Wood Energy Supply Options for City Forests Limited

July 2009

Forest Environments Ltd

Executive Summary

City Forests Limited (CFL) has a forest estate that sits within close proximity of Dunedin city and its growing industry. The potential to use some of the forest's woody biomass to meet the demands of Dunedin's industry has been recognised by CFL. Society's growing recognition of woody biomass as an efficient and clean energy source is coming to the fore, and CFL wish to be positioned for best advantage.

This study has estimated that CFL will produce 15,500 – 17,000 cubic metres (m3) of 'log stem residue' per annum within the next four-five years, as the annual harvest settles at a sustainable yield of 300,000 cubic metres. The log stem residue is currently of marginal value, subject to an unreliable market and low prices. Retrieving additional value from this residue is the core objective for CFL in evaluating a potential bioenergy business.

A number of bioenergy supply chain options were examined, with production of wood chip from air-dried logs proving to be the most feasible and profitable. A supply chain that fits within the current CFL harvesting systems, with little deviation from current practice for harvesting crews, has been determined to be the most cost effective. There is potential for fine-tuning this system, with the use of hook bins being one example, as real-time awareness develops around the requirements of handling the stem residues.

Incorporating the recovery of the woody residue as part of the harvesting operation reduces the site requirements for storage, and also reduces the likelihood of contamination of the logs. To ensure the operation is as efficient as possible and to maintain the productive output of the harvesting contractors it is important that minimal time is attached to handling of the residue and that the on-site accumulation of recoverable volume is minimised.

Dunedin's short summer period is a major constraint in the production of high calorific value wood chips. Air drying the logs will need to be managed carefully, with chipping occurring over a summer period of four-five months. A low capital investment strategy will require the storage of the woody residues in an un-comminuted form for as long as possible. Once comminuted, the dry wood chips (maximum 30% MC) are relatively stable and are less likely to suffer from significant dry matter losses.

A significant storage facility will need to be constructed to enable the comminuted material to be stored with less risk of reabsorbing moisture, and to allow for sufficient build up of wood chip for subsequent sale over the peak demand in winter.

To meet the anticipated demand of wood chip from Dunedin's industry, and to realise a good return on investment, CFL will need to produce a minimum of 12,000 m3 of wood chip per annum (8,000m3 of log input). At this level of supply, core capital investment should be restricted, with hiring of specialist equipment proving to be more cost effective.

As production grows further capital investment should be contemplated, with a shift from hiring equipment to purchase of equipment. Favourable return on investment occurs at 15,000m3 of log input. The internal rate of return at this volume is satisfactory for capital invested and the business risk involved.

It is recommended that CFL take further steps to better understand their ability to produce a quality wood chip product at a low cost. This includes field trails that will help understand the storage of log residue, and the effect of time and weather on seasonal drying of logs.

The potential to utilise process heat from the CFL-owned Milburn processing plant should also be investigated. Such a process could add significant value to the wood chip through densification of the product. The capital investment required and return on investment will need comprehensive investigation.

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1.0 Introduction

An opportunity exists for Dunedin City to provide a significant proportion of its industry's energy requirements using locally owned and sourced wood fuels as a renewable fuel resource. Doing so will also create additional opportunities for forest companies, such as City Forests Limited (CFL) to create additional revenue utilising an existing waste stream.

The Dunedin City Council (DCC) in partnership with CFL and Otago Polytechnic (OP) received funding from the Energy Efficiency and Conservation Authority's (EECA) Wood Energy Grant Scheme (WEGS). The fund was used to investigate the opportunity of creating a locally owned and sourced wood fuel using local energy consultant, Transitionz Group Ltd, and land management consultant, Forest Environments Ltd.

The project is separated into demand (end user) and supply side (forest supply) components and reporting will be completed according to partner reporting requirements. This report, "Wood energy supply options for City Forests Limited" addresses the requirements of the supply chain, from forest floor to point of sale. From a forest owner's perspective it is important to understand the security of demand for the woody bioenergy product, the cost of production of the product, and any barriers that may limit the potential of this new business stream.

This report follows on from the study completed by Transitionz Group Ltd, which considered the potential demand for wood energy in Dunedin. The recommendations from these two reports, "Wood Biomass Options for the Dunedin City Council" (July, 2009) and "Wood Biomass Options for the Otago Polytechnic" (July, 2009) have directed this study to analyse wood chip as the preferred product of supply for CFL.

This report begins by assessing the volume of usable woody residue that is available within the CFL estate. It then discusses the operational considerations of a potential bioenergy business; evaluates these considerations with due applicability to the CFL estate, and provides recommendations for a CFL supply chain. The profitability of a bioenergy business is explored, with the potential risks of a CFL bioenergy business also discussed. Finally, recommendations for the next steps in the development of a bioenergy business are made.

2.0 City Forests Limited

2.1 The Forest Estate

City Forests Limited (CFL) is a trading enterprise of the Dunedin City Council. The company manages about 16,000 hectares of commercial forests, which have progressively been developed since 1906. All of the forests are located within a 70 kilometre radius of Dunedin City.

The net stocked area stands at about 15,600 hectares, while a further 500 hectares is normally under preparation for restocking (MAF: 2008:9). CFL also manages close to 900 hectares of reserves, including natural forest, swamplands and habitats for native species. Such management fits well with CFL's commitment to improving the long-term sustainability of the forest resource. As well as managing for environmental benefit, CFL provides significant community benefit through the provision of recreational opportunities. Walking tracks, hunting and fishing are typical forest-based activities that are provided to the community. CFL holds Forest Stewardship Council (FSC) certification, which underpins their commitment to sustainable forest management. CFL was one of the first companies in New Zealand to adopt this environmental certification.

87% of the CFL estate is radiata pine. Other key timber species within the estate are Douglas-fir and cypressus. Larch and eucalyptus species are present in small volumes within the estate.

2.1.1 Forest Harvesting and Infrastructure

City Forests Limited operates a traditional New Zealand plantation forest harvesting system, utilising a mix of ground based harvest systems and cable haulers. The split of harvesting methodology is fairly evenly split, reflecting the topography and ground conditions of the various forests within the estate.

Five full-time logging contractors operate within the forests, producing between 220,000 and 280,000 cubic metres of saleable log product per annum.

2.2 Timber processing.

In 2006 CFL commissioned a dry-mill processing facility, based in Milburn. The throughput is predominately pruned radiata pine, sourced from its own forest estate, which is green-sawn at neighbouring sawmills before coming to the CFL mill for value-added processing and drying.

The plant kiln-dries and dresses sawn timber for both the domestic and export markets, focussing on the production of appearance-grade lumber for furniture, joinery and mouldings. Annually, about 24 000 cubic metres of logs are processed (MAF, 2009: 57)

The Milburn processing facility is situated centrally within the CFL forest estate, in relative proximity to the high producing CFL forests of Tokoiti and Waipori. It is strategically located on State Highway One, 48 kilometres south of central Dunedin.

Photo: CFL's Milton Processing site. Photo courtesy Stephen Jaquiery *(www.cityforests.co.nz)*

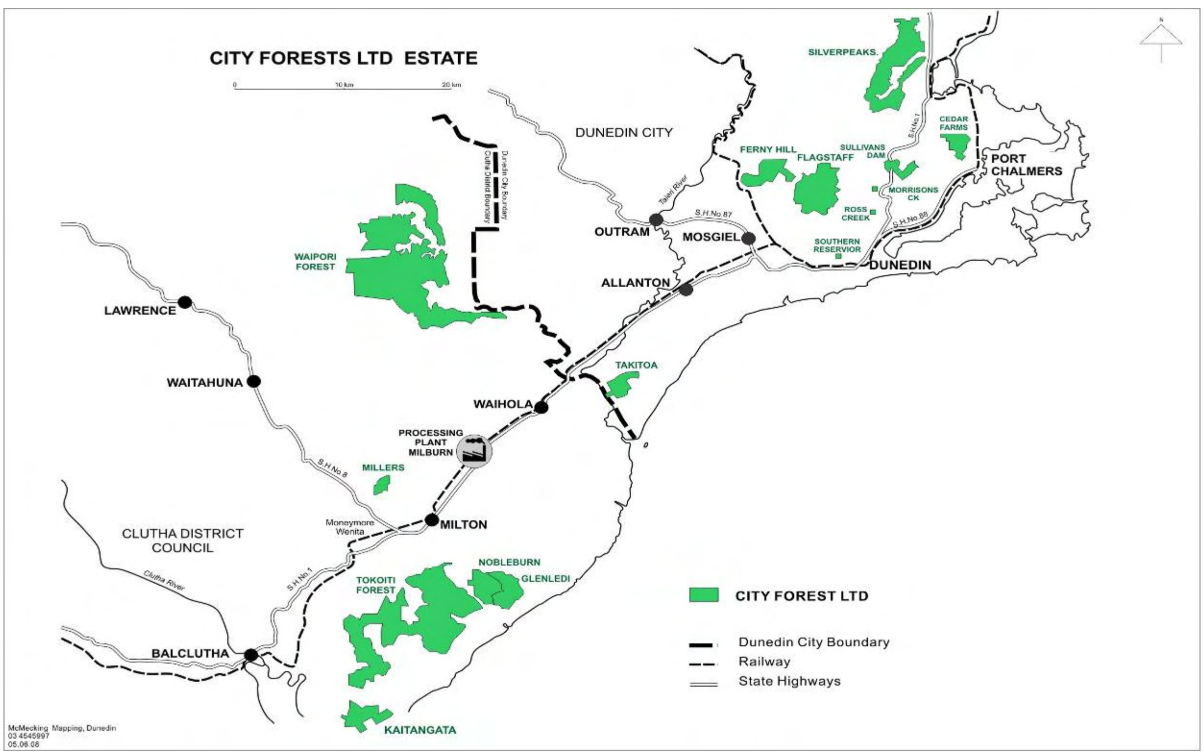
Though not currently utilised by CFL, the immediate proximity of the national rail main trunk line has the potential to provide cost-effective transport for forest products produced at the Milburn processing site. Currently, the cost effectiveness of road transport and the extra handling requirements attached to rail transport make rail transport economically less viable. However, the environmental advantages of rail, together with rising energy costs may provide better opportunities to utilise this form of transport in the future.

2.3 Chipping Facility

CFL has a fifty percent holding in a chip mill on the outskirts of Mosgiel, on the northern Taieri plain. This facility has the potential to process around 100 000 tonnes of wood chips per annum.

2.4 Geographic spread of CFL forest estate and key infrastructure

The map below provides an overview of the geographical distribution of the various forests within the CFL estate. It also provides reference to the processing plant, and to the city of Dunedin. All of the forest lies within a 70 kilometre radius of Dunedin city.

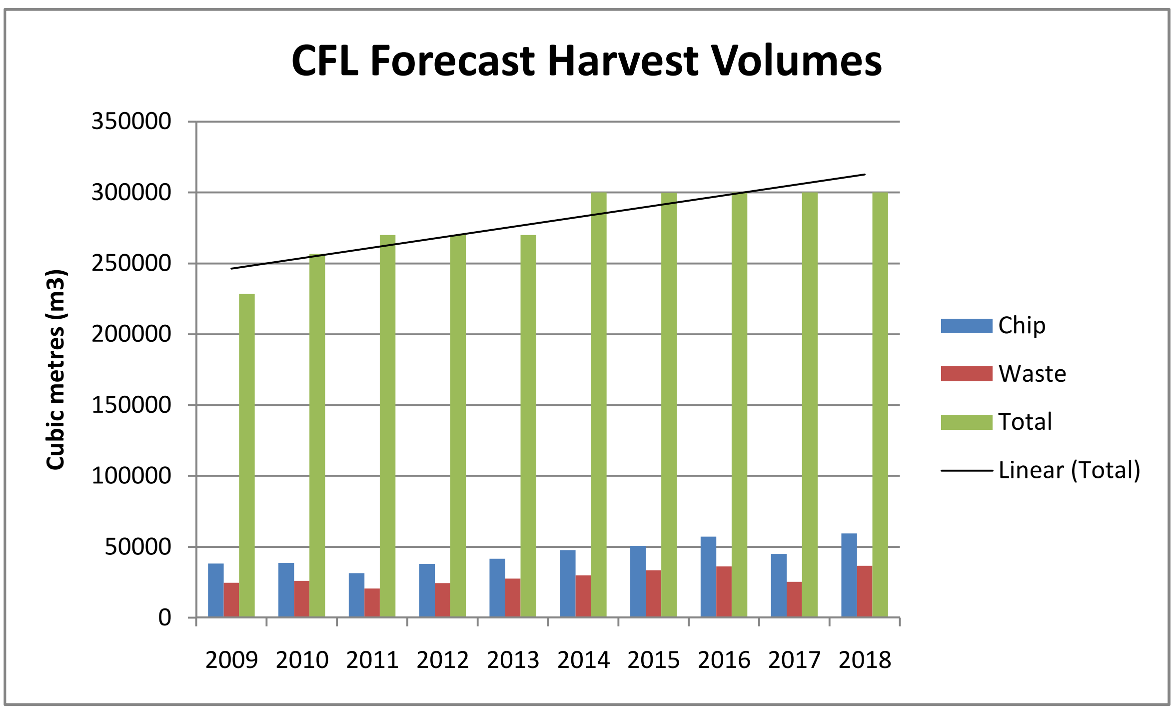


Map 1.0. City Forests Ltd, Forest Estate (*courtesy CFL*)

3.0 The CFL forest resource

Forecast harvest volumes from the CFL estate are depicted graphically below. Over the next decade, a steady annual increase in production is planned. The current harvest volumes of 200,000-220,000 cubic metres / annum will rise to an annual harvest volume of 300,000 cubic metres / annum by 2014. The sustainable harvest volume is likely to be maintained at 300,000 cubic metres there on in.

Market conditions, logistical constraints, environmental and social conditions may impact upon the ability to meet expected harvest volumes. The globalised economy, upon which the forestry industry is so reliant, imposes many uncontrollable factors upon forest owners such as CFL.



Graph 3.0 CFL Forecast Harvest Volumes, 2009 - 2018

3.1 Forest Residues for Energy Production

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 unutilised. It is these forest residues that have the best potential to be used as an energy product, due to the ability to add economic value to a product that is currently valueless.

Forest biomass supply for energy is typically generated from logging residues. This material is a mixture of wood, bark and needles. 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 (road side skid sites) and at the stump (cutover).

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

3.1.1 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 systems used by CFL will typically mechanically delimb the branches on the cutover site, thereby leaving significant woody residue behind. Conversely, the hauler systems will drag whole trees to the landing, and then mechanically de-limb at this point. As such, hauler landings exhibit a much greater accumulation of woody residue, due to the significant volume of branch residue.

The branch residue that is generated as part of the log-making process is smaller in size and as such quicker to dry than that of the stem residues. However, they are also more costly to handle due to their small piece size and low density, and are typically 'contaminated' with needles and soil. These needles need to be left on the forest floor whenever possible, as they contain high levels of macro-nutrients such as Nitrogen, which provide an essential contribution to the nutrient status of the forest soil. The CFL Forest Asset Manager is "reluctant to reduce the potential for such valuable nutrient recycling to occur within the forest by removing the branch residue from the cutover" (pers comm K.Chalmers, 10/04/09).

3.1.2 CFL Cutover assessment:

As a part of this study, an assessment of the potential woody residues within the CFL estate was made. A manual walkover of the cutover was carried out on three recently harvested sites to assess the cutover residue within the CFL estate. Though only a small sample, it does provide some good indicators of the level of stem wood residue that remains on the cutover within the CFL estate.

	Billet wood	Chip wood	Total stem residue
Mean (m3 / ha)	13.29	23.25	36.54

Table 3.1.2a CFL Cutover residue assessment

The volume of merchantable stem residue that remains on the landing at the completion of a harvesting operation will often be driven by the market for billet wood and chip logs as they stand at that time. The demand for billet wood, in particular, fluctuates markedly.

To form a comparison with other forest cutover sites within New Zealand, the 'Bioenergy Knowledge Centre's' calculator for residue recovery was used. The results are tabulated below.

	Poor Quality Stand	Average Quality Stand	Good Quality stand
Ground Based samples (m3/ha)	41.82	27.68	17.83
Hauler samples (m3/ha)	84.87	55.97	27.68
Mean (m3 / ha)	63.35	83.65	22.76

Table 3.1.2b Typical stem residue recovery from New Zealand forest cutover

(From the Residue recovery calculator, at www.bkc.co.nz. A default value of 615 cubic metres / hectare was used) .

The cutover residue assessments, though small in sample size, provide an indication that the stem residue that remains on the CFL cutover is typical of New Zealand plantations.

For CFL, recovering these cutover residues will not be cost effective due to 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. A decision to recover more of the cutover residue will instead be driven by CFL forest managers placing greater emphasis on recovery as part of the core harvest operation. Forest managers, in turn, will be driven by a more reliable and profitable end-user market for this log product.

Photo: Typical woody residue that has been mechanically windrowed on the cutover, to allow for reestablishment of the next crop of trees. Note the soil contamination within the residue.

3.2 Forest residues generated at forest landings.

The forest landing, or skid site, is the main point of woody residue accumulation in the forest. Such woody residue is largely tree tops, branches, and log off cuts that have not been able to be utilised by the harvesting crews in meeting their log grade supply requirements. Normally, this is because of defects within the log at that point.

The amount of residue that accumulates at the forest landing is influenced by two key factors:

1. The harvesting system used.
2. The quality of the forest crop.

The residue that accumulates at landings is of a higher priority than the residues accumulating on the forest cutover because of the following reasons:

- There is a condensed, cumulative volume
- The volume of residue is located within a processing site that is best positioned to make use of forest harvesting and processing equipment.
- 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 potential energy by-product.

3.2.1 Landing management and accumulation of stem residues

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 4000m3 and 7000m3 of harvestable log product on each landing. 5,500 – 6,000m3 of recoverable volume is quite typical (pers comm G. Bonner, 13/04/09) but there can be significant deviations either side of this figure.

The manual harvesting systems present within the CFL estate see rapid accumulation on hauler landings, with the delimbing of the trees taking place on the landing itself. The ground based systems will typically delimb on the cutover, thereby reducing the biomass build up on the landings. Currently woody residue that does not meet a log specification is discarded, often being thrown far from the landing with the use of grapple loaders. Maintaining a clean landing is considered to be a key component of efficient harvest practice, and harvesting contractors will keep all non-saleable log product distant from the forest landing.

Topographical limitations, especially in the steeper forests within the CFL estate, 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.

Creating larger log storage areas is infeasible on some sites, due to topographical limitations, and is simply too costly on other sites. Earthworks costs are high and need to be restrained. The environmental implications of creating very large forest landings are also a key consideration for forest managers.

Requirements to meet the demands of export and domestic log markets will often create the need to manage for high numbers of log grades, creating multiple log piles over the full extent of the landing. Cutting over 12 different log grades is not uncommon, with sometimes 20 different log grades being cut.

Photo: Stem residue accumulation at a CFL forest landing.

3.2.2 CFL Forest Landing Residue Assessment

Assessing the amount of residue that accumulates on the forest landings is a difficult task, due to the large and random volume that accumulates on these sites. As a part of this study, three harvest contractors weighed a sample of the volume of stem residue that accumulated during their harvesting operations. The residue volume was weighed, using the scales of gravel trucks, and then compared against a pre-harvest inventory.

This assessment provided two simple assessments:

1. An indication of the accuracy of the forest inventory process in determining the accumulation of stem wood residue.

2. An approximation of the different proportions of stem wood residue which can be expected to accumulate on the forest landings. In this assessment, the stem wood residue was classified into three types:

A) Billet wood. 1.0m – 3.0m length, SED 10cm.
B) Blocks. Larger than slovens, but smaller than billet wood.
C) Slovens. The offcuts from the butt logs, typically short, but of large diameter.

The information from the samples was reconciled against YTGen inventory estimates, so as to provide estimations of the recoverable woody residue component of harvesting operations. For the purpose of this study, woody residue that can be potentially used for wood chip is no smaller than the billet wood grade as specified above.

Numerous studies provide evidence as to the inefficiency of handling very small pieces of residue. Understanding this, and that many wood chippers will not process log residue of less than 1.0 metre in length, has been the basis for the utilisation cut-off point for wood chip production.

	Poor Quality Site	Average Quality Site	High Quality Site
Total woody residue as proportion of total recoverable volume	20%	12%	4%
Usable woody residue as proportion of total recoverable volume	12%	7%	2%

Table 3.2.2a Log stem residues, as proportions of total recoverable volume.

Table 3.2.2a summarises the expected average log stem residue volumes, as a proportion of total harvestable volume, which can be expected to be harvested from different quality sites within the CFL estate. The usable proportion (billet wood grade, or non-saleable chip log grade) is quantified as the 'usable proportion' of woody residue.

This information, together with the forest inventory forecasts from YT Gen, was used to assess the likely woody residue accumulation within the CFL estate. This is shown in table 3.2.2b below. The harvest volumes are indicative only, forecast from the forest harvest plans for 2009 – 2014.

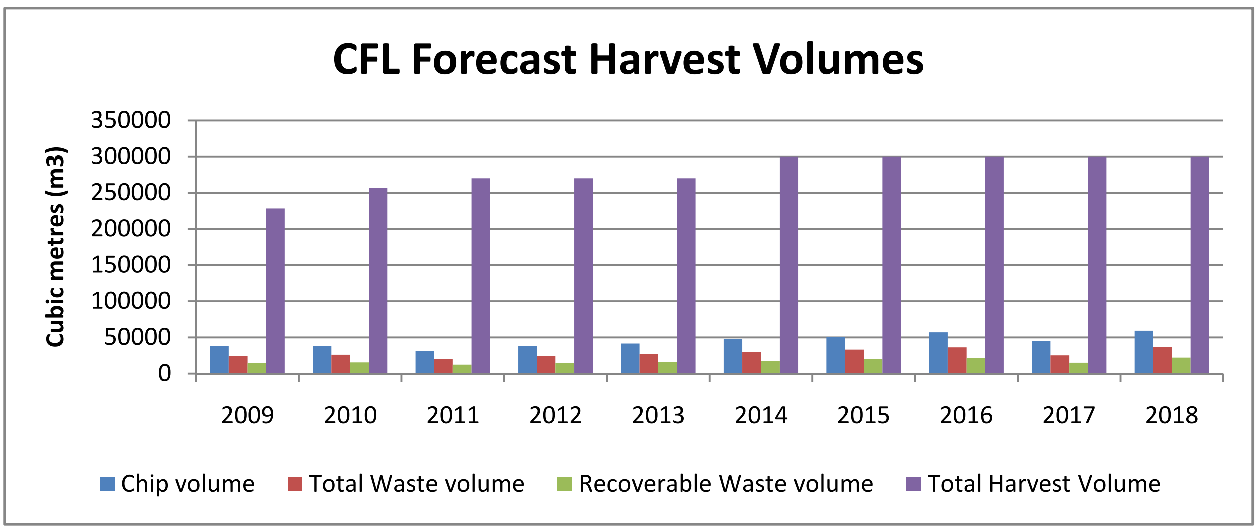
	Saleable Log Volume (m3)		Stem Residue (m3)		
Forest Contractors	**Log Product Daily Output**	**Average Daily Output**	**Poor Quality Site**	**Average Quality Site**	**High Quality site**
A-Hauler	215-275	245	30	17	5
B-Hauler	215-275	245	30	17	5
C- G/based	215-275	245	30	17	5
D- G/based	135-190	160	20	5	3
E- G/based	70-120	90	11	6	2
Total	850-1135	990	121	62	20
Annual Production	212,500 – 283,750	247,500	30,250	15,500	5,000

Table 3.2.2b Estimation of recoverable stem residue from harvest operations.

The table above provides an indication of the various daily volumes of woody residue that will accumulate on individual forest landings. Daily output from an 'average' quality forest compartment will produce an estimated annual recoverable production of 15,500 m3 of solid wood stem residue. This residue is of a 'billet wood' type grade, or an out-of-specification chip (excess sweep, kink etc) log grade.

Further analysis of the recoverable wood waste from CFL operations identified a ten-year mean of 17,000me of recoverable stem residue. For the purpose of this study, a conservative mid-figure of 16,000m3 of recoverable stem wood residue per annum has been used.

Graph 3.2.2c below indicates the forecast harvest and waste residue volumes over the coming decade.



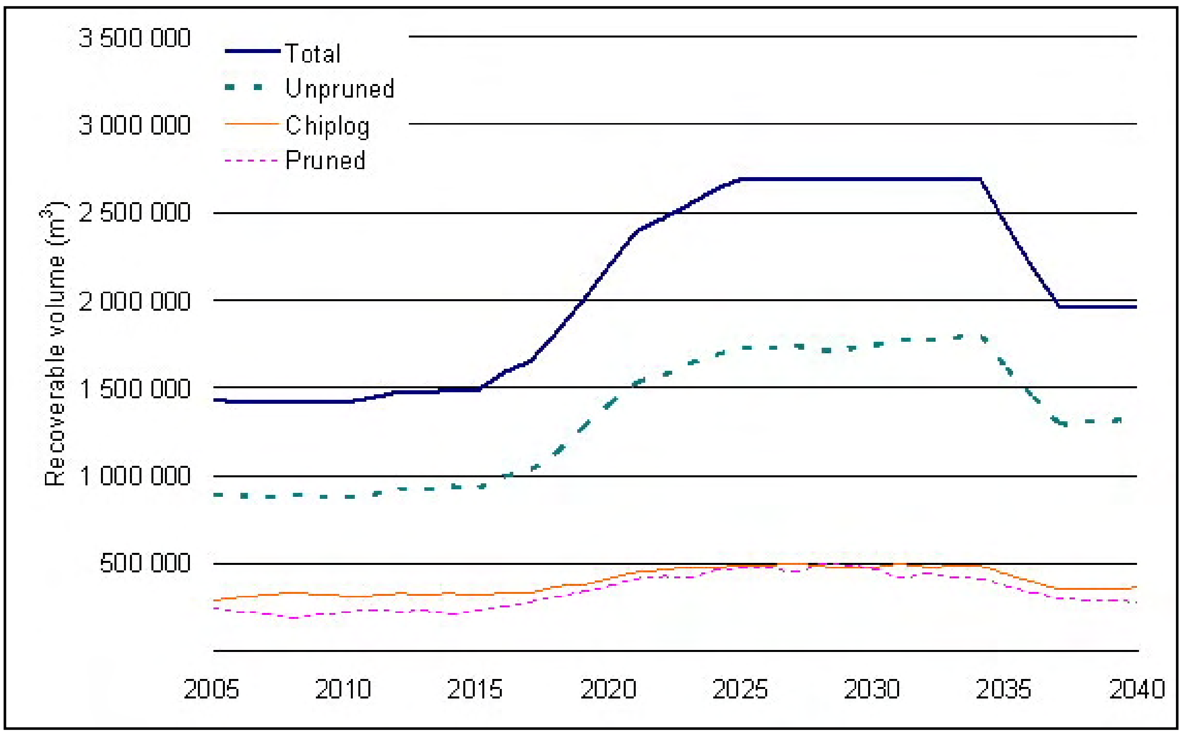
Graph 3.2.2c Forecast recoverable harvest volumes (m3)

It is important to note that this is an estimation only, matching a small field trial against inventory tools. PS log volume reconciliations were also undertaken, but due to the lack of consistent markets for billet wood it is difficult to understand how much potential billet wood remained on site unsold. However, some forest compartment summaries indicated 6-9% of saleable volume as being billet wood.

3.2.3. Additional log supply for woody biomass.

The assessment above relates to the utilisation of log stem residue that is not being effectively recovered in the current forest management system.

In addition, the potential to use some of the expanding chip log supply should be contemplated. As exhibited in Graph 3.2.2c above, the supply of chip logs is expected to increase significantly over the next decade. The expansion in the CFL supply is in parallel with that of the greater 'Southland / Otago' region, as shown in Graph 3.2.3 below.



Graph 3.2.3 Otago and Southland combined wood availability, by log product (under scenario 4). Source: Otago and Southland wood availability forecasts for the period 2007 -2040 ***(www.maf.govt.nz/mafnet/publications/wood-availability/otago-southland2006/page-07.htm)***

The ensuing market dynamics of an expanding regional chip log supply is beyond the scope of this study, but there is clear impetus for CFL Forest Managers to assess the feasibility of some substitute markets for a portion of their chip log supply, or some of the other low-value log products.

3.2.4 Existing management of low-value stem residues

CFL currently supply a number of markets with their lower-value log products, retaining a high degree of security in the ability to sell low-value products, but with a low net value per unit of product.

The billet wood market, selling woody residue of lengths between 1.0 and 3.0 metres, is considered a marginal market. This product is sold for a sale price that effectively provides the harvesting contractor with some cost recovery value, and the forest owner (CFL) with a negligible financial return. The primary benefit to CFL 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 importance.

Unfortunately the billet wood market is unreliable. The purchaser regards billet wood as a second grade product and reflects this in the price paid per unit. Purchase of the billet wood product is not consistent, but will occur on a site by site, day by day basis. Forest sites that are increasingly distant from the end-user's site are less favoured, due to the increasing transportation costs which are paid for by the purchaser.

The lack of market reliability for this product means CFL do not traditionally manage for this sale, but instead treat the billet wood sale 'as a bonus'. This lack of reliability also impacts upon the harvest management system. If a sale for billet wood exists, harvest contractors will often stack these short logs for loading out only to find the cartage system is not meeting their output. Given the lack of available space on the forest landings, such accumulation of logs is not desirable, impacting upon the efficiency of the core harvest management system. It is standard practice for harvest contractors to discard the billet wood products over the side of the landings, away from the log storage area. Retaining the space on the landings aids efficiency of harvest operations, and is more valuable than an unreliable market providing minimal financial return.

The irregularity attached to the sale of billet wood is portrayed by the volume sold by CFL during the 2008-09 year. 3765 m3 was sold in this period, representing a small fraction of the estimated volume of 16,000 m3 that is produced.

The sale of firewood is another outlet for the low-value residues present on CFL landings. This market is a consistent outlet for these minor species which have few alternative markets for logs that are out of round wood specification.

4.0 Operational considerations for producing wood chip

4.1 Producing a quality wood chip product

The key principle underpinning the production of a quality wood chip is that minimising moisture content is the most significant factor (Nurmi 2000), as moisture content determines the net calorific value of the fuel. To produce a wood chip of high energy content requires woody residue of low moisture content.

To achieve a dry wood chip product, with a targeted moisture content of 30%, the raw log residue can either be:

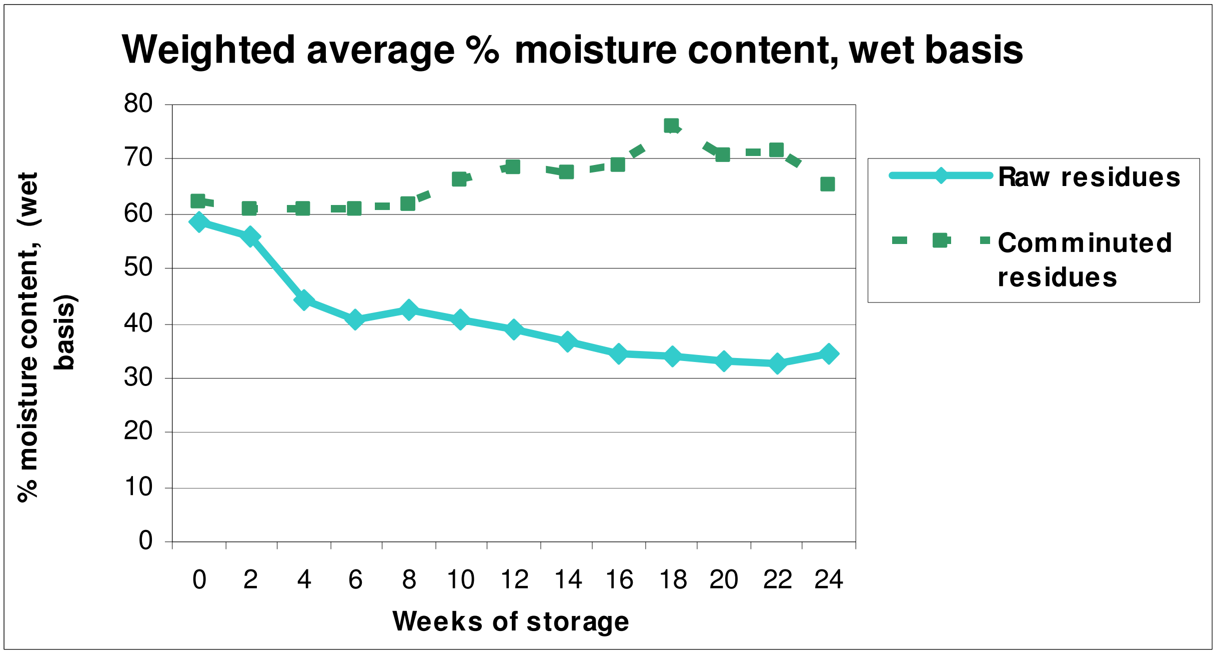
- Chipped green, drying the green wood chip, and then storing.
- Chipped dry and stored immediately

4.1.1 Chipping green logs, then drying and storing.

It is important to note that chipping green logs and then storing the resultant chip without subjecting the chip to a heat process is not an option for CFL. Storing comminuted (broken up) material of moisture contents between 25% and 50% wet basis, in large piles and for long periods, will increase the risk of it being subject to microbial activity. This will increase the risk of degradation, and also increased heat generation and thus the risk of combustion.

Hall (2009: 7) discusses the effects of drying time on both raw (unprocessed residues) and comminuted residues. Residues were stored in two forms – comminuted and raw - at a logging landing in Kinleith Forest, and were tested for changes in moisture content over time. Though the conditions are not detailed, the following graph provides clear trends. The raw residues left at the landing lose significant moisture over the 24 week period, dropping from an initial green moisture content of 59%, to 35% at week 24. This experiment was undertaken over summer months.

Conversely, the comminuted residues absorbed moisture, increasing from 61% at week 1, to settle around 69-71% over time, finally dropping to 66% at week 24.



Graph 4.1.1 Changes in moisture content over time in stored residues. (From Hall, 2009:7)

There is little ability to passively dry the residue once it is comminuted, as stated in two reports (Nurmi, 1999 and Hall, 2009). As such, any supply chain that aims to chip green logs and then dry the green chip to low moisture content (25 – 30%) will require a level of process heat.

Graph 4.1.1 above, shows that log residues will dry over time if they are subject to the correct drying conditions. This is discussed more in Section 6.2 of this report.

4.1.2 Chipping dry logs and storing:

This process requires logs to be dry before they are chipped. It has the advantage of requiring less total energy to produce the wood chips. The chipping machinery, however, generally requires more energy to chip dry logs than green logs, with an associated higher level of repairs and maintenance.

A significant constraint in this system is that it is difficult to obtain dry log products in the Dunedin climate. As a part of this study, City Forests Limited took samples from a number of logs that had previously been felled. These samples were oven dried, with the resultant weight loss used to calculate the moisture content. Though only a small sample, its findings demonstrate the difficulty in air drying logs in the Dunedin climate.

Time since log harvest	Range of Moisture contents	Average Moisture Content
0 – current harvest	49-57%	52%
6 months	33 – 63%	45%
8 months	43 – 54%	49%
12 months	37 – 43%	39%
15 months	45 – 54%	53%
24 months	49 – 51%	48%
Seasoned firewood	29 – 52%	41%

Table 4.1.2 Moisture Content of log samples, over time

It is important to note that these samples were taken after a relatively wet period of weather in May. The variability in the results indicates the importance of the site at which the logs are drying, and that correct layout of logs helps the potential for drying considerably. It is difficult to know what the moisture content will be of log samples taken in the summer months, but current trails underway will help CFL Forest Managers to understand this better.

4.1.3 Potential for CFL to use process heat

Using process heat from their Milburn dry-mill plant is an option for CFL, and warrants thorough examination. It is likely that the capital expenditure associated with such a process will be high, but there is potential to supply a higher value (greater calorific value) wood chip product if successful.

Discussions with Neville Auton, the Dunedin City Council's Energy Manager, raises the following possibilities surrounding possible utilisation of the process heat at the CFL Milburn plant.

To dry the chip, the following options are possibilities:

1. Heat recovery from the kiln operation, air to air heat exchangers. This would need logging to confirm airflows and then return on investment analysis.

2. An economiser in the flue of the boiler to capture waste heat, potentially having the ability to capture a percentage of the boiler capacity

3. Utilising the spare capacity of the boiler to provide hot water to a separate chip drying facility.

(pers.comm N.Auton, 30/06/09)

Any of these possibilities will need to be examined in detail to determine their feasibility and return on investment.

4.2 Residue recovery options – during or after harvest?

Residue from a landing can be recovered either during the harvest operation, or after the harvesting operation is complete. Both options have their advantages and disadvantages.

4.2.1 During the harvest operation:

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, will require additional space on the processing site.

4.2.2 Post-harvest recovery operations:

Evaluating the potential for residue recovery from a typical abandoned landing provides the advantage that the residue recovery programme is divorced from harvest operations, so harvesting efficiencies can continue at their best.

However, there are three obvious disadvantages in recovering the waste residue from an abandoned skid site:

- Typically the residue is pushed by bulldozers or skidders 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.

4.3 Transport

Woody residues can be carried from the forest to the end user, or to an interim storage area, in two main ways - in their original unprocessed form, or in a reduced particle size.

Carrying residues in their raw form involves loading a product of low uniformity and low bulk density. Typically the loads have large air voids. The density of a load of residue is defined as the proportion of the load volume which is airspace, and what is solid material. Bin wood – stem sections of length of less than 3.7m with no branches, have an estimated residue density of 40-45%. This compares to logs, at 60-70% and chip (comminuted) at 30-35%, or 35-40% compacted (Hall, 2009 (b)). There is a limited ability to compact raw woody residues, beyond careful stacking techniques.

Typically cartage operators are paid on the weight of material they carry from the forest to the utilisation facility. This highlights the challenge facing all cartage operators of placing enough material in a box of fixed maximum dimensions to reach the maximum legal weight for each trip they undertake. To carry anything less than the maximum is to under-utilise the truck's capacity. Unfortunately, unlike many other materials commonly transported in bulk, woody biomass in its various forms has a relatively low bulk density.

Analysis of truck weights carrying billet wood show an average cargo of 25.5 tonne. This is an example of a truck 'bulking out', where available cargo space runs out before the maximum payload is reached. One recommendation is to investigate larger bin carriers, which provide for an additional 12m3 of carrying volume. These are being used elsewhere in New Zealand.

If the log residue is dried on the landing for a lengthy period, then the moisture content will typically drop from 55-58% to 35 – 40% after a period of 3-6 months. Though providing a higher energy product, it is lighter and as such, less attractive for the cartage company to cart.

4.4 Comminution

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

1. Chip at a central processing yard, external to the forest.
2. Chip in-forest, after the harvest operation
3. Chip in-forest, during the forest operation

4.4.1. Chipping at a central processing 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.

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.

The other major advantage of chipping at a central point is that the resultant chip product can be immediately stored under cover, thus reducing the possibility of the wood chip reabsorbing moisture. Reabsorption of moisture by the wood chip needs to be considered in the Dunedin climate.

4.4.2. Chipping in-forest, after the harvest operation

This option also has its advantages, but is considered infeasible within the CFL estate, in the Dunedin climate and in meeting the forecast end-user demand.

Such a system requires the on-site storage of log until the logs are sufficiently dry to chip. If consistency of demand of the wood chip product is generated then there is potentially no requirement for two-stage transport, with the product being delivered immediately to the end customer. As such, there is no need for costly capital investment in storage systems, and the need to cart raw residues of high moisture content / low energy content is eliminated.

However, there are some major limitations to this strategy of chipping in-forest:

1. There needs to be a storage system within the forest that allows the woody residue to be stored in a manner that allows for drying of the logs, and provides for minimisation of contamination. The raw log residue will need to be sufficiently dry to enable the in-forest production of a wood chip of 30% moisture content. This will require either an extension to the existing skid site that is being used, or for the logs to be transferred to a historic skid site that is no longer needed.

An 'average' harvesting operation (5500 – 6500m3) within the CFL estate would accumulate 385m3 – 455m3 of log stem residue suitable for chipping. The random short length logs that are being stacked will provide a density of approximately 50% (pers.comm P.Hall 06/07/09). The 455m3 of accumulated residue will represent 900m3 of stacked pile, requiring an estimated area of 350 - 400m2 to store it in a manner which will allow air-drying of the logs to occur. A maximum pile height of 3 metres is recommended to allow the air-drying process to occur.

Extending skid sites is considered to be costly to the forest owner, due to both the construction costs, and also due to the degraded quality of land that results and the resultant loss of productive land. On some sites, this option would be impractical, due to the terrain and steepness encountered.

The possibility of stacking up log residue along the road verge was considered, but was dismissed due to the impracticality of transporting small logs for long distances by way of digger or loader. The cost, and opportunity cost for the harvesting crew, would be too high and would impact upon the output of the harvesting operation. Ultimately this cost would be borne by CFL, reducing the profitable margin on their saleable logs.

2. 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 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 drying. This would demand extra handling equipment, which could be rotated around each forest.

3. Managing a just-in-time chip delivery system is considered too difficult to implement. The delivery system that provides wood chip to the Dunedin-based end user requires utilisation of smaller trucks with a carrying capacity of 30-40m3. Chipping direct to truck will only be viable with fewer, larger trucks. Chip liners (80-90m3 capacity) are more suitable. An efficient just-in-time delivery system would need to be developed to enable full utilization of both the carriers and the chipper. Chip liners servicing the forest will need to be filled quickly and efficiently, to allow quick turnaround. Likewise, the chipper will need to be fully occupied to utilised. This would require trucks-in-waiting. Bulk loading and set-out trailers or containers are methods to overcome these delays.

Due to the reasons outlined above, the chip liners would not be delivering to the end user, but instead would deliver to a central storage yard. Such a transport system is cost prohibitive.

Alternatively, the logs are chipped on the skid site, discharging the chips onto the ground. This is not preferred, as some chips become unrecoverable from the ground and additional equipment is required to load from the ground into the trailer.

Due to the reasons listed above, the option of chipping in-forest is only considered viable, on an occasional basis, for the northern (Silverpeaks) forests. Such an option has been considered due to the following reasons:

1. The Silverpeaks climate is dryer. The potential for road-side storage and air drying is enhanced.

2. Delivering of log stem residue to the proposed processing site at Milburn involves a considerable cart, through Dunedin city, and then back.

3. If suitable markets can be found on the northern side of Dunedin, perhaps longer haul markets, then direct to chip liner chipping operations may be suitable.

4.4.3. Chipping in-forest, during the forest operation

The potential to chip logs within the forest as a side-process of the core harvesting operations has been dismissed because of two main reasons. Firstly, green logs, with high moisture contents would be being chipped. As discussed earlier, this is not an option due to the immediate degradation of wood chip that would occur.

Secondly, the potential for the chipping operation to adversely affect the main harvest processing operation is high. Given the limited space available on the forest landings, managing concurrent operations would be difficult.

4.5 Summary table of the Potential Supply Chains.

The table below summarises the key advantages and disadvantages of each of the options that have been discussed.

Production of chip within the forest	**Advantages**	**Disadvantages**	**Assessment**
Option A: Mobile chipper, during harvest operation	1. Handling equipment present on site	1. Will be chipped green. 2. Will need process heat ot dry the chip 3. Is likely to impact upon harvest op	Not viable
Option B. Shift logs to CPY within forest, dry logs, then chip	1. Easy to shift from the landing 2. More efficient cartage (carting dry chip)	1. Need additional equipment within each forest, at the CPY 2. Additional capital investment in hook bins and trucks 3. An additional handling step required. Costly. 4. Some landings will not be suitable for drying logs	Low. May be suitable for some northern forests.
Option C. Store logs at landing. Chip at landing, after harvest operation is complete	1. Transporting dry chip from forests is more efficient than transporting high MC logs	1. Problematic to ensure chip liners re coordinated with the chipping op. 2. Likely under utilisation of chip carriers and chipper. 3. Some landings will not be suitable for drying logs. 4. Additional handling – chip liners will not be able to deliver to end user, but to central yard instead.	Low. May be applicable to some northern forests.

Option D. Shift wet log residue from forest to external CPY during harvest operation. Chip when logs are dry, at CPY.	1. Easy to manage as part of the daily harvesting op. 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
Option E. Dry logs in the forest. Shift the dry logs from forest to the external CPY for chipping.	1. Transporting a higher energy product. 2. Chipping directly to storage, with greater ability to retain a quality product.	1. Won't meet the payload with cartage. Low utilsation 2. Need sufficient storage space, of good quality for drying. 3. Additional machinery and handling, adds cost 4. Less ability for total quality control.	Potential. Some detrimental limitations.

Table 4.5 Summary table of potential supply chain options

5.0 Optimising the supply chain

Option D above is the most effective and feasible method for producing a quality wood chip product from the CFL forest estate. This wood chip supply pathway is consistent with current harvesting systems, with little deviation from current practice for harvesting crews. There is potential for fine-tuning this system, with the use of hook bins being one example, as real-time awareness develops around the requirements of handling the stem residues.

Incorporating the recovery of the woody residue as part of the harvesting operation reduces the site requirements for storage, and also reduces the likelihood of contamination of the logs.

To ensure the operation is as efficient as possible and to maintain the productive output of the harvesting contractors, it is important that minimal time is attached to handling of the residue and that the on-site accumulation of recoverable volume is minimised.

Use of the traditional log and load system and treating the woody residue as a valued log product is the best starting point for log residue recovery. No additional capital outlay will be required to service the forest operations, though it is noted that a greater consistency of cartage trucks will be required. The limitations of this current system are attributable to the lack of security of demand for the billet wood product rather than difficulties with the transport system itself. There are, however, a limited number of bin wood trucks servicing a number of forest owners. If a regular market for the billet wood is developed then a more consistent supply of trucks would be necessary to ensure the harvest operations continue to work efficiently.

The billet wood 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. Toward the end of the operation this would be especially important, as any remaining residue left after harvest contractors have left the site is difficult to retrieve. Self loading bin wood trucks do not currently operate in Otago, though they do exist.

Use of 40m3 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 tow rope 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 CFL or their cartage contractors.

It is recommended that traditional systems are used during the period of market development. As the market develops, CFL should work with their key cartage contractors to explore the potential efficiency of using hook bins. A work –time study will underpin this.

Discussions with the CFL forest managers have raised the possibility of utilising the gravel trucks that currently leave the forests empty before returning with a full load of gravel. Though the gravel trucks do not have the carrying capacity of log trucks, they will occasionally form a cost-effective component of the overall transport system.

The gravel trucks will carry an estimated 4-5 / m3 of log residue. For such a limited carrying capacity, it would only be viable to make use of these trucks when they are in the immediate vicinity of the harvest operations. The use of these trucks has not been costed into the supply chain analysis, and should be considered to be an additional option when their use is appropriate and cost-effective.

5.1 Management of residues on the landing:

Forest harvest contractors will need to ensure that the residue is handled in a manner which ensures contamination is minimised. "Blading up" of residues will not be allowable, but residues will be able to be heaped rather than stacked if this allows a more efficient residue recovery system.

Hall (2009) provides detail explaining the requirements for handling the various pieces of residue on the landing. "For stem wood sections with lengths of 1 m to 2.5 m a grapple will also work adequately. When the length of the stem wood drops to below 1 m, handling this material with grapple loaders becomes slow and ineffective. Knuckle boom operations can still be used, but the head needs to be altered or changed to either a brush grapple (wide with multiple tines), a clam bucket type arrangement or a normal bucket fitted with an opposing hydraulic thumb.

It is recommended that in the early stages of the market development, CFL seek to recover the larger volume, longer length, pieces of billet wood. These are easier to handle throughout the supply chain, and as such are more cost-effective.

6.0 Management at the Processing Site:

The geographical situation and availability of spare flat land at the Milburn processing plant make it an ideal site for a future wood chip processing facility. As discussed in Chapter 2.2, this site is located on State Highway One, 48km south of Dunedin.

The majority of the 2009-2019 harvest volume is coming from the two southern forests, Tokoiti and Waihola (refer graph 2.5). Transport logistics for both of these forests requires the log residue to travel past the Milburn plant on their way to Dunedin city.

6.1 Constraints in the processing system

There are a number of constraints to address when considering the process of wood chip production. These are discussed below.

6.1.1 Drying and Storage

One of the difficult tasks in managing woody residues for bioenergy is the provision of a storage system for the residue. The objective of the storage process is to minimise the moisture content of the residue, and as such to minimise the degradation of the residue, at a minimal cost. Decomposition of woody biomass converts the wood into water, CO_2 and heat. This is neither desirable in the pile or in the environment (greenhouse gas emissions) so the residues need to be managed accordingly (Hall, 2009:5).

Storage of the woody residue is required at two stages – firstly as a raw log product, and secondly as a comminuted product, prior to delivery to end user.

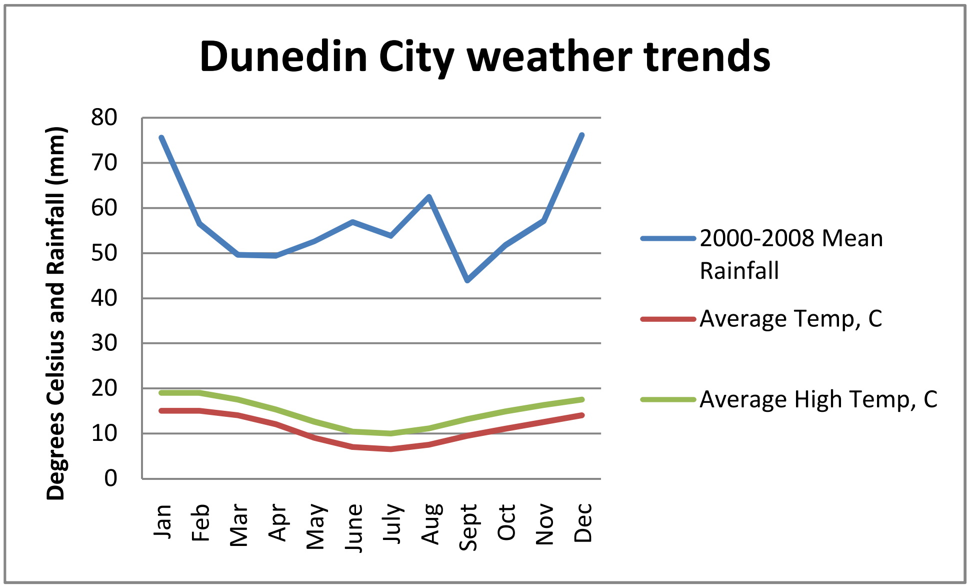
The effect of outdoor storage on the fuelwood properties of Norway spruce logging residue was conducted in Finland (Nurmi, 1999). The initial moisture content of the fresh residue was 56% on a green weight basis. After 12 months of drying, the residue at the landing was 42%, and on the cutover was 29%. The author of this report states that the variation in results is primarily due to the different storage positioning. The material on the cutover site was in an open, well ventilated area and as such dried to a lower moisture content.

To provide some context as to why producing a dry wood chip product may be difficult to achieve, some background information about Dunedin's climate is provided below.

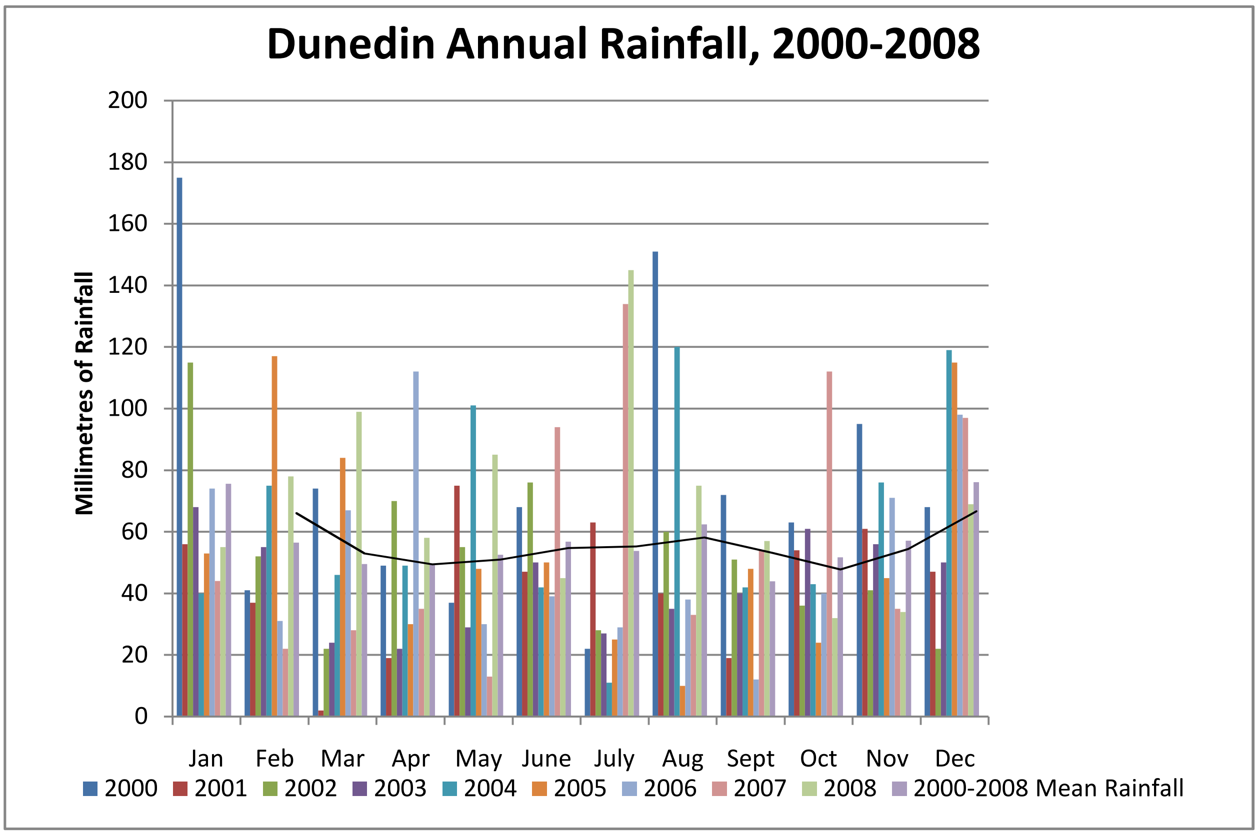
6.1.1.1 The climate of Dunedin – a significant constraint

Dunedin has an equable climate. The average annual rainfall is 768mm, spread fairly evenly throughout the year, with rain days averaging 162 per annum (Source: NIWA CliFlo data). The most settled period is from February to April, but sudden weather changes are associated with the passage of cold fronts, which are usually followed by a spell of showery, south-westerly weather. Winds are mostly from between north-west and south-west; north-easterlies are also very frequent and at times are accompanied by mist or fog.

The warmest months are January and February, with mean temperature 15°C; July (6.5°C) is the coldest. In January the mean daily maximum and minimum temperatures are, respectively, 19°C and 11°C; in July the daily range is from 10°C to 3°C. The average duration of sunshine is 1,730 hours per annum, and it is close to 39 per cent of the possible amount in each month, except in December, when it attains only 34 per cent of the possible.



Graph 6.1.1.1a. Temperature Data sourced from NIWA CliFlo data, and Dunedin City Council.



Graph 6.1.1.1b Dunedin Annual Rainfall, by month. (Data taken from Dunedin City Council Rainfall Statistics.)

As the two graphs above show, the rainfall in Dunedin is consistent throughout the year. This is a considerable disadvantage to forest owners contemplating air drying as the main method of drying logs.

6.2 Developing a drying system for Dunedin's climate

It is considered that there are a number of steps which can be taken to aid the effectiveness of air drying logs.

A low capital investment strategy will require the storage of the woody residues in an un-comminuted form for as long as possible. Once comminuted, the dry wood chips (maximum 30% MC) are relatively stable and are less likely to suffer from significant dry matter losses.

Drying time (seasoning time) is dependent upon many parameters of both the material to be dried (shape and size of pieces, wood density, presence of bark) and the storage conditions (method of storage and stacking, air flow, temperature, humidity).

Large diameter logs will be difficult to dry in the Dunedin climate, and as such a method to enable rapid splitting of these logs is advised. Such a process has been budgeted for in the financial analysis of this study.

The log residue should be kept in its whole (or split for larger logs) form for 6-12 months, depending on the season (6 months over summer, or longer for winter periods) prior to comminution. Doing so will provide the best method for producing a dry chip product that is not subject to decay or combustion in storage.

Through a simple trial, Hall (2007:8) showed that with careful storage, including no ground contact and individual piece storage and a location that provides exposure, then log sections and slovens will markedly reduce their moisture content. Over a 24 week summer period these pieces dried from 60% MC wb to 30% MC wb. Corresponding pieces that were located within a residue pile showed a decrease in moisture content from 60% MC wb to 40% MC wb.

Hall's study shows that by drying the log residue for six to eight months, they will dry significantly, and as such provide a much higher fuel value. This residue will experience some dry matter losses, but at less than 1% per month, this is considered minor.

A trial undertaken for the Greater Wellington Regional Council in 2008 / 09 showed that holding forest residues for approximately 2 months over summer months will produce a fuel product with water content of 25% or less (pers.comm Russell Judd 10/04/09). This trial used covers over the piles of residue, but with full air flow allowed through the stacks. The trail included a mixture of wood residue including branch material and stem residue.

6.2.1 Recommendations to CFL for a log residue storage system

Recommendations to CFL for a log residue storage system include the following:

1. The storage area should be well drained, and preferably sealed. Any water that collects must be able to drain away effectively.

2. Larger diameter logs (greater than 20cm diameter) should be split before stacking.

3. Logs should be stacked on bearers to ensure the stack does not come into contact with the ground

4. Log stacks should be situated to allow full air flow, with the cut ends exposed to the prevailing wind.

5. Log stacks should be exposed to the sun.

6. Using polythene covers, cover the tops of the log stacks. This is especially important for logs stored over the winter months. The ends of the logs must be left exposed to the air flow.

7. Scoring, partial or total removal of bark will assist drying.

6.3 Chipping the log residue

6.3.1 Timing of chipping operation

The higher moisture content of logs in the winter months requires chipping to be avoided in these this period. It is anticipated that the chipping operation is best undertaken after the wet and cold weather of winter and prior to the heavy rains of late spring. October and November would traditionally be considered suitable months, though this will change from year to year. The main chipping period will be between February and the end of April. Over this period the mean temperature is significantly higher, and rainfall less persistent. With Dunedin's changeable weather patterns, CFL forest managers should plan for a maximum of five months (21 weeks) of chipping operations per annum.

Frequent moisture content monitoring will enable a decision to be made as to when logs are chipped. A rotational 'first-in, first-out' system is preferable so as to reduce the potential dry matter loss of the log residue.

6.4 Storage of the wood chip

To retain a quality product in Dunedin's cooler climate, undercover storage is recommended after comminution has occurred. Though it is necessary to minimise the length of storage period of the wood chip product to ensure the minimisation of the dry matter losses and fungal and bacterial activity within the wood chip, it is essential that storage facilities provide for a buildup of wood chip supply in readiness for peak demand months.

The seasonal demand for wood chip will see storage capacity as a key issue; ensuring sufficient wood chip is available during periods of high demand, and having sufficient storage cover to ensure the quality of the stored wood chip is maintained during the summer periods of low demand which also coincides with the periods of peak production of the chip.

Adding this buffer minimises strain on harvesting and transport systems, allowing for a continual and reliable operation. It also serves another objective of maximising the use of the capital investment, providing greater demand for the wood chipper.

Nurmi (1999), observed dry matter losses and increases in moisture content of wood chips stored for one year. If the chip has a moisture content of greater than 25%, there will be a possibility of self heating if placed in a large pile. This can be mitigated by keeping the pile heights under nine metres, and / or limiting the amount of time that the chip sits in a pile to less than 10 days (Garstang et al, 2002, in Wilkerson etal, 2008). Drying to less than 25% MC is the only viable option for the safe, long-term storage of wood chip. It is considered that this will be difficult to achieve in the Dunedin climate without the use of process heat.

The 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. If the storage is for short periods, then contact covers will work. However, if there is pile heating, then the contact covers will tend to trap the moisture (pers.comm Peter Hall, 04/06/09). The moisture will tend to rise from the centre of the pile to the upper 500mm.

Good ventilation is necessary to prevent the buildup of condensation and to prevent the formation of moulds, the spores of which can present a serious health hazard if inhaled.

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.

A conveyor, leading from the hopper to the trucks would aid the efficiency of such a system. The hopper could be filled by the loader with a bucket attachment.

6.5 Other infrastructure requirements:

Significant capital investment will be required to maintain an efficient wood chip production system that is able to meet the Dunedin City industry demand for bioenergy. Some of the major capital required is discussed below.

6.5.1 Loader

A loader will need be required to unload trucks, and to subsequently stack and shift log piles. The same loader, with a bucket attached, could also be used to feed the hopper with chips when loading out chip trucks.

6.5.2 Excavator

A small 12 tonne excavator will also be needed. This will handle the logs that need splitting, and to subsequently feed the wood chipper.

6.5.3 Chipper

A chipper underpins this operation. Within Dunedin City there are a number of wood chipping processors that already exist. These have been evaluated during the course of this study, and are discussed below.

The Bandit Beast is operated by Hall Brothers of Dunedin. This is a drum chipper, with an output of 80 cubic metres / hour, producing loose chip wood at a cost of $9 / m3 for cattle bedding material, or $12 / m3 screened. The screening process will filter out the fines, allowing a consistent chip product to be produced. The benefit of this machine is that it can handle all woody residues, regardless of the shape and size. However, the resultant wood chip is inconsistent in its mix, and is not considered to be suitable for the light-commercial wood chip market. To obtain a consistent product Doug Hall is investigating the potential to purchase knives for the Bandit Beast. This is a high-output machine, and potentially difficult to manage to ensure a cost-effective system is maintained with full utilisation of machine.

City Forests Limited are joint owners in a chipping plant located in the industrial estate of the Taieri Plain, on the outskirts of Mosgiel. This plant produces chip product for the export market, utilising green pinus radiata as the raw product. The chipper was assessed for its suitability for creating dry wood chip, but was dismissed because of its inability to take small length logs (billet wood) or to chip dry logs in a cost-effective manner. Currently it is designed to chip green logs (of high moisture content) and shifting to a dry wood product would cause excessive wear and tear on the plant, a need to resharpen knives on a frequent basis and would entail a high electricity cost to run such a process (pers. Comm. P.Johnson 15/03/09). The lack of available covered storage space at this chipping site was also a limiting factor.

Ernslaw bio-energy operates a modern Heizohack HM10-500 KT chipper, which processes 15 tonne of dry log product per hour. The chipper is powered by a John Deere 7530 tractor, offering full flexibility and portability. This chipper features a large in-feed conveyor and the capacity to work with low powered tractors. The screens regulate the chip size, making the chips ideal for auger fed chip-heating systems, and can be changed to suit specification very quickly. Any chips that don't pass through the screen are automatically recycled within the chipper. The resultant wood chip is a quality, consistent product that is well suited to light-commercial use. This chipper will not handle logs greater than 500mm in diameter.

Photo: The Heizohack HM10-500 KT chipper

Photo: Wood chip produced by the Heizohack HM10-500 KT chipper

Delta Environmental Services operate two 'Rippers' from Dunedin. Like the Bandit Beast, these machines are high output, with the larger model producing 80m3 - 100m3 / hour. The smaller model is hired out at $380 / hour for excavator and shredder, and the bigger model at $470 / hour for excavator and shredder. The Rippers are shredders, rather than chippers, and as such produce a mulched product that is suitable for hog fuel, but not a chip. This is not a suitable product for the market that has been identified in this study.

Photo: Wood shreddings produced by the 'Ripper'

Photo: The 'Ripper' in action.

Alan Knight is an independent contractor operating a knife chipper that processes up to 100 m3 per hour from green logs. This machine will not take logs less than one metre in length, as they simply get thrown around the tub, tearing long shreds off the log rather than chipping the log. It will, however, take large diameter logs – up to 650mm. The hire rate for this chipper is $400 / hour for the chipper ad the digger to feed the logs. The owners are reluctant to chip dry logs with this, due to the increased wear on the knives and the increased energy consumption to power it.

Photo: Alan Knight's Chipper, being fed with full length logs

6.5.4 Summary

Of all the chippers that were assessed, Ernslaw Bioenergy's Heizohack HM10-500 KT was considered the most suitable. The wood chip produced was of a consistent, high, quality, and the flexibility and portability of the plant was also a key advantage. However, its inability to process larger logs is a limitation, as is its limited throughput. It is recommended that a larger model of the Hiezohack would be suitable for a potential CFL operation.

6.5.5 Labour Requirements

One full time employee will be required to unload trucks, and then split and stack logs. The other main duties will include covering the stacked logs with tarpaulins, monitoring log delivery dates, monitoring log moisture levels, and loading out chip trucks for delivery.

A second employee will be needed during the peak chipping period of summer. Duties will be focussed on chipping dry logs direct to storage.

7.0 Supply and demand assessment

7.1 Meeting the City's demand for woody bioenergy

Note: Appendix 1.0 "Dunedin City's demand for woody bioenergy" explores this in more detail.

As part of this study, Transitionz Group Ltd assessed the City's demand for woody biomass as an energy source. The assessment focussed on the potential for the Dunedin City Council to convert two sites to wood biomass, namely Moana Pool and the Octagon Ring Main (ORM) sites.

The report found that in comparison to existing supplier contracts using LPG, potential savings from wood chips are significantly favourable with savings of 40-55% achievable. Wood pellets do not perform as favourably economically, due to the higher delivery costs. A 5-year (2009-2013) analysis for both sites shows significant savings for wood chip despite various LPG annual price increase scenarios of 5, 10 and 15%. Again, wood pellets did not perform well in comparison.

Fuel delivery prices were obtained from several wood chip and pellet suppliers for analysis and have shown the price is the factor influencing financial returns. The analysis showed that wood chip is the preferred woody biomass product to consider supplying to both of these sites. Such analysis can be considered to have similar merit for other industry considering a change to woody biomass as an energy source. However, each business contemplating such a switch to woody residue should understand the advantages and disadvantages of both wood pellets and wood chips before making a decision.

Transitionz Group Ltd evaluated the wood chip demand for three sites in Dunedin City. Using a 30% MC wood chip product, and a heating value of 12.5GJ/ t for the log residue, the following figures for annual demand were generated.

	Demand (GJ)	**Volume of wood chip (m3 / year)**
Dunedin City Council- Moana Pool	20,645	6,410
Dunedin City Council- ORM	13,140	4,080
Otago Polytechnic	13,227	4,110
Total	47,012	14,600

Table 7.1 Wood chip demand from evaluated sites in Dunedin.

7.2 Demand for wood chip at CFL's Milburn Processing Plant

Currently CFL use coal, and smaller amounts of wood shavings, to power their heating processes at their Milburn processing facility. The purchase price of coal is significant, and any move to reduce this consumption would be welcomed by CFL.

Cursory calculations undertaken by Neville Auton, DCC Energy Manager, suggest that between 10,000 and 12,000 m3 of wood chip would be required to displace coal as the primary energy source. Potentially such a conversion to wood chip may be prohibited by the de-rating of the boiler capacity if it has to burn wetter wood chips (greater than 40% MC). The potential to pre-dry the wood chips, using the spare boiler capacity during kiln turndown periods is worthy of investigation.

Generating an accurate figure of the potential demand at the Milburn plant is beyond this report, but is a recommended next step. For the purposes of understanding potential demand, the conservative figure of 10,000m3 wood chip / annum has been used.

7.3 Meeting demand for wood chip

As discussed in Section 3.2.2 an estimated 15,500 – 17,000m3 / annum of billet wood grade log residue could be collected and delivered to the processing yard at Milburn. For the purposes of this monthly supply analysis a figure of 16,000m3 / annum of billet wood grade has been used.

Three scenarios have been analysed to assess the necessary residue inputs, storage facilities required, and demands on machinery throughput. The results are outlined in the table below.

	Scenario 1	**Scenario 2**	**Scenario 3**
Wood Chip (m3) Demand	16,500	25,000	43,000
Wood Chip (m3) Buffer supply**	3,500	5,000	7,000
Total wood chip supply (m3)	20,000	30,000	50,000
Billet wood (m3) Supply	8,000	12,000	16,000
Chip logs (m3) Supply	0	0	4,000
Total log supply (m3)	8,000	12,000	20,000
Daily chipping throughput (m3)	75	112	185

Table 7.3 Scenario supply and demand volumes

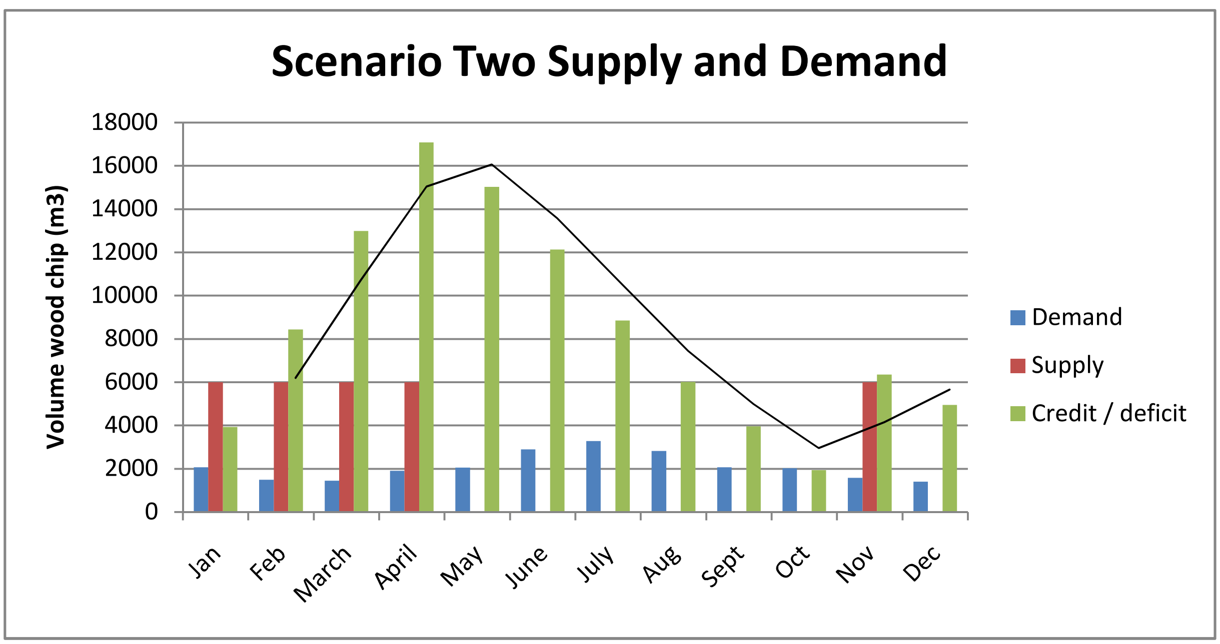
** Additional supply has been included, to allow for a buffer of wood chip stocks to be accumulated in store. This is necessary for security of supply in periods of non-production.

With knowledge of the local Dunedin requirement for wood chip, scenario two above reflects a likely demand for wood chip within the next 12-24 months. This scenario is absorbing three quarters of the estimated billet wood of CFL.

7.3.2 Tracking supply and demand, and accumulation of store volume.

Using Scenario Two as an example, the supply / demand balances were tracked to graphically depict the peaks and troughs in a five month production system. The peak chipping months in summer allow for a buildup in storage of wood chip to over 16,000m3 of loose chip. Following the completion of summer chipping, this volume is rapidly reduced during the winter, when demand peaks. The graph below illustrates the supply / demand fluctuations throughout a twelve month period. The monthly demand figures have been taken from the Transitionz Group Ltd study, and extrapolated.

The volume supplied in Scenario Two below includes the production of an additional two months volume of wood chip, as a storage buffer. In this scenario, supplying a market demand of 25,000m3 / annum will require 30,000 m3 of wood chip to be produced annually. 5,000 m3 is produced as a buffer, to ensure continuity of supply in adverse conditions that may limit wood chip production.



Graph 7.3.2 Seasonal fluctuations of supply and demand for wood chip (Scenario Two)

7.3.3. Meeting the market's requirements for quality

Wood fuels have varying moisture content, and so varying energy content. As such, each tonne of woody biomass is not equal in energy content. Under a weight based payment system, a supplier has no incentive to provide a product of high energy content. This runs contrary to the demands of the purchaser, and to the principles of sustainability. Purchasers will be disadvantaged by such a system, paying more for a product that is of lesser quality.

A system that is based on energy content will be fair to all parties, and represent the most equitable system for woody biomass fuels. To maximise ability to access the Dunedin market, City Forests will need to position themselves for the sale of a quality product that is easily transferable.

As previously discussed, producing a wood chip of low –moderate moisture content (25-35% MC) may be difficult to achieve in Dunedin's winter and spring months. However, literature reviewed in the development of this study would suggest that production of a low moisture content product (~30% MC) will be possible over the summer months.

The Dunedin end users demanding wood chip are requesting a good quality product of maximum 30% MC. Though there is a possibility of such users paying a lower rate for a lower value product, there are often physical constraints in the ability of boilers to process wood fuels of higher moisture contents. Many boilers have trouble igniting wood chips of moisture content greater than 30% MC, and others will need to be de-rated. Systems in which a boiler needs to heat off the excess residue before burning the wood fuel for energy generation are not efficient or desirable. In short, the production of wood chips with high moisture content will not be a saleable product.

The additional transport costs attached to carting a product of higher moisture content is another incentive to produce a low moisture content product.

The undeveloped market for wood chips as an energy source is partly due to the public's skepticism of the product. Providing a high quality product will assist in improving the acceptability of the forest residue fuels.

The potential to upgrade the fuel needs evaluating. A product that is of higher value to the end user will command a higher price (based on energy content) and will also help in the growth of the market share of woody residues. If fuel upgrading requires energy densification, such as drying, the cost of transportation per unit will decrease. This will allow for longer-distance cartage at a more economic price, thereby providing the potential to capture a greater market share.

7.3.4 Demand for clean energy:

Growing consumer awareness of the need to address climate change is now firmly on the agenda – at a local, national and global level. The need to reduce carbon emissions has been globally recognised, and is being driven by regional and national legislation.

The Emissions Trading Scheme (ETS) is likely to improve the incentive for industry to make a change to the use of clean energy, with an additional cost attached to greenhouse gas emissions emitted from energy sources. As wood fuels do not incur carbon charges, they will become priced for greater comparative advantage.

Organisations that are addressing their carbon footprint, or undertaking life cycle analyses of their products are beginning to use wood chip for marketing advantage and to reduce their likely obligations under an emissions trading scheme. Such a strategy is already being implemented by some wine growers, for example.

CFL are in a position to take advantage of this increasing enthusiasm for clean fuels. It is recommended that CFL utilise their environmental credentials earned through the Forest Stewardship Council (FSC) certification system to reinforce the positive environmental implications of energy generated from plantation forestry. A bioenergy brand, centred on this recognised environmental certification is worthy of future investigation.

8.0 Investing in a Bioenergy business

Previous sections of this study have addressed the forest resource opportunities and barriers, the potential constraints within the supply chain, and the market demand for woody biomass as an energy source. Though there are some challenges within the supply chain system, they are not insurmountable, and the basis for a bioenergy business looks strong.

Investment in a bioenergy business will require significant capital investment by CFL. To determine the break-even price and volume for CFL to produce and supply wood chip to the Dunedin market place, the likely return on this capital investment was evaluated under a number of scenarios.

Hiring the necessary equipment to produce wood chip (chipper, loader, excavator) was compared to purchasing this same equipment. In both analyses the need to construct a storage facility ($250,000 cost) was budgeted.

The budgeted costs that were in the analysis included those associated with harvesting and transport, wood chip drying and processing, storage and delivery to the end user. The costs included depreciation, tax, overheads, and employment.

8.1 Summary of results

- The cost of production for wood chip is estimated to be between $75.00 - $80.00/m3 of log input.
- The delivered sale value is $12.50 / GJ. This is for a 30% MC wood chip product.
- Hiring in the chipping equipment to allow wood chip production demands a reduced capital investment of $300 - $350,000. This is predominately the construction costs of a wood chip storage facility.
- Purchasing the equipment to allow production of wood chip demands a capital investment of $1.0 - $1.1 million. This includes a chipper, loader and excavator.
- If purchasing the processing equipment, throughput of 8,000m3 of logs (Scenario One in table 7.3) is not viable.

- If purchasing the processing equipment, break-even occurs at 11,000m3 of log input.
- Favourable return on investment occurs at 15,000m3 of log input. The internal rate of return at this volume is satisfactory for capital invested and the business risk involved.
- Volumes greater than 15,000m3 require additional equipment and capacity. At 15,000m3, machine utilisation is optimised.
- If hiring the chipping equipment (chipper, loader, excavator), the rate of return from 8,000m3 of log input provides a sufficient rate of return on investment to encourage entry into the venture.

8.2. Further discussion

The results that are summarised in Section 8.1 above demonstrate that there needs to be a significant demand for wood chip (~ 25,000 m3 of wood chip (12,000 m3 of log input)) before CFL should consider purchase of the equipment necessary to allow full production.

As outlined in Section 7.1 such levels of demand are quite likely, especially if further analysis confirms that the CFL boiler at the Milburn processing plant will require the volumes of wood chip anticipated.

It is recommended that during the start up phase of a bioenergy business, CFL hire the chipping equipment needed. Not only is the return on investment (at low production volumes) more favourable than that under a capital purchase scenario, but by hiring the equipment it will allow CFL to better understand the supply chain requirements and the machine utilisation that is so important to this process. Important lessons will be learnt during this period, subsequent to significant at capital investment.

If purchasing the chipping equipment, CFL should examine the potential to further utilise the equipment by producing a lower value product for markets that do not demand a high calorific wood chip product. Wood chip for cattle pads is one example. Producing wood chip for cattle pads could be undertaken in the winter months, and with logs of high moisture content. Doing so would assist in maintaining a positive cashflow, full time employment and high machine utilisation.

CFL should consider the Energy Efficiency Conservation Authority (EECA) wood energy business grant. This grant can provide up to 40% of the project cost, up to $200,000, and has previously been used to purchase equipment such as chippers.

8.3 Venture Risks:

A bioenergy business makes good sense for CFL. It has sufficient resource to produce a wood chip product that will meet a proportion of Dunedin's industrial demand for a clean energy source. Tightening regional air quality regulations, growing consumer awareness about 'clean energy' and an impending whole-of-industry Emissions Trading Scheme are all key drivers of local demand for wood energy. The proximity of the CFL estate to Dunedin - a medium sized city which experiences high than average demand for heat energy – reinforces the business potential.

There are, however, a number of risks attached to a CFL embarking on such a business. These are discussed below.

8.3.1 Difficulty in producing a quality product.

As previously discussed, the Dunedin climate may prove to be detrimental to the production of a high calorific wood fuel product. This study has recommended a supply chain system that is low cost and utilises air drying as the main method for producing a log that can then be chipped directly into a saleable wood chip product. There is a risk that the inconsistent Dunedin climate will restrict the drying ability of the logs. As discussed, producing a dry product (30% MC) underpins the saleability of this product.

If it proves to be infeasible to produce an air-dry log of low moisture content, then chipping logs of high moisture content may need to be contemplated. However, this will then require the resultant wood chip to be further dried before it can be sold. Such a process is likely to involve recovery of the waste heat of the Milburn processing plant.

8.3.2 Slow development of market

The market demand for wood energy has not been quantified. However, there are a number of indicators that suggest consistent growth is likely. It is recommended that further market analysis is undertaken in the near future to better understand the likely demand. In the interim, developing a low cost bioenergy supply system is recommended.

8.3.3 Supply competition

The prospect of making additional revenue from forest residues has come to the fore for a number of forest owners in recent months. Previous discussion pertaining to security of supply enforces the need for CFL to sign long-term supply agreements with Dunedin end-users.

Traditionally forest owners compete against one another for market access, especially in the highly competitive export market. The emerging bioenergy market is reliant on a low cost structure, an increase in public awareness and perception of the quality of wood fuels, and growth of wood fuel supplies through increased demand driven by consumer awareness and by regulation.

To grow market share in energy supply, a consistently high value and reliable product needs to be sold to the end user. A risk to CFL, and other potential suppliers of wood energy products, is that a poor product is released to the market place by one or a number of suppliers. The subsequent damage to the credibility of the wood energy product would be hard to retrieve.

It is recommended that an industry 'Otago energy supply' cluster be investigated. Working collaboratively will ensure that the value of the product is maintained. Industry agreements to meet quality standards will underpin such a cluster. The potential to share resources (chippers, chip dryers, storage etc) should not be dismissed, with the potential for greater machine utilisation to occur. Potentially a joint business could be developed that manages the wood chip supply chain from forest to point of sale, for all forest owners.

9.0 Next Steps:

The risks identified above need to be better understood. As such, the immediate steps which CFL should contemplate include:

1. Market analysis of the end user demand in Dunedin. Gain a better understanding of Dunedin's industry demand for wood chip as an energy source.

2. Establish long term supply contracts with key industry end-users, providing consistency of demand and value.

3. Discuss a potential collaboration with other forest owners to ensure reliable, quality supply is provided to the end users, and potential shared utilisation of infrastructure.

4. Access capital start up funding through the Dunedin City Council Economic Development Unit Industry fund, or through EECA. Again, investigate the potential to access this as part of industry collaboration.

5. Implement field trials immediately. These should include the following:

- Storage of residue, and effect of time and weather on seasonal drying of logs
- Storing residues under cover, in different size / shaped stacks, and effect on moisture content.
- Storing wood chips under cover, through a variety of seasons, to determine whether re-absorption of water is occurring.
- Using hook bins in the forest to determine the impact on quality of residue and time efficiencies of operation.
- Hire of a chipper to evaluate its throughput, input of log specifications, and any potential likely processing difficulties.

6. Investigate the potential to utilise process heat from the Milburn processing plant to add value to the wood chip through densification. The capital investment required will need to be well understood.

7. Understand the potential for the Milburn boiler to utilise wood chip in place of coal, and the resultant efficiency of this switch. The likely impacts of an Emissions Trading Scheme need to be considered in this context.

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12.0 Appendix 1.0

Potential demand for woody bioenergy from Dunedin City

(The information in Appendix 1.0 has been provided by Transitionz Group Limited).

During the initial work on this section, it seemed that the best way to estimate heating overall demand in Dunedin, was to estimate domestic demand based on the number of households and average energy consumption figures, and to estimate non-domestic demand by analysing the energy requirements of individual businesses and organisations. It soon became obvious that the latter task was very large and would involve extensive surveying and beyond the scope of this report.

Several energy databases are available that, when combined, would include a wide range of industrial sectors, such as wood processing, dairy processing, education, food and beverage processing, hospitals, other manufacturing, and commercial or domestic sectors.

The following resources will be utilised:

The BRANZ Home Energy End-use Project (HEEP) study investigated energy use in New Zealand homes. A random selection of more than 400 homes throughout New Zealand investigated all aspects of energy use in the home from lighting and appliances to hot water cylinders and home heating.

EECA maintain a database of detailed end use energy consumption estimates based on national level data and a lot of specific information where available. This database contains estimates of national energy use broken down into different categories including sector, technology, end use, region, and fuel type.

The Bioenergy Association of New Zealand (BANZ) maintains a heat plant database. The database is nationwide, has been recently updated and includes a wide range of mainly industrial sectors: wood processing, dairy processing, education, food and beverage processing, hospitals, other manufacturing. The survey has a list of known boilers greater than 100 kW around New Zealand.

1.1 Theoretical demand

Energy use in Dunedin includes the agriculture, commerce, industry and household sectors. These sectors consume 12.5 PJ/y[1] (3,500 GWh/y) of energy in the form of biomass, electricity and fossil fuels (for transport and non transport). In theory, it may be possible for all these sectors using electricity and fossil fuels to switch to wood biomass. These sectors were analysed to get a better understanding of the potential for wood chips and pellets.

Each table below lists actual energy use in energy (GJ/y) for the sector alongside the potential chip and pellet volumes equivalent (m^3/y) to the actual energy use. The conversion assumes 30% and 7% moisture content for chip and pellet respectively.

1.2 Residential demand

The HEEP project found that more than half the houses had a solid fuel fire which played a major role for heating homes. The average energy consumption of houses using solid fuel burners was approximately 14.4 GJ/y (4,000 kWh). This is likely to be higher for southern regions but a conservative estimate will be sufficient for estimating potential demand.

According to the 2006 Census, there are 44,800 houses in Dunedin City equating to 645,120 GJ/y (179.2 GWh/y) using HEEP heating demand estimates for solid fuel burners. The following energy statistics have been obtained from EECA's Energy End Use Database for Dunedin City. The HEEP figures are slightly higher than what is reported on the EECA energy database of approximately 400,000 GJ/y for solid fuels.

[1] EECA End Use Database

Household end use[2]		Actual Energy (GJ/y)	Potential Chips (m^3/y)	Potential Pellets (m^3/y)
Heating	Biomass	259,135	82,923	23,541
	Electricity	1,136,244	363,598	103,220
	Fossil Fuel (Non-Transport)	131,769	42,166	11,970
	Total	1,527,148	488,687	138,731

1.3 Non-residential demand

Non residential data was collected from the EECA energy database. Sectors include commerce, industry, agriculture and transport and storage. Heating statistic for various sectors has been collected.

Heating use- Commerce end use[3]		Actual Energy (GJ/y)	Potential Chips (m^3/y)	Potential Pellets (m^3/y)
Heating	Biomass	13,616	4,357	1,237
	Electricity	362,191	115,901	32,903
	Fossil Fuel (Non-Transport)	670,481	214,554	60,909
	Total	1,046,289	334,813	95,048

[2] EECA End Use Database

[3] EECA End Use Database

Heating use- Industry end use[4]		Actual Energy (GJ/y)	Potential Chips (m³/y)	Potential Pellets (m³/y)
Heating	Biomass	1,232,235	394,315	111,940
	Electricity	189,217	60,549	17,189
	Fossil Fuel (Non-Transport)	1,135,610	363,395	103,162
	Total	2,557,061	818,260	232,291

Other energy sector data for Dunedin with a heating capacity greater than 100,000 GJ have been mentioned below. A detailed list is available from the EECA end use database.

Heating use- Non residential users[5]		Actual Energy (GJ/y)	Potential Chips (m³/y)	Potential Pellets (m³/y)
Biomass	Paper and Paper Products, Printing and Publishing	946,464	302,868	85,980
	Wood Processing and Wood Products	285,771	91,447	25,960
Fossil Fuel (Non transport)	Concrete, Clay, Glass and Related Minerals Manufacture	124,228	39,753	11,285
	Dairy Products	483,417	154,693	43,915
	Beverages and Other Food Processing	204,240	65,357	18,554
	Concrete, Clay, Glass and Related Minerals Manufacture	124,228	39,753	11,285
	Education Services: Tertiary Education	151,567	48,502	13,769
	Health and Welfare Services	292,423	93,575	26,565

[4] EECA End Use Database

[5] EECA End Use Database

BANZ maintain a heat plant database of all boilers in New Zealand greater than 100 kW. The database identifies plant capacity, fuel type, annual energy use, age of boiler and location. The database was not fully complete and missing several Dunedin sites. Nevertheless, it would be useful for identifying potential customers. Because the list was not in a suitable format to easily obtain information, an analysis for Dunedin was not considered.

1.4 Demand scenarios

Approximately 20,000 t of useful waste wood for recovered from CFL skid sites annually has been identified equating to approximately 250,000 GJ. Assuming 30% MC and a heating value of 12.5 GJ/t for the resource. The DCC and OP sites would require an annual supply of approximately 51,000 GJ and could account for 20% of annual recovered wood resource.

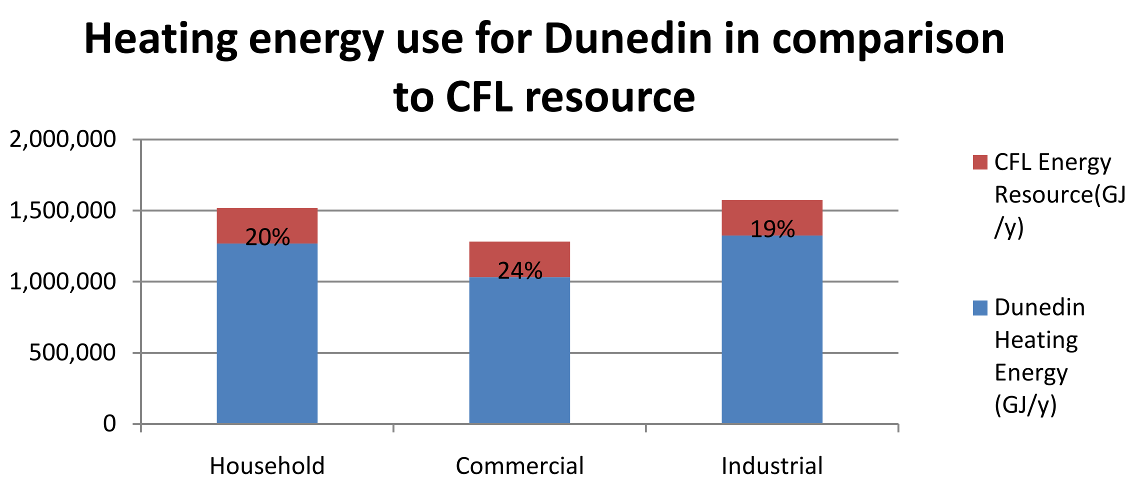
Supply and Demand Energy Balance			
	%	Credit (GJ)	Debit (GJ)
City Forests Limited	100%	250,000	
Dunedin City Council- Moana Pool	-8.26%		20,645
Dunedin City Council- ORM	-5.26%		13,140
Otago Polytechnic	-7.05%		17,635
Balance	79%		

Table 1.4. Supply demand analysis balance

Other potential demand

To get an understanding of other potential markets in Dunedin CFLs wood fuel resource has been compared against sector energy use, identified above.

Using data obtained from EECA End Use Database and not taking into account existing biomass energy or demand from DCC or OP, CFLs energy resource could meet up to 20%, 24% and 19% of household or commercial or industrial energy use respectively.



1.5 Real demand

While potential energy demand for the city can be estimated using research data, theory and assumptions, actual demand is a little more difficult to assess. There are many factors or drivers that will influence a decision to convert to a bio-fuel product and these will be identified below. An in-depth survey is the most likely method for getting an understanding of real demand for this product but is beyond the scope of this report.

1.6 Drivers for converting to wood biofuels

Several drivers have been identified that could encourage organisations and individuals to convert to wood biofuels as outlined below:

1.6.1 Financial

Converting to biofuels for financial reasons will be favourable for energy users of LPG, electricity and oils. Price increases and the age and condition of some heating plant may mean that switching to woody biomass, for a particular household or organization, is financially worthwhile, especially where a reliable supply of fuel is available nearby such as in Dunedin.

Fuel prices for electricity and gas have been included in Fig 2.3.3a and b. The commercial rate for electricity and natural gas was approximately $40/GJ ($0.15/kWh) and $16/GJ ($0.06/kWh) respectively. In comparison, wood pellet and chips range between 4-10 c/kWh respectively. Rate s are much higher for residential users.

The inclusion of an emissions trading scheme (ETS) is likely to see charges to energy supply companies and coal mining companies at the point of sale. It is likely that this cost will be passed onto the end user in the form of increased energy prices. Thus, another financial reason that favours wood biomass as a charge would not apply.

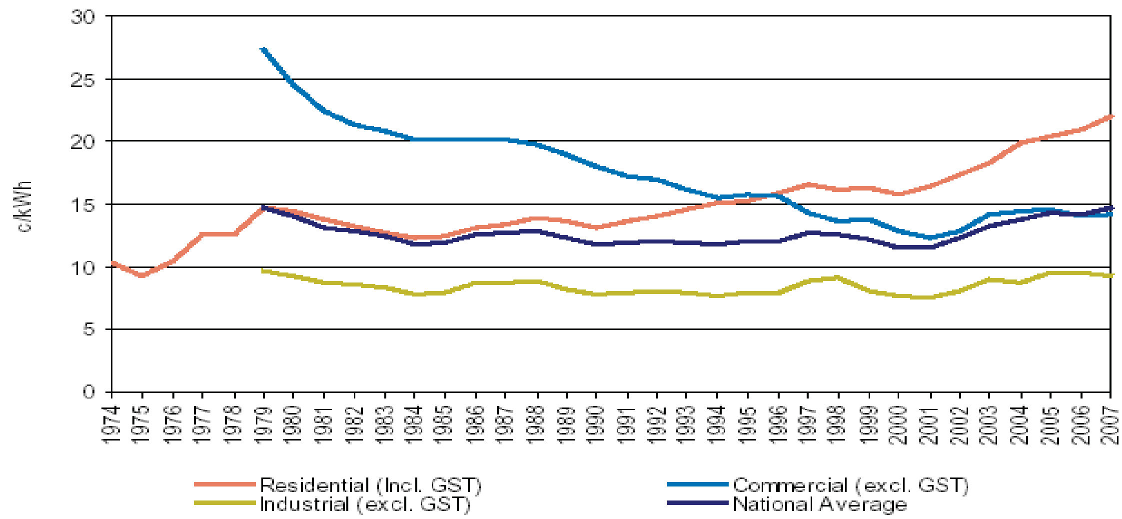


Figure 1.6.1 Electricity Consumer prices (real 2007 prices)

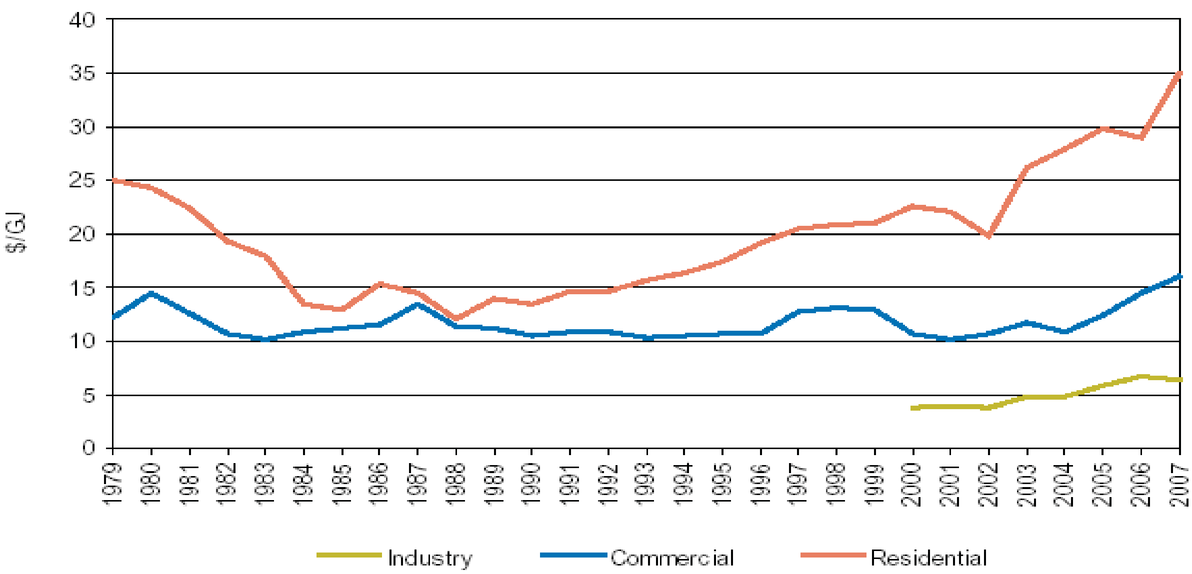


Fig 1.6.1 b Natural gas prices (real 2007 prices)

1.6.2 Resource consent issues

Discharging pollutants to air to produce energy for heating is an activity that requires regional consent from the Otago Regional Council (ORC). There is likely to be increased pressure by the Ministry for the Environment's National Environmental Standard (NES) for air quality. This standard sets a maximum level for particulate matter, PM10, at 50 µg/m³ in the Dunedin air-shed. The Dunedin air-shed currently exceeds this standard and the ORC is required to ensure compliance with the standard by September 2013.

	Plant < 1 MW	Plant <1 MW (and only burns complying fuel)	Plant >5 MW (and/or burning non complying fuel)
Air zone 1	Permitted activity	Permitted activity	Discretionary activity
Air zone 2	Permitted activity	Permitted activity	Discretionary activity
Air zone 3	Permitted activity	Permitted activity	Discretionary activity

ORC are signalling a move to tighter standards more aligned with the United Kingdom and Australia emission rates[6]. This is likely to have the greatest impact on coal fired boilers requiring new consent and is an opportunity for fuel switching to wood biofuels.

To get a better understanding of the likely requirements, the ORC was contacted for guidance with meeting NES requirements and how this could affect this project. The following reply was received:

"...The [Otago Regional] Council understands that many coal powered boilers in the Otago region have been in operation for many years and a majority of the boilers are old. Most such boilers' emissions are not acceptable to the current developed countries emission standards (e.g. UK emission standard for industrial boilers is 25 mg/m3). Whilst there is no

[6] Otago Region Council, email correspondence with Nigel Goodhew, 24 April 2009.

New Zealand National emission standard set for PM10 emissions for boilers, in the Otago region we wish to promote other developed countries emission rates such as 25-50 mg/m3 (similar to UK or Australia as our long term consent requirements).

We also understand that requiring lower emission rates such of 25-50 mg/m3 would mean significant upgrades to many coal fired boilers in the Otago region involving high capital and maintenance costs. The affordability of technology to upgrade old boilers should be considered carefully along with achieving good emission rates and improving the polluted status of the confined areas.

Therefore, the determination of a suitable emission rate (either for PM10 or SO_2) will be considered on a case by case basis. All coal boilers, including school boilers, (with the exception of boilers with bag houses, e.g. Meridian Energy Centre, Dunedin) will require some form of upgrade, hence the ORC does not promote a 'do nothing' approach. Upgrading may involve either reducing the emission by filtration (e.g. bag filter) or changing the type of fuel, both of which should result in significant reduction of the existing emissions."[7]

1.6.4 NZ Emission Trading Scheme (NZ ETS)

The NZ ETS is currently under review by government and was developed by the previous government to meet international obligations to reduce greenhouse gas emissions under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

The Government has recently released a draft document outlining climate change regulations for stationery energy[8]. The document suggests energy suppliers (thermal generation and coal mining) will be charged at the point of sale that may have the effect of price increases to the end user. It is difficult to determine how much of this cost will be passed onto the end user, but it is reasonable to assume an additional cost will apply. This may be a driver for all fossil fuels with particular emphasis on high CO_2 emitting fuels. Coal combustion emits approximately twice the amount of CO_2 in comparison to LPG.

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[7] Otago Region Council, email correspondence with Nigel Goodhew, 24 April 2009.

[8] http://www.mfe.govt.nz/publications/climate/emissions-trading-bulletin-10/emissions-trading-bulletin-10.pdf

1.6.5 NZ Energy Efficiency and Conservation Strategy (NZEECS)

The government has set targets for the increased use of forestry derived biomass for energy in its NZEECS set in 2007. The document outlines targets for various energy uses, including:

- to provide an additional 7 PJ per year of consumer energy from forestry residue by 2025 off a base of 0.8 PJ in 2005. 7 PJ per year equates to 800,000 green tonnes of forest residue.

- to provide an additional 3.5 PJ per year of residential and commercial consumer energy from woody biomass by 2025 off a base of 8 PJ per year in 2005.

These targets make it highly likely that in future residues will become a valued resource as opposed to an inconvenient waste.

1.6.6 Funding options

Until 30 June 2010 EECA are providing funding for studies and capital cost projects related to wood energy. At that point in time the fund will be reviewed and it is unsure if it will continue. In addition, EECA have other funding pools such as the Energy Intensive Business and Crown Loans Grants available. These grants provide support by offsetting project costs and can be an incentive

1.6.7 Marketing opportunity

Organisations and businesses interested in reaching environmentally conscious consumers are likely to be interested in woodchip and pellet fuels because of their renewable carbon neutral features and some organisations would use this as a marketing opportunity.

2.0 Key constraints

Not all businesses or organisations are suitable for converting to wood biofuels for reasons such as:

- Lack of available space for fuel bunkers
- Vehicle access for fuel
- Location of boiler house
- Additional fuel cost if already using a low cost fuel such as coal
- Additional costs for fuel transfer systems
- Market is still in infancy in New Zealand

Site visits of market segmentations was planned to get an understanding of possible physical constraints. However, it was not certain that this would be representative of the group. Because of this, site visits were not undertaken as the suitability of one site could be completely different to the next, making it difficult to ascertain.

2.1 Finance

As much as financial considerations may mitigate for a change to renewable energy, so may they be prohibitive of the change. This is especially likely where energy is currently derived from efficient plant burning a cheap fuel (e.g. coal) and where there is no non-financial incentive to switch such a moral conviction, or marketing benefits.

Even if an organisation or household wants to make a change, finance may be prohibitive due to the cost of converting old plant or buying new plant.

In addition, there are many uncertainties such as the continuation of government grants, fuel availability and fuel prices.

2.2 Security of supply

While large volumes of woody biomass are available in the managed forests around Dunedin, there is not yet a large and reliable supply available to Dunedin households and businesses. Wood chips are available from Ernslaw Forests in Naseby (140km from Dunedin). There is a wood pellet plant operated by Solid Energy at Rolleston and Rotorua. Another company is supplying wood chip and pellets to Dunedin schools but the source of this fuel is unknown. There is also a pelletiser in Green Island but the reported quantities are not considered significantly large. This can be seen as a constraint to business and households and an opportunity to CFL.

2.3 Uncertainty

In addition to the uncertainty surrounding fuel supply, the National-led government has decided to review the previous government's Emissions Trading Scheme and expressed a general desire to slow the pace of adaptation to a low carbon economy. The onset of a worldwide economic downturn has specifically made the government unwilling to pursue policy that increases prices or decreases international competitiveness because New Zealand's projected liability under the Kyoto Protocol has recently become an apparent surplus.

2.4 Fuel volumes and storage

The last constraint that requires specific discussion is fuel volumes and the issues with storage. Some organisations converting to woody biomass will have no storage facility at all, or liquid fuel tanks that will be unsuitable for solid fuel in chip or pellet form. These organisations will need to find space and funds to build a woody biomass storage facility and all associated hardware.

In cases where a coal boiler is already in use, there will already be a storage facility. However, wood biomass chip has less energy per unit of volume than coal which requires the storage volume to be increased. Another way around this is to increase deliveries. This may entail using smaller, less economic trucks, which may disturb other activities on the site.

3.0 Key significant potential end users

While specific energy use relating to users has not been determined, key potential end users have been identified. The following users are commercial and industrial:

- Dunedin Energy Centre
- University of Otago
- Wakari and Dunedin Hospitals
- Dunedin City Council
- Speights (Lion Breweries)
- Schools
- Sealord Group
- Ravensdown
- AgResearch

4.0 Discussion

While potential demand for the city has been estimated, factors that determine whether a business would consider switching to a wood fuel cannot be determined, and given the time constraints to review potential demand for the city, more time could be allocated to refine and select target markets and to develop a survey.

However, from personal experience and analysis, energy users of LPG gas, diesel or other expensive oils requiring a continuous heat load throughout the year will demonstrate favourable fuel savings if moving towards a wood chip fuel system because of the delivered price.

Several sites around Dunedin are considering converting or are about to convert to wood fuels. These include Wakari Hospital, University of Otago, Otago Polytechnic and several schools. It is not known where the fuel for these sites will be sourced but there is potential to supply these sites in the future. Other potential sites have been identified and there is likely to be many other opportunities for developing the Dunedin market.

The ORC will be introducing new clean air requirements in 2013 that will affect all operators of coal fired boilers requiring renewal of consent. Operators have two likely options of either installing bag filtration systems or moving towards a cleaner burning fuel. Bag filtration systems are expensive and require on-going filter replacement while, alternatively, many coal boilers are configured for retrofitting a wood chip system, as a bunker and feed auger already exist. This favours the use of wood fuel so coal boilers requiring renewal of consent would be another potential target market.

Appendix 2.0

Background information on woody biomass, its production and local supply.

1. Review of energy production from woody biomass

An opportunity exists for Dunedin City to provide a significant proportion of its industry's energy requirements using locally owned and sourced wood pellet or wood chips as a renewable fuel resource. Doing so will also create additional opportunities for local forest owners to create new revenue utilising an existing waste stream.

The purpose of this review is to identify and comment on research relating to the characteristics for a quality fuel source including wood properties, recognise supply chain options and related issues including transport considerations, identify suppliers of plant and wood fuel and identify other projects in NZ and abroad.

2. A quality biomass product

A key attraction of any biomass fuel is consistency and quality in terms of dimensions, calorific value and moisture content. To produce a valuable end product, the quality of the raw material is important.

This section will investigate research, in terms of the qualities of the individual products, which are likely to be useful for this project.

2.1 Woodchip

Research collected as part of this review along with information gathered from personal conversations with various parties such as Scion Research and the Bio-energy Knowledge Centre have been drawn together to get an understanding of the various chip qualities as outlined below. Two samples of different chip products are pictured.

Sample 1. Wood chip sample was not consistent with some large pieces. All chips had sharp edges and a higher proportion of bark.

Sample 2. Wood chip sample was very consistent in shape and size. All chips were soft and no sharp edges with a low proportion of bark.

2.1.1 Woodchip properties

Low moisture content- A high moisture product increases the volume require and can cause bridging and additional wear on the fuel feed system. In addition, from a transport perspective, the supplier is paying more to haul a product which has less value. The moisture content should be less than 30% at point of sale. However, boilers can be designed to operate on a dryer or wetter product but wetter product can cause ignition issues if boiler is started from cold.

High calorific value- Calorific value is related to moisture content and a chip with low moisture will have a higher heating value per volume of mass. A high calorific value is in the favour of the supplier, from a sale perspective, as the product has a higher sale price. It is also favourable to the end user as a volume of the bunker can be reduced.

Consistency- A consistent product in terms of heating value makes it easier to budget expected costs for the end user. An inconsistent product could increase transport costs affecting cost benefit analysis.

Chip size and shape- Chip sizes vary in relation to the type of chipper so screening the chips will provide a general template for the chip size. A cubic chip or chunk is most ideal and should not be greater than 5 cm in longest dimension.

Raw material- The chip should be clean and have minimal bark. Chippers prefer continuous feed so longer lengths of raw material are ideal have a higher production rate compared to branches and small limbs.

Fuel transfer- Fuel transfer relates to the delivery of the product from the truck or container to the storage bunker. Ideally, the bunker is located below the tipping platform for the delivery but this is not always the case. If tipping directly to bunker is not an option, two other options exist. Namely purchasing equipment and leaving on site or making arrangements for the supplier to arrange transfer. For smaller users, purchasing fuel handling equipment can be a large proportion of the total project cost, making the project uneconomic. For large users, fuel handling equipment is less an issue because the cost is not significant. Most suppliers do not have an option for transferring fuel but this is changing as the market increases.

2.2 Wood pellet

In New Zealand *AS/NZS 4014* specifies a test method for assessing various fuels used when determining the power output, efficiency and particulate emissions of domestic solid fuel burning appliances. This standard covers soft and hard woods and wood pellets. The standard relating to pellets has essentially become the benchmark by default. Table 1 specifies pellet characteristics from this standard.

The Pellet Fuel Institute in the US has established two residential fuel standards, a premium and standard grades. The Premium Grade Pellet Standard - specifies the inorganic ash content shall be less than 1% and made from white wood (no bark) because this is lower in ash. The standard goes on to specify pellet bulk density too. The Standard Grade Pellet Standard - includes the same criteria but has a less stringent inorganic ash specification of less than 3%.

Property	Specification
Diameter	Max 10mm
Length	Max 38mm
Density	Min 640kg/m^3
Water content	4 - 8%
Ash	Max 0.5%
Gross calorific value	18 – 21MJ/kg
Fines	Max 1%

Table 1. Pellet characteristics according to the AS/NZS 4014.6 Wood pellets

Source: Pellet fuel standards 2006 Bio-knowledge Energy Centre.

2.2.1 Wood pellet properties

Low moisture content and high calorific value- Moisture content needs to be in the 6-9% range and this will provide a high heating rate of approximately 17-18 MJ/kg. A maximum sawdust moisture content of 10% reduces the energy required to dry the sawdust. It is possible to convert solid wood to pellets but more cost and energy is necessary.

Flow-ability- The shape of a pellet promotes easier flow between the bunker and fuel delivery system reducing the chances of blockages. As a result, reduced bunker costs can be achieved. For smaller operations a grain silo is an excellent solution.

Raw material- Wood pellets need really clean material and no green matter. The more chopped up the feed stock the better such that dry wood shavings are the best. Dry saw dust is another adequate raw material, but this is relatively uncommon compared with wet saw dust. Wet saw dust must be dried, at some expense, to a moisture content of around 10-12% before being made into pellets. A third common material known as 'hog fuel' describes poor quality biomass that may be used in boilers, or potentially as a fuel to dry sawdust, but is unsuitable as a raw material for pellets.[11]

Fuel transfer- The pellet should to be easily transferred to the bunker. For smaller operations, purchasing fuel handling equipment can be a large proportion of the total project cost, making the project uneconomic. For large users, fuel handling equipment is less an issue because the cost is not significant.

3. Calorific values of wood species

Wood chip from forest biomass residue has a moisture content of around 40 – 50%, when freshly cut and around 20% when air dry. Net calorific value of some common pinus radiata forestry residues values are given in Table 2. This highlights the highest energy value for a wood product lying in the dry off cuts, shavings and saw dust.

Fuel type	**Net calorific value** (MJ/kg wet basis)
Green off-cuts	8.22
Bark	8.49
Dry off-cuts	15.68
Green saw-dust	8.22
Dry saw-dust	15.68
Dry shavings	15.68
Pulp chip	8.22
Hog fuel	9.28
Wood pellets	17.17
Dry fire wood	16.74

Table 2. Net calorific values of *Pinus Radiata* common forestry residues and biomass fuels

Source: http://www.scionresearch.com/BKC/calorific_value_calculator.html

4. Boiler suppliers in New Zealand

Around 50% of the capital cost of a bio-energy heat plant is in the boiler, the other 50% in the fuel storage and handling system[16]. This is a very basic rule of thumb as substantial variation will exist between cases of retrofitting wood pellet or chip boilers depending on the storage and handling system required.

Boiler suppliers and manufacturers' suitable for this project have been identified as follows:

Manufacturer	Brand	Range
Spark Energy	KOB	80kW – 1.3MW
Living Energy	Binder	49kW - 60MW
Taymac	Taymac	100kW – 2.3 MW
Fogarty Industries	Fogarty	80kW – 2MW

Table 3. Boiler suppliers and specifications

5. Wood pellet and wood chip suppliers in New Zealand and Australia

Biomass fuel has only recently been produced in the wider Dunedin area, with a pellet producing plant in Naseby, wood chips available from Naseby and, potentially, Tapanui and wood pellets may soon be available from Green Island (800 t/y Hans Pietsch, pers. comm.)

Prior to the establishment of these new companies, the nearest plant of significant size was in Christchurch. The future supply of raw materials to this plant is unknown and pellets may need to be produced elsewhere. If insufficient pellets were available locally, additional pellets would be most likely to come from one of three sources:

1. Christchurch (capacity of 4 t/h, 120,000 t/y)

2. Taupo, if the plant proposed by Nature's Flame is built (capacity of 120,000 – 200,000 t/y)[15]

3. Rotorua (capacity of 120,000 t/y)

In an EECA report on wood pellets, the authors concluded that the breakeven point for manufacturing pellets would be about 1,500t/yr,. However, many assumptions are required to come to this conclusion, most importantly that the price of pellets was NZ$250/t and sawdust was the raw material at NZ$10/t. If the pellet price was NZ$350/t, the breakeven point would be 900t/yr. This was based on a total investment of NZ$1.25m and 10% annual depreciation. It did not include costs related to drying, marketing or infrastructure.[11]

Component	**Cost NZ$(x1000)**
Front end loader	25
Heat plant including boiler and bag filter	25
Pellet machine	424
Sawdust storage silos	100
Other technical parts	75
New buildings	100
Engineering costs and contingencies	275
Total	1.68 million

Table 4. Approximate cost of a pellet plant capable of producing 4000t/yr

Source: New bioenergy options for New Zealand – an evaluation of wood pellet opportunities, Nielsen et al, EECA, 2004

Other producers of wood pellets in New Zealand are located at Huntly (1t/hr), Hastings (1t/hr, using own raw materials), Timaru (0.5t/hr using Silver Beech), Conical Hill (0.5t/hr), Ernslaw project using Douglas Fir), and possibly in Invercargill.

Australia is the world's largest exporter of wood chips, shipping over 6 million oven dry metric tonnes (odmt) in 2007, mostly of eucalyptus (about 70%) and pine (about 30%). The price FOB (delivered) in 2008 was NZ$326/odmt for eucalyptus and NZ$366/odmt for pine[9]. The price of wood chips has increased markedly in recent years, with prices are around twice what they were in 2003. However it is uncertain whether this trend will continue given the current global economic climate.

It seems unlikely that the volumes of biomass required in New Zealand would justify importing wood chips in the short to medium term. Furthermore, the need to import biomass for fuel significantly detracts from its appeal as a sustainable energy resource. On a national scale, it would then be, by definition, unsustainable.

5.1 Cost of product

New Zealand has the potential to generate a large amount of woody biomass due to its geography and climate. The annual production of woody biomass residues from plantation forestry alone is estimated to be 4 – 6 million tonnes. In 2004 wood provided 6% of New Zealand's total energy need[4].

The total sale of wood pellets in New Zealand was 3 - 5,000 t in 2003, entirely to the domestic market. This will probably change significantly as Solid Energy is in the final stages of building a pellet plant in Taupo able to supply 120,000 t/yr with a maximum capacity of 200,000 t/yr.

On average over the last two years more than 800,000 m³ of woodchips were exported from New Zealand with most of the chips destined to Japan. Japan is the main buyer of woodchips in the world, but the current economic climate and a glut of product has led to a significant drop in orders in Australia and this is likely to also be felt in New Zealand.

In 2004 the market price for wood pellets was $350/t ($18.42/GJ). In 2008, the University of Otago used 150 t annually at a delivered rate of $450/t ($21.05/GJ). Ernslaw Bioenergy supply wood chips at a rate of approximately $11/GJ not including the cost of delivery.

In terms of production costs, Hall (et al, 2001)derived specifications and costs of harvesting, handling and processing equipment for landing and cutover residues including

[9] http://lemn.fordaq.com/fordaq/news/woodchipexportprices_17506.html

loading and unloading[14]. In the same report, specifications of transport vehicles are analyses and presented based on relevant legislation and payloads. This report will be useful for estimating handling and transport costs for this project.

5.2 How is woody biomass being sold

Wood biomass is being sold based on the energy content of the fuel measured in dollars per unit of energy. For wood pellets, the consistency of the product makes it easy to calculate the cost to the client. However, some of the energy values been reported may not be accurate.

Wood chips are different again because moisture content can vary according to storage and climate conditions such as relative humidity. Some businesses are taking moisture content samples using specialised equipment and using tables to estimate energy content before charging on the volume. Again, energy values being reported by suppliers may not be accurate and accurate measurements of truck weight and volume are not ideal.

Wood chip and pellet suppliers are exploring long term supply contracts, 10-year contract, renewable after 5 years, to provide peace of mind and price security to their clients. Contracts do not include the costs of transport and are linked to the Producers Price Index.

6.0 Woody biomass fuel handling systems

Whether converting or installing a new biomass heating system, handling and storage of the fuel can be an issue. For small users, this can represent a significant proportion of the over project costs. For large users this cost can be absorbed into the project as it is not significant.

In some European countries trucks are set up to deliver fuel with specialised equipment able to pump, blow or auger the fuel to the bunker. This is starting to happen in New Zealand and a Dunedin business is providing this service to the University of Otago. Nevertheless, it is still in its infancy and this is likely to become more common.

There are several fuel handling products available in New Zealand:

Wood chip suction blower

Suction blowers come in a range of outputs and can be specified to either take wood fuels directly from a grain chute at the back of a truck (needs a flexible hose and hose connection) or is fitted with a hose that can be manually (e.g. by a person) handled to take fuel from a pile of wood chips. The output of this appliance is $15m^3/h$. Approximate cost $20,000 + GST.

Wood chip suction blower with tipping trough

This device performs the same function as the wood chip suction blower described above, yet adds a trough with motorised auger that enables the fuel supplier to tip the wood chips straight into a steel trough.

The tray blower comes as either a standalone unit or in a version that can be fitted to a tractor and driven by the tractor's drive. The standalone unit comes, again, in a range of outputs. A high-output 18.5 kW version has a capacity of up to $40m^3/h$. Approximate cost $35,000 + GST.

7.0 Scandinavian projects

Sweden and North America represent the world's largest consumers of wood pellets at 800,000 and 850,000 t/yr respectively, while consumption in Denmark, Austria and Germany in 2001 was 250,000 t, 120,000 t, and 100,000 t/yr respectively.[18]

Research into wood pellets and chips as fuels has been centred in Sweden, Austria, and Denmark with other European countries contributing. Development of wood pellet technology and uptake has been subsidised by the government in each of these countries.

Swedish research has indicated that heating and electricity could be completely provided by biomass, most of it sourced locally.[19] Sweden has a large forestry industry but still imports 100,000 t of pellets annually, has an extensive district heating systems, an advanced bulk pellet distribution system and a stoves, boilers and furnace making industry.[6]

Austria is suited to biomass fuel use because many large apartment blocks are on centralised heating.[6] In Denmark, woodchips represented 3.4%, or 836 PJ, of primary fuel consumption in 2004. The growing consumption of wood chips for fuel in Denmark has lead to an increasing volume being imported. Denmark must compete on an international level for woody biomass which is becoming more difficult as other countries increase their demand.

A primary reason why biomass can be used with such success in the European countries mentioned above is their use of district heating. District heating is used to heat the homes of 100 million people in Europe and the infrastructure is in place to make use of local biomass resources.

District heating is not used in New Zealand but a study suggested that biomass district heating systems in New Zealand were feasible in at least some locations. However retrofitting of a District Heating system is unlikely to be a realistic option in most cases.[15]

8.0 Conclusions

A supply of wood pellets and/or wood chips to Dunedin is available from reasonably local sources such as Naseby and Tapanui, and from large established pellet producing plants in Christchurch, Rotorua and potentially Taupo.

As a fuel, wood chips are cheaper to purchase but more expensive to handle and store. However, despite this, chip operating costs are much cheaper when compared to other energy sources such as gas, providing a positive cost benefit analysis. Nevertheless, businesses have many different drivers for converting to biomass and financial benefit is only one of the perceived benefits. Other drivers can include environmental, marketing opportunities and regulatory compliance.

A key variable in keeping a biomass fuel system cost effective is minimising the transport, both of raw product and wood pellets or wood chips. Scion Research has undertaken significant research on this subject and this will be a valuable resource for this project.

Supply chain analysis identified several chain operations for delivering from the forest to the point of sale. Significant research on this subject has been identified and costs and recommendations will be useful for this project.

The qualities of a biomass wood product have been identified for wood chip and pellet. Feedstock quality is very different for each product. New Zealand has a standard for pellet characteristics but not for wood chip. Nevertheless, qualities have been identified for providing a high quality wood chip.

Finally, biomass fuel systems have been successful in some European countries due to their use of district heating plans and large apartment blocks, neither of which is common in New Zealand. Other drivers are likely to be successful in New Zealand such as environmental, regulatory obligations and financial.