Electricity costs vary from year to year depending on business exposure to spot market and the inflow into hydro lakes. The price range forecasted is based on the average price paid by typical commercial and industrial electricity users.

The electricity calculation was complete by using the known retailer mark-up on wholesale prices to the wholesale price forecasts. The mark-up between wholesale and commercial and industrial prices was taken from the 2012 year, which is the most recent data. The retailer mark-up was relatively stable in the years prior to 2012.

Table 6 Electricity prices 2012 (MBIE Energy prices, 2014)

Wholesale price ($/GJ)	Industrial price ($/GJ)	Industrial price margin	Commercial price ($/GJ)	Commercial price margin
23.61	29.64	26%	46.62	97%

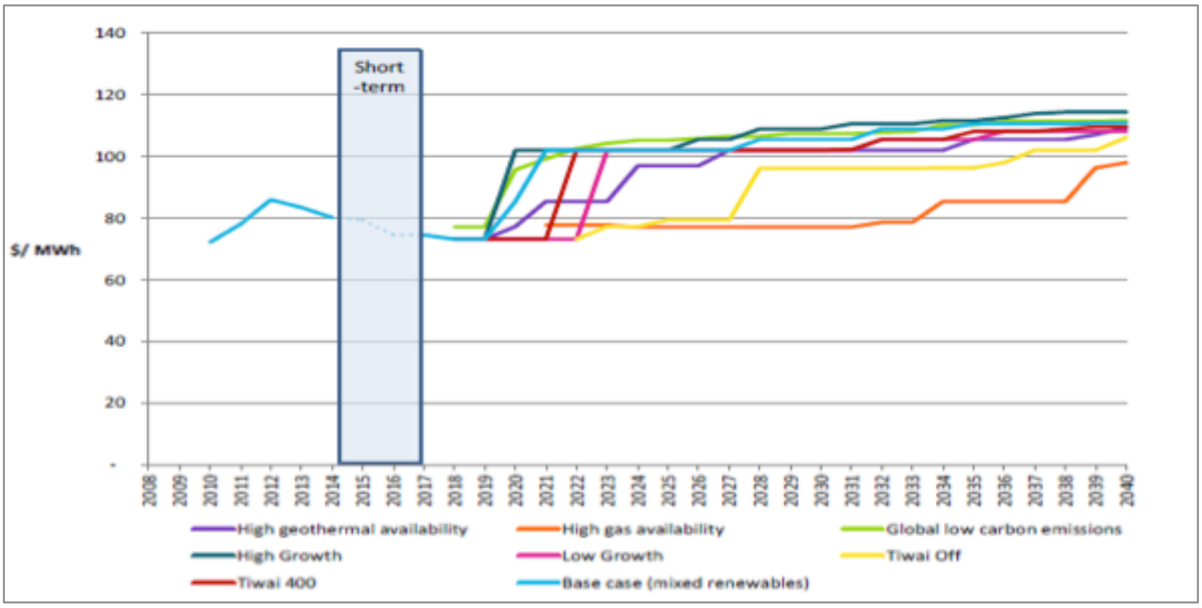


Figure 28 Wholesale price indicator (MED, 2015)

The commercial margin will be added to the high scenario wholesale price forecast to give the high price for supplied electricity while the industrial margin will be added to the low scenario to give the low price.

Table 7 Electricity price forecast

Price ($/GJ)	2015		2020		2030	
	Low	High	Low	High	Low	High
Electricity whole sale price	22	22	20	29	20	31
Margin added to whole sale price	26%	97%	26%	97%	26%	97%
Price range delivered (industrial and commercial)	27	43	25	57	26	60

9.4 Wood pellets

Wood pellets are not made locally in Southland. The closest producers of pellets are in Nelson and Rotorua. They are shipped/transported to the lower South Island. Wood pellets therefore have more exposure to increased transport costs than a locally produced product does.

Currently wood pellets cost between $400 and $530[2][3] per tonne. Pellets have a 19.1 GJ per tonne energy content (Wood Energy South, 2014). Therefore pellets cost 25-28 $/GJ. (Wood Energy South, 2014).

Table 8 Wood pellet price forecast

Wood pellet prices	2014		2020	
	Low	High	Low	High
$/tonne	400	530	475	630
$/GJ	21	28	25	33

Wood pellets are expected to increase in price in line with inflation.

9.5 Seasoned wood chip and green wood chip

Seasoned wood chip for thermal fuel is used in Southland and supplies small to large commercial users. Green chip (excluding saw dust) is not used in Southland for biofuel. For substantial growth of wood boilers, wood suppliers suggest that green chip is a less constrained option, as there is a limit to the dry chip resource. The dry chip resource is not however constrained in the immediate future and one major supplier had capacity to increase supply volumes.[4]

Pine wood chip with 20% moisture content is delivered for $170 - 190/tonne. The price applies to deliveries within the region of the mill.[5] An estimate of a 20% increase from the low to high wood chip price was made, where the chip could be more expensive due to being transported a greater distance, having lower volumetric throughput and poor hopper access. The price could increase further where significant distances are involved.

Table 9 Wood chip price calculations

Wood chip prices	Net energy content	Prices 2014 ($/GJ) Net	
	GJ/tonne	Low (short distance)	High (longer distance)
Energy Content at 20%	14.61	11.6	15.6
Energy Content at 58%	6.51	10.8	14.7

If gross energy value was used the price would appear 26% cheaper. The difference between Gross and Net is the energy required to evaporate the moisture in the wood during the burning process. Net energy is therefore a true indication of price of the energy in a typical boiler. However recovering lost heat from evaporated water is feasible with wood energy.

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[2] Personal communication with Martin Wilks , Otago Pellet Fires (29/5/2015)

[3] Personal communication with Brook Brewerton (5 June 2015)

[4] Personal contact with David Blue (28/5/2015)

[5] Personal contact with Karl Findlater, Findlater sawmill (29/5/2015)

Table 10 Wood chip prices

$/GJ (Gross)	2014		2020	
	Low	High	Low	High
Wood chip - seasoned (20% moisture content)	11.6	15.6	11.6	15.6
Wood chip - green (58% moisture content)	10.8	14.7	10.8	14.7

9.6 Diesel – thermal fuel

20% of New Zealand diesel is imported as refined diesel and 80% is imported Dubai crude oil and processed domestically (Refining NZ, 2014). Diesel is subject to international price fluctuations. The international prices of crude oil can vary by large amounts over the period of a year as recent history has shown. Between May 2014 and January 2015 the Dubai crude oil dropped from over $US108/barrel to $US46 a barrel.[10]

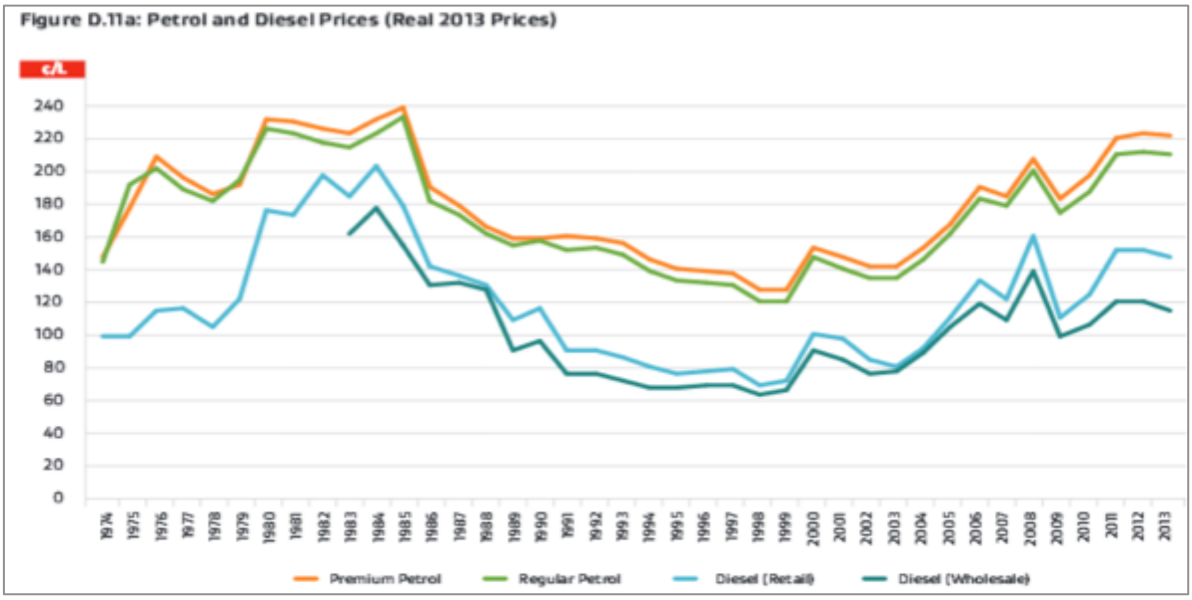

Figure 29 Energy in New Zealand 2014 Diesel prices (AA, 2014)

The price of diesel was calculated using the current price of diesel at the pump and then deducting a portion of the importer margin to give the range of prices. The price forecast range of Dubai Crude, out to 2020, was found and a conversion factor of 8c/l change in diesel price for every $10NZD/barrel was applied. This gave the 2020 price range. The significant range of prices forecast in 2020 is a function of the possible instability of crude oil price, though providing there are no more price shocks, the futures market expects the price will increase by 16% from mid-2015 through to 2019 (Index mundi, 2015).

Table 12 Diesel prices

Diesel (NZ$/GJ)	2015		2020	
	Low	High	Low	High
Diesel*	28	34	25	52

9.7 Comparison of thermal fuel prices

The following graph in Figure 30 shows comparative thermal fuel prices in 2015 and 2020. Prices are for the delivered price of energy, excluding GST. Prices are all 2014 real price unless otherwise stated.

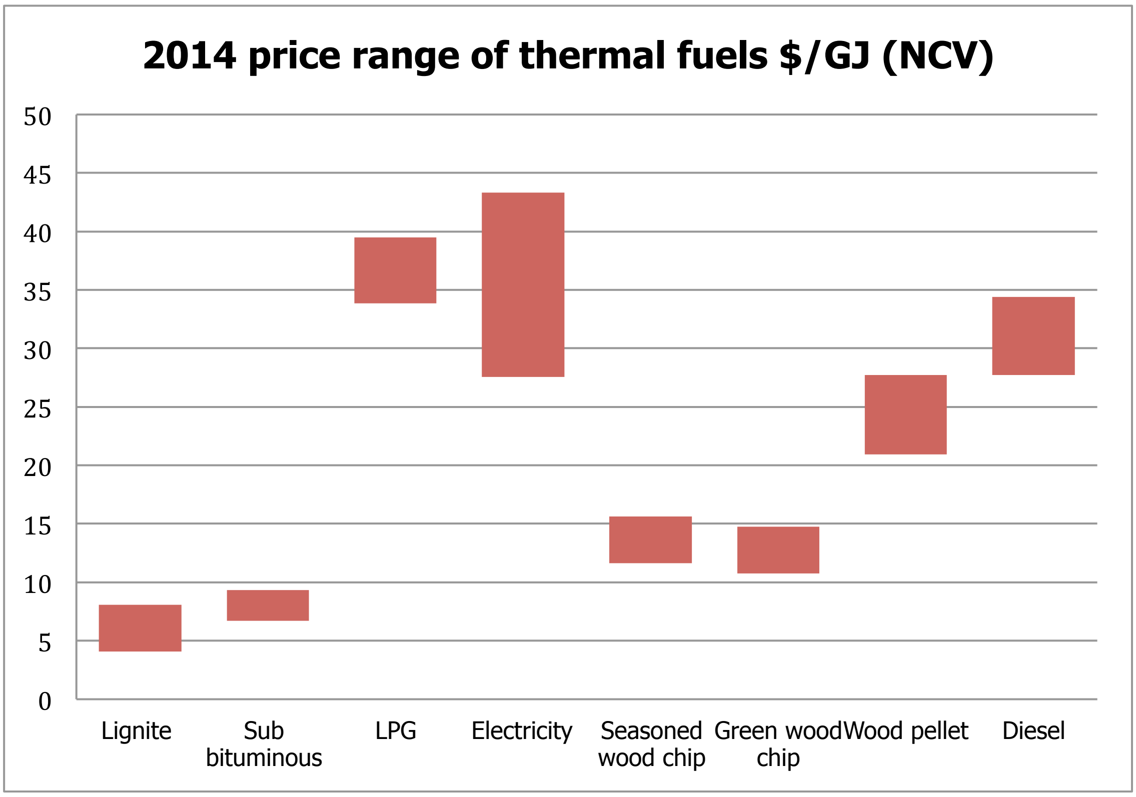

Figure 30 2014 Price range of thermal fuels, $/GJ

In 2014 coal was the cheapest fuel, which is well known. Wood chip fuels are the next cheapest fuel. Wood pellets are the next cheapest of the remaining fuels. Note the diesel price is actually based on 2015 prices as that better reflects current prices. All other 2014 prices are similar to 2015 prices. 2014 prices were typically used, as the data was more readily available than 2015 data.

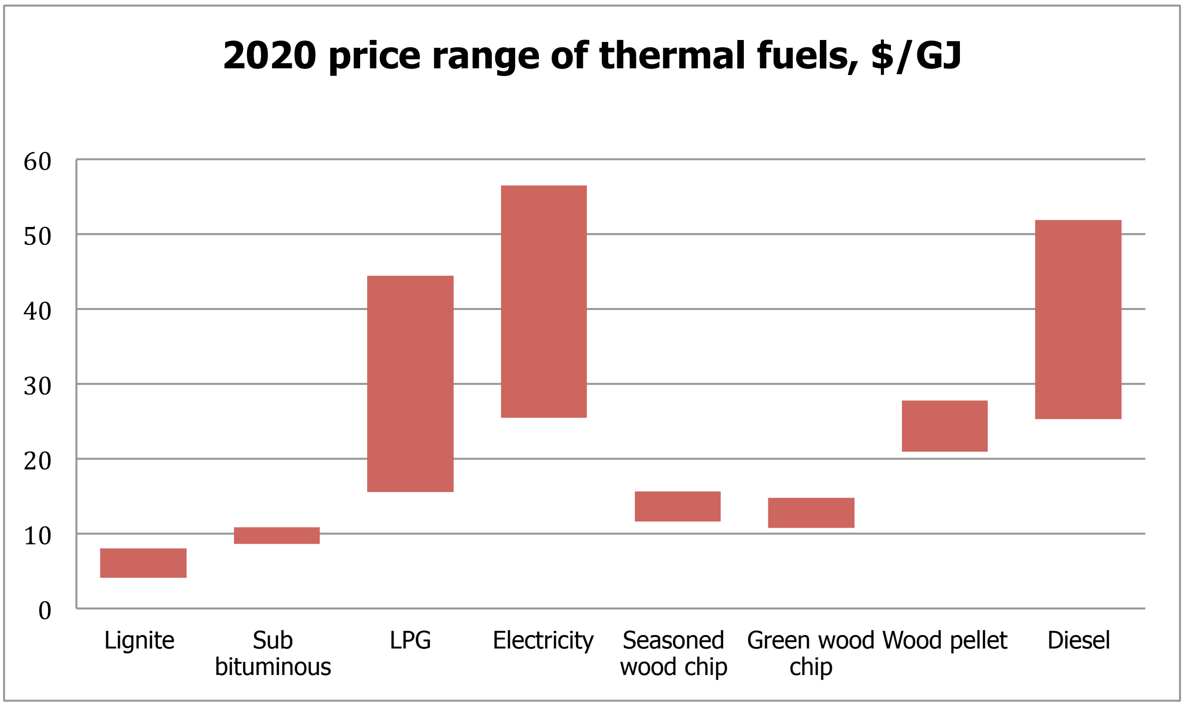

Figure 31 2020 Price range of thermal fuels, $/GJ

Looking out to 2020 there isn't really any significant shuffling of positions. The most noticeable difference from Figure 30 is that prices for LPG, diesel and to a lesser extent electricity have a larger range of prices. Only time will tell how market forces affect the eventual price.

Domestically produced thermal fuels tend to be priced according to production and delivery cost with competition and demand influencing costs to an extent. Generally speaking prices of domestically sourced fuel are expected to adjust with inflation.

9.8 ETS or emissions price

When the emissions trading scheme (ETS) was first introduced it was priced at $25 per credit where one credit allowed for 2 tonnes of green house gas (GHG) emissions to be emitted. Recently the price of an ETS credit in NZ has been as low as $5.20 per unit.

In New Zealand's Climate Change Target, discussion document 2014, the New Zealand Government department conducting the consultation referenced the IPCC who calculated the effective carbon price for New Zealand to reduce GHG emissions. The value was between $60 - $200 NZD per tonne of GHG by 2030 (MfE, 2015). This could potentially be the GHG emissions price if New Zealand wanted to reduce GHG emissions significantly through the ETS or carbon pricing mechanism.

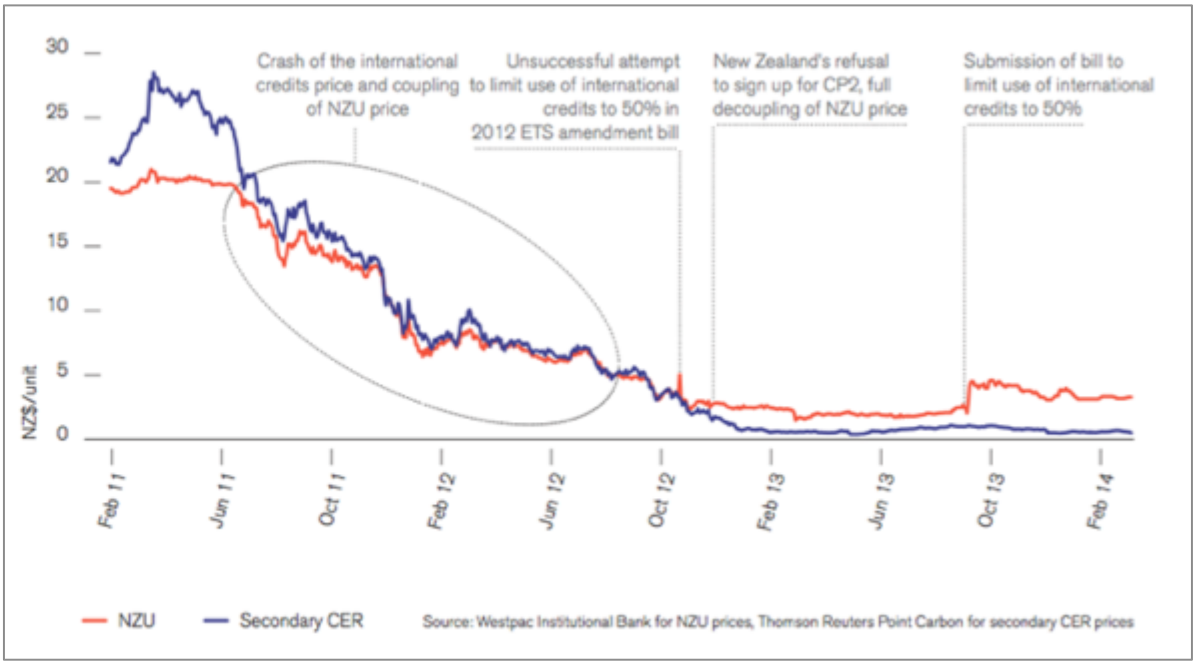

Figure 32 New Zealand Carbon Price (MFE, Climate change consultation document, 2015).

Of all the political parties in New Zealand the Greens are the only party that have stated a price, of $25 per tonne of GHG emissions (Greens Party, 2014) albeit under an alternative scheme. Labour favours continuing with the ETS but increasing the price, though they do not mention a specific price (Labour Party, 2011). National very recently set new GHG reduction targets that were judged as inadequate in comparison to our trading partners (Climate Action Tracker, 2015). Given the climate policy history of all parties and the current policy information available, the Greens proposed $25/tonne is likely to be the strongest price New Zealand pays for GHG out to the end of the next election cycle.

Figure 32 shows the current carbon price, as well as significant events affecting the price.

For this assessment, the emissions prices are presented as follows:

- $2.25 (Current price of $5.50 @ two credits for one tonne of emissions)
- $25 (The highest stated price put forward by a New Zealand political party)

For a long term understanding of the price impacts of GHG emissions the following has also been added to the 2020 data even though these high prices would likely only be applied sometime after 2020, if at all. These prices do however represent what the IPCC considers the effective price required to reduce carbon emissions. These prices could be a reality if New Zealand took serious action to reduce GHG emissions.

- $60 low effective range IPCC recommendation
- $200 high effective IPCC recommendation

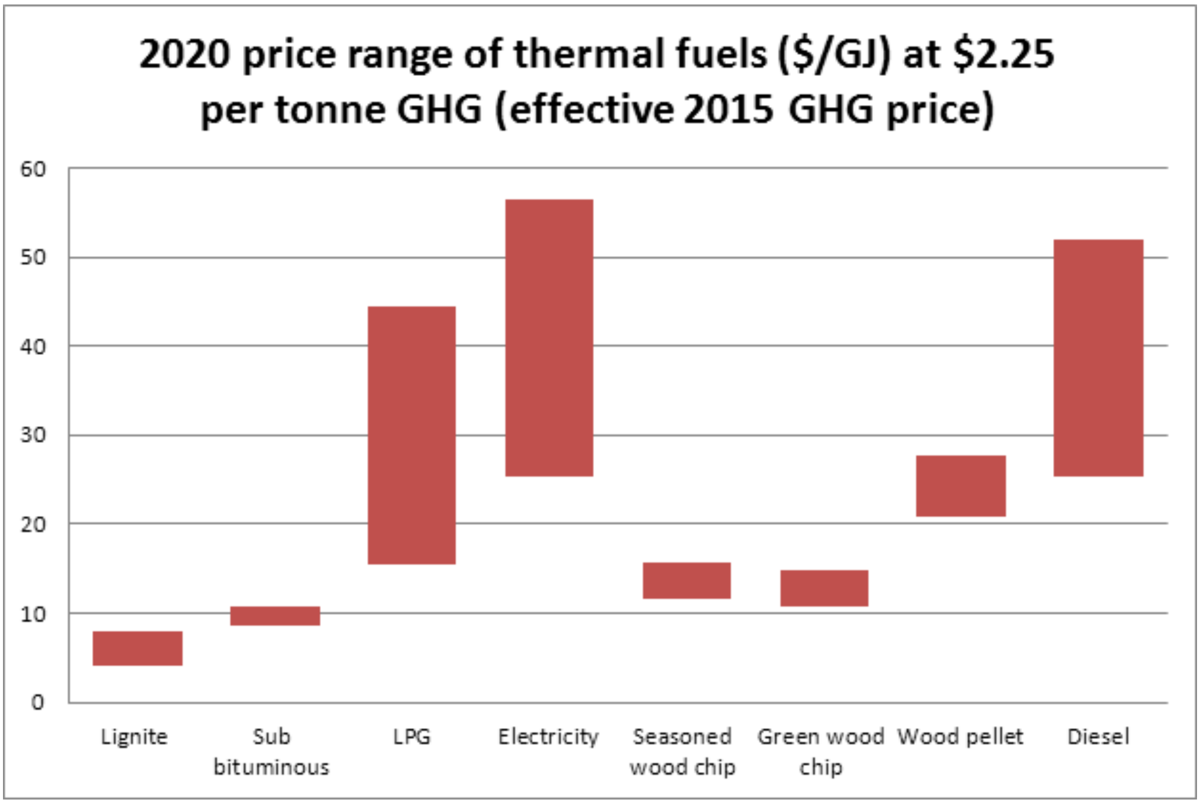

Figure 33 2020 thermal fuels price ($/GJ) at $2.25 / tonne GHG

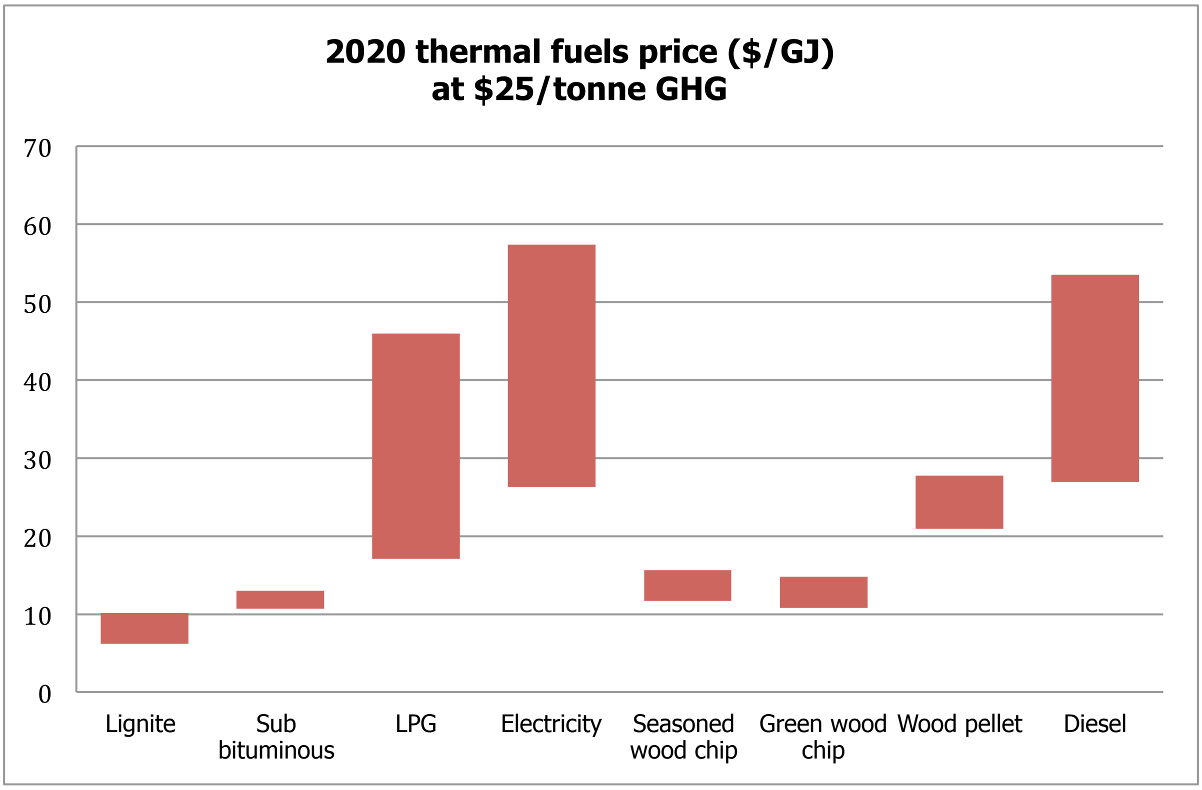

Figure 34 2020 thermal fuels price ($/GJ) at $25.00 / tonne GHG

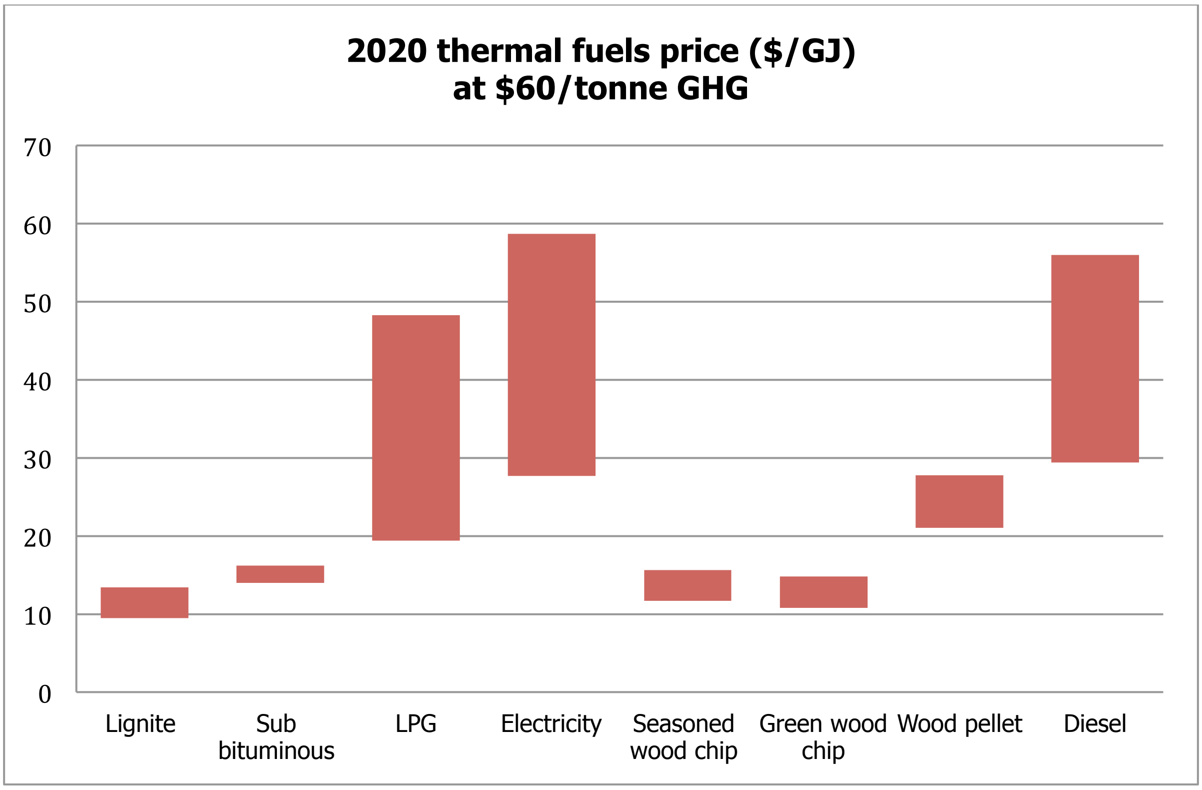

Figure 35 2020 thermal fuels price ($/GJ) at $60.00/ tonne GHG

It should be noted again that the figures above only include fuel costs and do not include plant capital costs and maintenance costs.

When carbon costs $25 per tonne for GHG emissions the price of carbon intensive lignite fuel approaches wood fuel cost but is still cheaper than wood fuels given the data used.

Looking further into the future there may be a GHG emissions cost in line with what the IPCC has suggested as an effective price for New Zealand. For a $60 per tonne of GHG emissions, coals are comparable with wood chip fuels. At $200 per tonne of GHG emissions all the renewable fuels become the clear winners. It is likely electricity would also fare better than what is shown, as a clear price signal would incentivise development of renewable electricity.

9.9 Summary

The following points summarise the existing thermal fuel situation, as well as the impact of a functioning Emissions Trading Scheme:

- Coals are currently the cheapest fuel with wood fuels being the next best;
- Domestically produced fuels are the most stable in price while imported fuels have uncertainty of price;
- Renewable fuels show greatest resilience to an effective GHG emissions price;
- Changes in diesel prices do not have a large effect on the final price of fuels (excludes international shipping).

10.0 Delivering the wood fuel to the end user.

This section of the report discusses the options for delivering the wood fuel to the end user, and provides a recommended best option, cognisant of best available information at this point in time.

10.1 Residue recovery options

There are five main production and delivery systems that can be used when recovering residues for downstream energy use. Note - these systems are focussed on recovering the previously defined merchantable volume, being logs between 1.0m and 3.0m in length. It does not include the recovery of smaller offcuts (slovens etc.), branches or other smaller woody biomass.

- Raw biomass material transported directly from forest to the end user and then processed.
- Raw biomass material transported from forest via a central yard or storage point to the end user and then processed.
- Raw material transported from forest to a central yard for processing and/or storage. Wood fuel is transported to the end user.
- Raw material processed at forest landing and wood fuel transported to a central storage yard then transported to the end user.
- Raw material processed at forest landing and wood fuel is transported directly to the end user (EECA, 2014:27).

Those with the least handling steps are generally the most efficient. Intermediate handling and processing will usually add cost. However the specifics of each situation, including transport distances, will determine which option is the most efficient.

There are two options for timing the collection of wood fuel from the landing, which influence the potential options for subsequent processing. They are:

- Post-harvest recovery.
- Integration with log harvesting

10.1.1 Post Harvest Recovery

There are three obvious disadvantages in recovering the waste residue from an abandoned skid site:

- Typically bulldozers or skidders push the residue into 'birds nests' with significant amounts of soil contaminant mixed in. This contamination provides difficulties when wanting to chip the product, ultimately lowering the quality of the product.
- To store the log residue product effectively will require extra storage space, or will compete heavily for the existing space on the landing.

- Additional handling equipment is needed to handle the woody residue in a separate operation, after the harvesting operation is complete. This additional handling adds significant cost, estimated at $4/tonne of product handled.

The space requirements for woody biomass are a significant limitation for forest managers considering the recovery of log residues after harvesting operations. Topographical limitations, especially in the steeper forests within the Southland area, create restrictions in the size of the forest landings that can be constructed. Typically the forest skid sites are 35 metres wide by 70 metres long, creating a footprint of 2450 square metres. Hauler pads are usually in addition to the landing area.

Harvesting crews will spend on average between four and six weeks at each harvest landing, harvesting a forest area of between 4-12 hectares. During this period the rate of accumulation of woody residue will compound rapidly. It is normal practice to process between 4000m^3 and 7000m^3 of harvestable log product on each landing. 5,500 – 6,000m^3 of recoverable volume is quite typical but there can be significant deviations either side of this figure.

These estimations are reinforced by Visser et al (2009:5), who undertook a survey of New Zealand landings, showing that the median value of landing use is 3 weeks, corresponding to the accumulation of 15-25 truckloads (about 375-625 t) of biomass per landing at the end of that period.

"Exploring the option of stacking the residue on the landing, we can calculate the space this would take up, if properly stacked. Assuming 100 kg m-3 as the bulk density of loose logging residue, the 400 tonnes accumulated at a landing would represent 4,000 m3, and organized in 3 m tall stacks (considering 3 m as the maximum height at which a loader can comfortably stack such material) would occupy a surface of 1,200 m^2." This equates to a half of the typical forest skid site, making it impractical to store the residue on the same skid site that the operations are occurring on.

10.1.2 Transporting to disused skid sites

Transferring the log residue to a disused skid site or landing is an option. The best possible method for a short transfer to occur would be by using large (40m3) hook bins. As the harvesting crew processes the logs, the log residue is thrown into the hook bin directly. This will provide a clean residue product, and will ensure the skid sites are kept clean without impacting significantly on the harvest operation. However, there would be significant capital cost attached to such an operation. Three hook-bins would need to be rotated for each harvest operation that is underway. Also, dedicated hook-bin trucks would be used to transport the bins.

Again, there is insufficient volume from each harvesting operation to justify individual cartage units. The potential to share amongst crews is only moderate, due to the potentially wide distances between the crews across the various forests. At each central yard, there would be a need for the log heaps to rebuilt to allow maximum use of the site. This would demand extra handling equipment, which could be rotated around each forest.

Also, moving loose residues with low bulk density can add significant cost to operations and requires careful evaluation.

The processing equipment (chipper/hogger) must be mobile to travel from landing to landing. The volume at each landing might be in the order of 250 to 350m^3 of solid wood. For a large chipper/hogger that is only 8 to 10 hours' work meaning the machine will have to shift site every day or so, with significant production down time.

When chipping on landings it will be difficult to chip or hog directly into a truck due to limited space or placement of raw material, so discharge to ground is likely, leading to fibre loss, risk of dirt and moisture contamination, and lower production. Lastly, forest managers will usually try to rehabilitate skid sites as soon as possible after harvesting, so that they can be replanted into the next crop. For all these reasons, chipping at landings is often not a preferred option.

10.1.3 Integration of wood energy recovery, during harvesting

Handling the wood residue as a component of the wider harvesting operation has a number of advantages, including the ability to use the harvest crew's on-site machinery to handle the residue. The advantage to a harvesting crew of clearing log residue from the processing site in an efficient manner has obvious economic and safety benefits. The potential cost savings with such a system arise from the reduced handling of the residue product, as the product does not need to be re-handled. The continual clearing of the skid site will provide a clearer work site, and thus a safer and more efficient work environment. Such a system would require additional planning and adaptation from the existing harvest system, and depending on its configuration, may require additional space on the processing site.

10.1.4 Chipping on site, during harvesting operations

When considering the use of a chipper on site, so as to sit alongside the main harvesting operation, the space limitations would not accommodate either the chippers or the transporters. In addition, within the context of the Otago plantation resource, the volume of biomass that accumulates on a daily basis is typically too little to justify integrating a comminution machine on site.

10.1.5 Shifting logs off site, during harvesting operations

The three remaining supply chain options can be described as:

1. Load bin or truck with woody biomass as harvesting progresses / truck direct to end-user / accumulate and store / hog or chip to wood fuel storage.
2. Load bin or truck with woody biomass as harvesting progresses / truck to CPY /accumulate and store / truck to end user for processing.
3. Load bin or truck with woody biomass as harvesting progresses / truck to CPY /accumulate and store / hog or chip at CPY / truck wood fuel to end-user.

The methods for removing logs from the site are described below:

- Stockpile and load out as a log product. In this option, the woody biomass is treated the same as other log products, that is, it is stacked up on the landing and when a truckload is available a truck is requested and the material is loaded out. This system assumes there are sufficient suitable trucks available to remove the material on an 'as required' basis. If truck scheduling is inadequate, problems will occur. Production of the biomass material is a cost to the logging operation in terms of handling and loading and the logging contractor should be compensated for this.
- Load to bins or setout trailers and truck out as filled. This requires leaving the bin or setout trailer at the harvesting crew and retrieving it when full and leaving another empty one with the crew. The bins can be left singly or in pairs and retrieved using a hook system like a jumbo bin or a semi trailer can be left on the landing for the crew to fill.
- A study of the use of setout bins in New Zealand (CEC, 2009) recommended the use of two bins delivered by truck and trailer where possible. This approach should lower cost as the machines are on site and downtime associated with moving to and from the site is minimised. Setout bins should also lead to lower levels of dirt contamination. It is likely that the trucks would need to be fitted with central tyre inflation systems to access landings in winter or wet conditions.
- The down side of the bins is that the transport system has a higher tare weight and lower payload than a conventional truck, and so is higher cost for longer haul distances.
- Stockpile and load out using self-loading trucks. The third option is to stockpile the residues and load-out after the logging crew has left. As discussed above, this is not a practical option, as there is insufficient space on the landings to store large areas of biomass. Self-loading trucks would typically be used to pick up material from a landing after the logging crew has left, as self-loading trucks are slower in loading, and suffer from a tare weight penalty, due to the weight of the crane and stabilizers.

10.2 Chipping

There are three main options when considering where to process the stem residue. These are, either:

1. Chip at a yard, external to the forests.
2. Chip in-forest, after the harvest operation. This has already been dismissed, as described above.
3. Chip in-forest, during the forest operation. This has already been dismissed, as described above.

10.2.1 Chip at a yard, external to the forest

To retain a profitable margin from the sale of any low-value woody residue, the supply system must ensure that the logs are handled as little as possible. Any extra handling of the log residue will add unnecessary cost to the operation, estimated at $3-$4/tonne per handling movement.

Chipping the raw material at the end user (such as a heat plant or further processing facility) has the advantage that the discharge can go directly into fuel storage or heat plant input, minimising handling costs, fibre loss and contamination risks. Large scale fixed location comminution machinery is typically also the lowest cost. However, this may not be a viable option for all due to space requirements for raw material storage and processing facilities. (EECA, 2013:26)

Chipping the product at a central process yard has the advantages of keeping chipping equipment in one site and minimising the potential for under-utilisation of the equipment. All other things being equal, if the log residue supply is maintained at sufficient levels to allow for constant throughput through the chipper, then there will be minimal down time. Larger chippers and hoggers that are able to cope with almost any sized material are expensive to buy and run. While they have higher throughput, they must be able to work close to capacity in order to minimise operating costs. A key consideration is whether the throughput capacity of the chipper or hogger matches the supply of raw material and the demand for product.

Alternatively, chippers can be transported to the central process yard as and when required. This is a viable option when limited volume of chip is being produced at any one site, and the capital cost of a chipper is not justifiable for the limited volume being produced.

A number of studies in New Zealand on drying radiata pine have shown that in good conditions it is possible to reduce moisture content relatively quickly. The main climate factors that dictate good drying include high air temperature, low humidity, good pile airflow and wind. The main storage consideration is stacking, or at least piling the wood. This reduces the amount of wood in ground contact and the impact of rainfall. Wood spread out and in contact with the ground does not dry as well as stacked or piled material.

10.3 Summary table of the Potential Supply Chains

Table 11 summarises the key advantages and disadvantages of each of the options that have been discussed.

Table 11 Summary of supply chains for wood energy

Production of chip within the forest	Advantages	Disadvantages	Assessment
Option A: Mobile chipper, during harvest operation	1. Handling equipment present on site	1. Insufficient space on skid site. 2. Difficult to maximise utilisation of chipper.	Not viable
Option B. Shift logs to CPY within forest, then chip	1. Easy to shift from the skid site.	1. Need additional equipment within each forest area. 2. Additional capital investment in hook bins and trucks 3. An additional handling step required. Costly. 4. Requires good-quality infrastructure to accommodate trucks.	Low
Option C. Shift wet log residue from forest to external CPY during harvest operation	1. Easy to manage as part of the daily harvesting operation. 2. Good ability for total quality control; including chipping in centralized location. 3. Chipping direct to storage, retaining a quality product. No contamination. 4. Less product handling	1. Transporting a low-energy, high-moisture product from forest to CPY	high

10.4 Recommended supply chain

With our current level of knowledge about retrieving wood residue, Option C above would appear to be the most effective and feasible method for producing a quality wet wood chip product from Southland forests. This wood chip supply pathway is consistent with current harvesting systems, with little deviation from current practice for harvesting crews. The logs would be stacked as per other log products, and loaded out as per other log products, with removal on a regular basis. It would be important for the cartage operators to keep trucks up to the harvest contractors to ensure that landings do not congest.

There is potential for fine-tuning this system, with the use of hook bins being one example, as awareness develops around the real-time requirements of handling the stem residues. For example, the use of $40m^3$ hook bins on the landing has merit. As harvesting crews produce the woody residue, it is thrown immediately into the awaiting bin. Cartage management is essential, with bins being removed immediately. The placement of a hook and towrope on the front of each bin will allow the harvest contractors to shift the bins from the landings when required. A secondary bin on each site will allow for rapid turnaround, with cartage contractors being able to quickly unload an empty bin and upload a full bin without impacting upon the forest harvesting operation.

Comparing this system to the traditional log and load system, there is a greater handling component with the traditional log and load system and a higher potential for contamination of the log residue. The advantage of the traditional log and load system is that it exists now, and as such it will not involve any additional capital expenditure from forest owners or cartage operators.

However, a strong recommendation of this report is that carefully-design time / productivity studies are commissioned to better analyse the supply chain options that are specifically applicable to Southland and Otago. The information that has been used in this report is based upon conversations with a number of forest owners, portable-chipping operators, and from national and international studies. Considerable differences of opinion exist between the people interviewed for this study; each with valid points that require considered attention. The studies that have been used to inform this report are often focussed on the Central North Island forest industry, which is significantly different in structure and scale from the Southland industry. There are sufficient variables, and opinions that would suggest other supply chain options should be considered and thoroughly evaluated via assessments of real-life trials.

10.5. Developing a central processing yard for wood chip production

Long-distance cartage of low-value wood residue is not economically viable, and as a consequence, processing must occur within close proximity of the forests producing the logs. Central processing yards (CPY) also need to be as proximate as possible to the end use, and ideally, are at the site of end use. Other attributes of a good site include:

- ✓ Dry, and open to log-drying winds.
- ✓ There is plenty of flat land, a weighbridge and under-utilised equipment such as a wheel loader.
- ✓ There are no resource consent difficulties.
- ✓ Cost-effective rental price.

Determining the best location for a CPY will be led by the need to most effectively service early cornerstone customers, as well as by securing the most commercially viable site.

It will be important to ensure sufficient wood chip is available during periods of high demand, and to have sufficient storage cover to ensure the quality of the stored wood chip. Any storage facility would need to provide for first in – first out rotational handling, minimising the possibility of inadvertent long-term storage through inability to access the older material. It would also be prudent to monitor the temperatures of the piles. The best cover for the chip product is a non-contact roof that allows for breeze flow through the site and for any moisture and heat build-up to escape. The ideal storage unit would entail three sides and a roof, with concrete floors and a rear concrete wall. This structure would allow for shifting and loading of the wood chip. There will need to be sufficient space within the storage shed to allow for free movement of machinery, especially when filling the hopper.

10.6 Recommended supply chains for large users of wood energy

Any large-scale user of energy would benefit from having their own log storage site and processing yard on site, and processing at the site of energy consumption. An on-site storage and processing system will minimise the handling of log products, and allow for greater control of the supply chain. For the energy user, they would need to invest capital in storage and processing machinery (chipper, excavator, loader), and buy log products direct from the forest owner or via a log-marketing agent. Logs will be delivered on a daily basis, temporarily stored, chipped, and then used. It would be necessary for the energy user to maintain a buffer of log stocks so as to ensure that consistent supply was available at all times.

11.0 Future Research

11.1 Biomass recovery options for Southland forests

As discussed earlier, there is a need to specifically evaluate the biomass recovery options from landings in Southland forests. This is still a relatively unexplored subject in New Zealand, particularly with regard to non-Central North Island (CNI) forests. CNI forests have, unsurprisingly, received the majority of the attention to date, due to the large scale, well-established forest infrastructure, and significant users of heat energy within close proximity to the forests. These attributes mean the studies lack some relevance to Southland and Otago forests.

A study that used real operations occurring in Southland plantations would evaluate the value of energy obtained by collecting, processing and delivering forest residue to a heat plant facility for conversion into energy. Evaluating the different supply chain systems, including in-forest chipping, and the use of dump trucks to shift residues from operational skid sites to Central Processing Yards (disused skid sites) should be evaluated in the context of the more scattered Southland forest estate. To give confidence to forest owners and potential energy users, it is important to validate this through field trials and extended time and motion studies. In their absence it will be very difficult to develop accurate estimates of delivered costs, and to draw reliable comparisons between alternative systems.

It would also be important to determine the actual amount and type of residue produced at typical landings, since the data used to date is based on a very limited number of local trials, and ballpark figures from forest owners. These methods are acceptable for this study, but a more refined analysis may well result in other opportunities – and potentially greater utilisation of residues - becoming apparent.

Other aspects of an assessment should aim to understand:

- The cost of processing skid site residues with a shredder, versus a chipper.
- The quality of the product that results, and its suitability for target boilers.
- The ability of the forest infrastructure to accommodate chip liners, or similar trucks.
- The most effective method of handling the wood chip, and the machinery and infrastructure required to do this.
- The costs and benefits to forest owners (e.g. revenue for product, and clean skid sites for replanting).

11.2 The profitability of growing short rotation forest energy crops

As discussed in Section 2 of this report, there is a potential opportunity to specifically grow short rotation forest crops for energy. This could represent a viable land use as stand-alone forest investments, or as an integrated component of farming operations. The shorter rotations would improve the likely acceptance of forestry as an investment, however its ability to provide a higher return on investment than alternative land uses (such as farming) requires specific research that is cognisant of the Southland environment.

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Appendix 1.0 Large forest owners within the project area

The corporate forest owners within this project area are described in this section.

Ernslaw One Limited

Ernslaw One operates in both the north and south island, with a significant forestry operation in Otago and Southland. In Otago and Southland, Ernslaw One owns and manages 29,323 ha of forest estate, of which 22,500 ha is in a commercial forest crop.

Rayonier New Zealand Limited / Matariki Forests

Rayonier NZ Ltd manage the 41,000 hectare Otago / Southland Matariki Forest estate. Of these 41,000 hectares, 30,000 hectares is plantation forest. Over the next decade, Rayonier will harvest 420-450,000 tonne / annum. Their forecast is for that amount to increase to 450-500,000 tonne per decade from there on in.

Craig Pine Limited.

The forest estate comprises eight forests of 3731 hectares of freehold land all situated in Southland. The net stocked area of forestry is 2983 hectares. Craigpine Timber Harvest approximately 20,000 tonnes of radiata pine each year from their own estate. It is possible to forecast that this annual increment can be maintained until 2034 when yield is set to at least triple.

Southland Plantation Forest Company of New Zealand Limited.

Southland Plantation Forest Company of New Zealand Limited (SPFL) appointed Southwood Export Limited (SWEL) to manage its 10,500ha of plantation grown Eucalyptus Nitens forests. The SPFL estate is comprised of forty individual forests where planting began in 1992. These forests are located within Southland/ Otago and are grown on a renewable and sustainable basis. The sustainable annual harvest is in the order of 250,000 tonnes.

Appendix 2.0 Evaluation of competing thermal fuel prices - background data and methodology.

Coal price notes

Coal price forecasts were sourced from a report based on 2013 data. The prices were inflation adjusted to 2014 prices. The international price assumptions for sub bituminous are already out of date due to the recent decline in international coal prices. In the model used to forecast prices the international price had a 2% influence per annum on domestic prices, however the detail of the model is not known and prices are given as per the forecast based on the 2013 international coal price estimates.

LPG price for imported LPG

Importer margins for LPG are not known, as there have not been significant volumes LPG imports in recent years. For this calculation the simplistic assumption that LPG importer margins are similar to diesel importer margins which comes to $3/GJ

Transport costs from Dunedin are also included in the cost calculation and come to $1/GJ

The futures market predicts only moderate increases in LPG price. Between February 2015 and 2019 and 11% increase is expected with a peak price in March 2016 15% above the February 2015 value.[6] The 2019 international futures price for LPG is US$419 per tonne which translates into NZ$11 per GJ.

Table 12 estimated and measured components of LPG delivered price - low range

LPG	**$/GJ**	
2019 price low price prediction assumptions	11	2019 futures market LPG price
Fuel cost	1	Assumes $0.234 per tonne*km. 30tonne per tanker truck[7]
Importer costs	3	Assumes 30% importer costs not including road transport
Total	16	

Due to the potential for LPG to remain cheap the 2019 possible New Zealand LPG price range is quite wide, though it is comparable with the range of other imported fuels.

Oil price calculation

To calculate the 2020 forecast and the current price of diesel two EIA forecasts were used.

[6] CME Group (2015) Argus propane Saudi Aramco swap futures
[7] Pearson (2007) Review of road freight costs in New Zealand and comparable Australian states

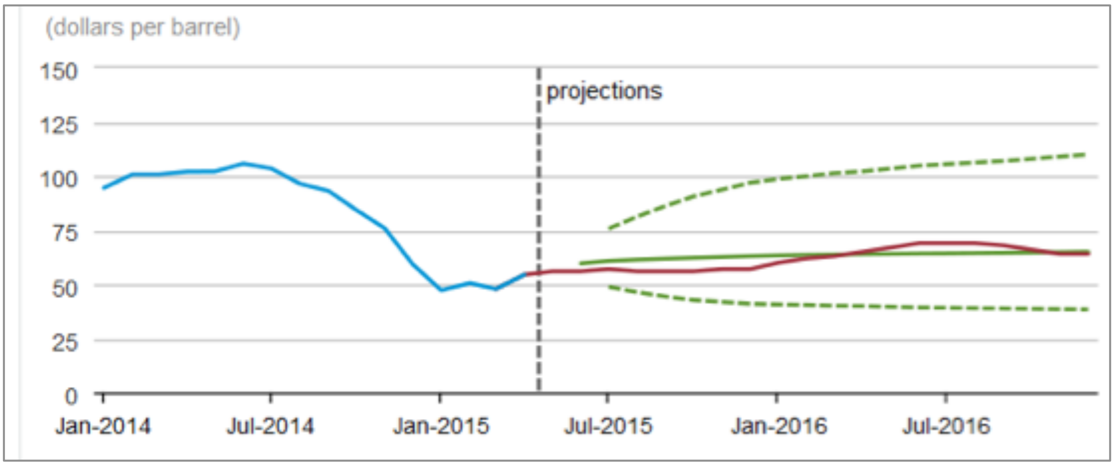

Figure 36 West Texas Intermediate (WTI) crude oil price $US/barrel[8]

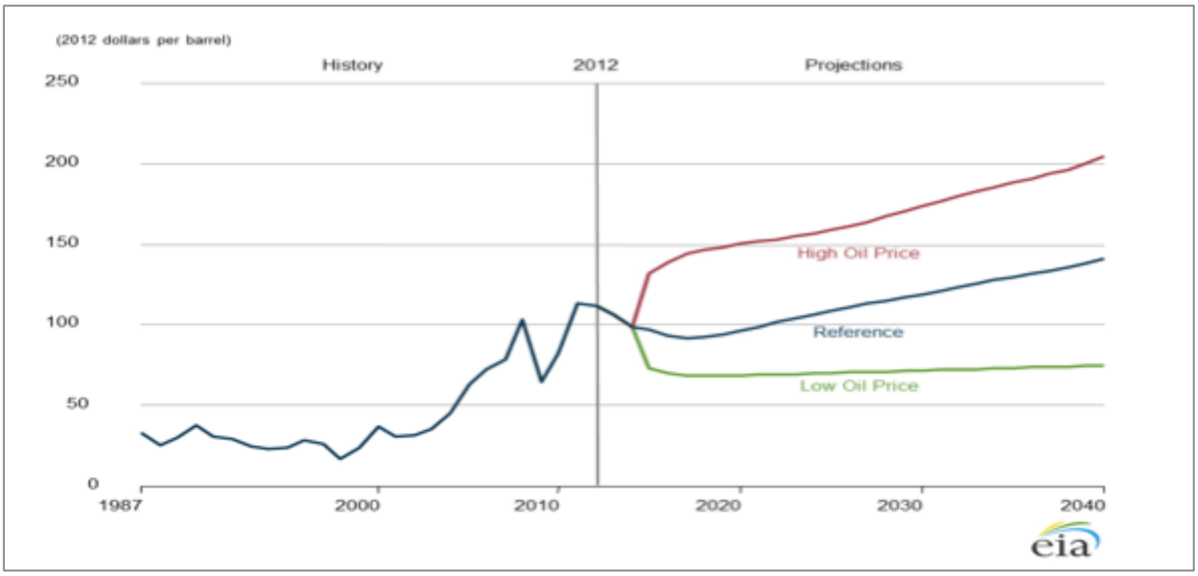

Figure 37 Average annual Brent spot crude oil prices in three cases, 1987 - 2040[9]

The WTI forecasts are more readily available than Dubai crude price forecasts and were used to get price forecasts. $4 was then added to convert from WTI to Dubai crude as West Texas intermediate (WTI) oil is typically priced around $4 less than Dubai crude and at the time of writing this report the WTI crude price was $4 less per barrel than Dubai crude.[10]

The 2020 price forecast range used Figure 36 and Figure 37 to encompass the full range of possibilities. Figure 36 gives the low price forecast reflective of recent low prices. Given the situation in 2014 that may well occur again before 2020 Figure 37 was used for the high price so to encompass all reasonable possibilities.

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[8] EIA (2015)

[9] EIA (2014) International energy outlook 2014

[10] Index mundi (2015) Oil Prices

As a point of interest this year the Dubai Crude price hit a low of $US46.34 per barrel, which has not occurred since 2005, however the price only remained that low for a short period.

Diesel suppliers that were contacted did not readily divulge pricing information. Therefore calculations were made from crude prices and it is estimated a delivered price is 2 – 14c/l below the pump price given the current importer margins are up to 25c/l.

For this report for thermal fuels price from 2014 are used as the best representation of current prices as 2014 data was more readily available than 2015 prices. However for diesel the 2014 price was quite a lot higher than the current price, which is not an accurate representation of current price. As such prices from July 2015 in Figure 36 were used for diesel prices that are listed in the final graphs as 2014 prices.

This gave a 2014 price of 28 – 34 $/GJ based on an exchange rate of NZD 0.75 per USD.

The June 2015 price of crude oil is US$52/barrel and price of diesel at the pump of 132c/l were used as the start point for all calculations.

A conversion factor of 8c/l change in diesel price for every $10NZD/barrel was applied to get from a change in crude price to a change in diesel price. NZ75c/$US was used as the exchange rate.[11]

GHG cost calculations under varying cost per tonne of GHG

Table 13 Factors used to calculated carbon emissions from thermal fuels[12][13]

Fuel	kg of CO_2 per unit	Unit	Energy content	Unit (energy content)	$KGCO_2$ per MJ
Coal - lignite	1.43	Kg	13.66	MJ/kg	0.105
Coal - sub bituminous	2	Kg	17.56	MJ/kg	0.114
LPG	3.03	Kg	45.98	MJ/kg	0.066
Electricity	0.138	kWh	3.6	MJ/kWh	0.038
Wood	0.0143	kg	14.61	MJ/kg	0.001
Diesel transport	2.72	litre	38.32	MJ/l	0.071

As lignite has a high water component between 30-70% where energy use to evaporate water is not factored into the equation, then providing there is not full heat recovery (which is unlikely in a coal boiler) the CO_2 emissions per joule of recoverable heat will be higher than shown above by and amount that is dependant of water content.

[11] RBNZ (2005) Oil prices and the New Zealand economy

[12] Ministry of the environment (2015) Summary of emissions factors for the guidance for voluntary corporate greenhouse gas reporting – 2015 http://www.mfe.govt.nz/publications/climate-change/summary-emissions-factors-guidance-voluntary-corporate-greenhouse-gas-reporting-2015

[13] Ministry of Business, Innovation & Employment (2013) New Zealand Energy Data File 2012

Once the CO_2 component of each fuel is known for a common unit of tonne CO2 per GJ, a price can be applied to give the relative cost of emissions under different emissions price scenarios.

Table 14 Price increase in ($/GJ) for alternative price of GHG emissions

	$2.25 per tonne GHG emissions	$5.50 per tonne GHG emissions	$12.50 per tonne GHG emissions	$25 per tonne GHG emissions	$60 per tonne GHG emissions	$200 per tonne GHG emissions
Coal - lignite	0.2	0.6	1.3	2.6	6.3	20.9
Coal - sub bituminous	0.3	0.6	1.4	2.8	6.8	22.8
LPG	0.1	0.4	0.8	1.6	4.0	13.2
Electricity	0.1	0.2	0.5	1.0	2.3	7.7
Wood	0.0	0.0	0.0	0.0	0.1	0.2
Diesel	0.16	0.4	0.89	1.77	4.26	14.20

As can be expected the fuels that produce the most GHG become relatively more expensive as the price of GHG emissions is increased while less polluting fuels such as wood chip and to a lesser extent electricity are less affected. It can also be seen at a price of $5.50 per New Zealand units, where one unit is surrendered pre two tonne of GHG emissions that the ETS component in fuels is relatively small for all fuels with coals being most affected.

Transport component

Another significant cost is transport costs and it has been checked what influence diesel price has on the cost of the fuel being transported. Coastal shipping and processing costs were not analysed in this manner due to significant unknowns.

Table 15 Additional $/GJ of transport at different rates

	100c/l	**200c/l**
Coal – lignite	0.20	0.40
Sub bituminous coal	0.12	0.24
LPG	0.14	0.29
Electricity	n/a	n/a
Wood (25km from source)	0.05	0.11
Wood (200km from source)	0.44	0.88
Diesel	0.02	0.04

As diesel is only 18% of total land transport costs then the difference between high and low price only has a small influence of total costs. The most affected is wood transported a distance of 200km. Where diesel cost was 200c/l instead of 100c/l the cost increase would be $0.44/GJ or 3.4% increase in costs total costs. The increase would be even less relative to other fuels considering other fuels also have a price increase.

Due to the small influence of diesel price as a portion of costs coupled with the uncertainty around diesel prices, it is not something that needs to be incorporated into thermal fuel decisions.

Transport costs calculation

Diesel prices were calculated first by measuring the distance for current transport distance from source to Invercargill.

Table 16 Transport cost calculations

Fuel	Start point	End point	Distance (km)
Lignite	New Vale	Invercargill	84.5
Sub-bituminous	Nightcaps	Invercargill	75
LPG	Dunedin	Invercargill	205
Electricity	n/a	n/a	n/a
Wood (25km)	n/a	n/a	25
Wood (100km)	n/a	n/a	100

Wood pellets were not included, as it was not known what the typical road distance was. The fuel component of pellet with the current travel distances would however be significant.

The following factors were used to calculate transport costs.

Table 17 Factors used to calculate transport costs

Factor	Value
Diesel (low price)	100c/l
Diesel (high price)	200c/l
Operating costs km/tonne (50% laden)	0.205
Cost % fuel	18.50%
Price Diesel 2007 (in 2012 real dollars)	118.49
100% laden load of fossil fuels	44 tonne
100% laden load of wood fuels	30 tonne

From the data a cost per round trip is calculated to give diesel cost per load. Then a cost per GJ can be calculated. From there it can be scaled to give a cost per GJ for both the high and low diesel price.