EECA
Energy Efficiency and
Conservation Authority
Te Tari Tiaki Pūngao

Forest residue harvesting for bioenergy fuels

May 2007 - Phase 1

Part 1 of 2

SCION
Next generation biomaterials

East Harbour

Contents

1. Executive Summary

New Zealand has substantial potential for production of biomass fuels from forest harvest residues. In 2005 forest harvesting produced an estimated 1.04 million tonnes of landing residues. At present less than 100,000 tonnes per annum are being utilised.

Short rotation crops may provide some fuel as a supply buffer, but will be more expensive than residues due to growing costs.

The raw materials are diverse in their composition, piece size and location.

Aggregation of residues is necessary to some extent to get a sufficient quantity of residues at one place to make processing them viable.

Current transport, handling and compaction technology does not make transporting of unprocessed residues viable over longer distances.

Moving to payment by energy content, not weight, would be fairer to both producer and buyer and may lead to improvements in fuel quality.

There is a variety of machines available off the shelf for comminuting woody residues; most configurations have been tried in New Zealand and each has its pros and cons. Choice of which machine is best will depend on the type of fuel and logistical set-up of the operation.

New Zealand engineers and manufacturers are capable of designing and building their own machines from scratch, and these may sometimes have advantages as they can be built to suit a specific site or need.

Current wood residue operations process a variety of residues at a variety of locations, sometimes producing a range of products with end uses not limited to fuels.

Producing fuel with consistent high quality will be critical to getting widespread acceptance. Fuel quality issues that can be affected by the harvesting system are moisture content (storage and drying times), fines (processing and screening) and dirt contamination (handling, loading, screening and storage).

There is considerable scope for further applied research into harvesting and logistics of woody residues from all sources, particularly residue handling, transport and load compaction. Engineering solutions research could cover:

Handling / loading

- cut-off saws on loader grapples
- large volume buckets + hydraulic thumbs
- feeding from the hogger directly into the truck transporting the fuel (equipment design).

Transport

- load compaction (raw and processed residues)
- truck design (for raw and unprocessed residues).

Processing

- screening to remove dirt
- screening to upgrade/segregate products
- processing (comminuting) machine efficiency and through-put
- effect of particle size demanded on productivity

Logistical

- segregation before piling
- loading, machine selection and operation
- processing into trucks not piles (cost analysis around logistics)

Fuel quality

- impact of ash content on operating costs
- payment by fuel value

In order to develop a viable business, the fuel processor (supplier) needs both a good scale of operation and a reasonable continuity of work. The scale of work required is in the order of 50,000 tonnes per annum to make it viable to invest in hogger capable of processing logging residues. The capital cost of these machines is such that a reasonable length of contract (three years) is required to make this investment attractive. In order to get the best fuel from the supplier, payment should be by energy content (not weight) as with biofuels weight is not necessarily directly linked to energy as it is with fuels such as diesel or coal. A further complication to the use of forestry residues is the separation between forest owners and wood processors. In order to produce the fuel, access to the forest is required. Forest owners may have only a marginal interest in encouraging the use of forest residues unless there is a revenue or other benefit in it for them.

The short-term nature of the case studies means that issues such as wear, occasional metal damage and its influence on repair and maintenance and machine utilisation were not quantified.

2. Introduction

Significant quantities of residues from forest harvesting are available as a source of fuel for bioenergy plants or as a feedstock to other uses (bio-refineries). Many New Zealand wood processors are fuelling boilers with the wood residues produced at their plant. However, it may also be economic to use wood residues that are a by-product of forest harvesting, and that are currently not utilised. This will particularly be the case where a plant has fuel shortages or an increasing demand for heat. It may even be possible to fuel a stand-alone plant with forest residue sourced biomass to produce electricity and/or process heat.

The type and quantity of wood residues produced during the harvesting operation will vary from site to site according to the source of residue and the harvesting process. Harvest residues are accumulated at landing sites, but there is also material left on the cut-over area, although this is less desirable for collection as bioenergy fuel because when left on the cutover it returns nutrients to the soil as it decays, and because with current technology it is expensive to collect.

Over the past 15 years a number of systems have been set up to harvest residues from New Zealand forests. Some have been successful and some are no longer operating. The common features amongst those currently operating are:

- mobile plant that operates from a variety of locations
- multiple customers for the output
- a variety of feed-stocks going into the processing equipment
- a variety of materials being produced, not limited to biofuels
- raw material is often being obtained free of charge
- none are collecting forest cutover residues

One of the common issues is that whatever woody biomass is used it is not all necessarily fuel grade after it has been processed. Some of it is wet and dirty and is better suited for mulch or composting uses. However, some of it is also clean wood and could be used as in-feed to pulp or panel plants. Segregation of these streams has a cost but gives a better overall result, the fuel is good quality and the different materials are used for what they are best suited.

There is often a need to find different markets for the output from one processing machine as there is insufficient demand for fuel for it to be economic to serve just the fuel market. The co-products markets are also somewhat inconsistent, with demand for material fluctuating. These factors, along with the low cost of competing fuels such as coal and gas, have made the biofuel market a difficult one. This is expected to change in the next few years as the costs of and restrictions on land-filling rise and the costs of fossil fuels increase.

The state of the current market for processed forest-derived residues influences what is happening with the processing equipment and how it is utilised. If there were a demand for higher quality processed residue then the residue processors would respond with subsequent improvement in equipment design and processing practices. The results of this study very much reflect the immature development of the processing of forest residues in New Zealand.

This report is a summary of research undertaken during the period October 2006 and February 2007 in the Central North Island area.

The purpose of the research was to identify the current state of the forest residues processing industry and to identify improvements in equipment or work practices that could be pursued in order to assist increase the amount of forest residues being utilised.

The research was undertaken by a limited number of site visits, telephone discussion with residue processing plant operators, and literature search.

3. New Zealand overview

This section describes the current state of the use of forest residues for biofuel in New Zealand. It is the result of intensive telephone contact over a relatively short period and therefore can only claim to be an estimate of the current extent of this industry. Some suppliers of information are understandably reticent because their industry is relatively recent, arguably marginally economic, highly competitive and still developing. Emphasis has been placed on obtaining information from users and suppliers of residue-based fuel.

Users of forest residues

The main centres for this activity are the Central North Island (CNI), and to a lesser extent Hawke’s Bay, Canterbury and Nelson. These areas are favoured by the close proximity of forests to industries with both a requirement for heat, steam and energy, and the infrastructure to use forest residues.

In general, owners of plants utilise a variety of waste-based fuels. Forest-based residues are often least favoured because of higher transport costs and less consistent fuel quality. The adoption of forest residues as a biofuel by users is strongly linked to the competing costs of gas and/or coal.

The Central North Island

Carter Holt Harvey (CHH) Pulp and Paper’s Kinleith Cogen (Co-generation of both steam or heat and power) plant (a joint venture between CHH and Genesis Energy) has a yearly requirement for approximately 340,000 tonnes (2.8 petajoules) of biofuel. This is about 20% of the plant’s fuel requirement. The plant also uses gas. One forest residue contractor, Central Waste Recyclers, supplies approximately 65,000 tonnes (0.53 petajoules) of forest residue hog fuel per year. The remainder is sourced from a stockpile of historic and current mill waste, including bark and sawdust.

CHH Pulp and Paper and Norske Skog (Norske Skog/Tasman/CHH joint venture, Kawerau) use forest residues in the form of hog fuel in their cogen boilers for the production of steam and to generate power. This plant has a yearly requirement of 150,000 to 180,000 tonnes of hog fuel (1.4 petajoules). Forest residues comprise about 50,000 to 80,000 tonnes (0.53 peta Joules). Two main contractors for the supply of hog fuel are Materials Processing Ltd and Plateau Bark Ltd.

Pan Pacific Oji Kokusaku (Pan Pac) has a cogen plant at Whirinaki in Hawke’s Bay with a yearly requirement of 240,000 to 270,000 tonnes of biofuel. An on-site supplier of residue-based waste produces 38,000 to 42,000 tonnes (0.34 petajoules) of hog fuel per year, the source for most of which is a processing yard located adjacent to the cogen plant. Most of the waste burnt at the plant is generated on-site.

South Island

The only identified user of forest residues for biofuel is Nelson Pine Industries’ plant in Nelson. Information supplied applies to 2005 when approximately 22,000 tonnes of biofuel was purchased, but how much of this was forest residue is not known. Currently, approximately 10% of the company’s total energy requirement is supplied from forest residue.

Potential users
Potential users, currently or soon to be involved in trials, are located in Kaitaia and Whangarei.

Owners of forest residues

Two forest management companies and 13 forest owner-managers were canvassed to find out if they were currently supplying forest residues for biofuel, or planning to do so in the near future.

Confirmed suppliers are Hancock Forest Management (Tokoroa and Nelson) and Pan Pac Forests (Hawke's Bay). In Northland, Rayonier and Juken Nissho both have current or planned trials to supply forest residues. Wenita is planning a central processing yard in their Otago forest and considering the option of using residues for biofuel.

Of the remainder, New Zealand Forest Managers was developing a biofuel system but the operation was terminated with the loss by fire of the Taupo Laminex plant using the fuel. Dunedin City Council (DCC) LATE (Local Authority Enterprise) DELTA, which operates a transfer station and landfill for the DCC (owner of city forests) was optimistic about the possibility of processing forest residues but was concerned about contamination of raw fuel by stones and rocks.

Forest owners in general saw advantages in removal of skid waste from their forests in terms of re-establishment or of minimising the hazard posed by "birds' nests" in cable hauler operations. One owner charged a nominal fee of $1/tonne for the residue.

Suppliers of forest residues

Six suppliers of forest residues were identified:

1. Wastepro Solutions Ltd, Waipa, Rotorua
2. Materials Processing Ltd, Cambridge
3. Wholesale Landscapes Ltd – Waste and Energy Solutions Division, Nelson
4. Central Wood Recyclers Ltd, Tokoroa
5. Plateau Bark Ltd, Kawerau
6. Pederson Holdings Ltd, Tokoroa

Wastepro Solutions Ltd
Wastepro Solutions Ltd, operating out of the Waipa sawmill site in the CNI owns one 600hp Wastepro mobile hogger currently supplying wood waste (not forest residue) for the CHH Kinleith Cogen plant. The hogger is also transported periodically to Matahina Forest (owned by Hancock Forest Management) where it is used to process waste from both skids and a central processing yard. The hogger is supported at Kinleith by an excavator loader and three men. Production rate is approximately 120m^3/hr. The company owns other waste processing machinery and supplies landscaping bark, pulp woodchips and animal bedding products.

Materials Processing Ltd
Materials Processing Ltd is based in Cambridge and operates three waste processing machines:

- a Crambo 6000 periodically based in both Kawerau and Rotorua, and handling predominantly municipal green, mill and log yard waste.
- a 475hp Screen Crushing Systems (SCS) Ripper also working at Kawerau for Norske Skog/Tasman/CHH.
- a JENZ "Shredder" – hammer mill/hogger processing C and D (Construction and Demolition) waste at Hamilton.

Wholesale Landscapes Ltd – Waste and Energy Solutions Division
Wholesale Landscapes Ltd in Nelson owns one 400hp SCS Ripper and processes forest residues for Nelson Pine Industries.

Central Wood Recyclers Ltd
CWR Ltd is based in Tokoroa and operates two SCS Ripper processing machines. One Ripper is based in the Tokoroa area processing forest residues for CHH Pulp and Paper and forest to dairy land conversion residues. The other machine is based at Pan Pac Ltd's log processing yard at Napier and processes log yard off-cuts and yard waste. The Pan Pac-based machine has been used in trials processing forest residues.

Plateau Bark Ltd
Plateau Bark Ltd is based in Kawerau and operates a WoodWeta hogger and processes central processing yard, log yard, and mill waste for Norske Skog/Tasman CHH.

Pederson Holdings Ltd
Pederson Holdings Ltd, located in Tokoroa, has recently purchased a Morbark 1300 (1998 model) for a contract to hog mill and yard waste for supply to CHH Pulp and Paper.

<u>Processing machines</u>

Wheeled or tracked options
Mobile wood processing machines come in two principal configurations: track mounted and self-propelled (Ripper & Crambo 6000) and semi-trailer (wheel) mounted and towed by a truck (WoodWeta, Morbark 1300 and Wastepro).

Wheeled machines have the advantage of being able to be towed to operating sites as a semi-trailer truck, and they may have to be moved frequently owing to their high processing rate. However, wheeled machines can be more difficult to successively position as they work on the waste at a given site. Regular shifting is sometimes necessary to keep the out-feed conveyer clear of the stockpile of processed waste. The alternative is to have a loader working next to the out-feed, moving it on a regular basis.

Waste processing machines are heavy (up to 40 tonnes) and soft or rough operating surfaces at remote sites such as logging skids may not be suitable for manoeuvring wheeled machines. Tracked machines have an advantage in this respect but transport costs are incurred as a low-bed transporter is required. Tracked processing machines are more expensive than the wheeled versions, but they can usually be driven by remote control by the driver of the in-feed loader. They can quickly reposition to clear the conveyer from the out-feed pile and move closer to the pile of material being in-fed.

SCS Ripper
The SCS RP2140TD Ripper is a Caterpillar-powered 400hp vertical shaft hogger. The Ripper is track mounted and must be transported to its operating site. It has a rotor head with 14 to 16 blades and interchangeable screens. Weight of the ripper is 27.5 tonnes, and the latest version costs approximately NZ$640,000.

Woodweta
The Woodweta 495F is a Caterpillar-powered 500hp hogger. The Woodweta is wheel mounted and can be towed to its operating site. It has a rotor head with 50 teeth and interchangeable screens. Weight of the machine is 36 tonnes, and the latest version costs approximately NZ$700,000.

Crambo 6000
The Crambo 6000 is a Caterpillar-powered 447kW (powering twin 160kW hydraulic motors) hogger. The Crambo operated by Materials Processing is track mounted and must be transported to its operating site. It has hydraulically powered low revolution twin augers with 67 teeth each and interchangeable screens. Fuel consumption is approximately 45 l/hr. Weight of the machine is 26 tonnes, and the tracked version costs approximately NZ$800,000.

Morbark 1300
The Morbark 1300 can be fitted with different-sized engines. The machine owned by Pederson Holdings is a Caterpillar-powered 860hp tub grinder with a 13ft (3.96m) tub and weighing approximately 40 tonnes. This model is mounted on wheels and towed to its operating site. It has a rotor head with 20 hammer teeth fitted for grinding hog fuel. Fuel consumption is approximately 100 l/hr, and production rate is quoted as exceeding 90m^3/hr. The cost of the latest version is approximately NZ$850,000.

<u>Systems</u>

Wastepro Solutions Ltd, Waipa
Wastepro's operation at Kinleith has the hogger located next to a processed fuel stockpile at the cogen plant. Mill and yard waste is brought to a central point on the site, and an excavator loader feeds this waste into the hogger.

Materials Processing Ltd, Cambridge
Operations at Kawerau involve the Crambo shredder located beside stockpiles of waste (log yard, logmaking, packaging, landfill mining) at the mill site. An excavator loader loads waste into the shredder. Shredded waste is stockpiled for removal by truck. A screening plant is also onsite.

Wholesale Landscapes Ltd – Waste and Energy Solutions Division, Nelson
Operations involve the location of the Ripper at a central site. An excavator loader loads waste from a skid site (less than 5km from the processor) into a bin truck (capacity up to $60m^3$ depending on the weight of processed waste) and trailer and it is then transported to the processor. The same truck and trailer are used to take processed waste from the central site to the mill after being loaded by bucket loader.

Central Wood Recyclers Ltd, Tokoroa
One of the systems used by this contractor involves the tracked Ripper being located at a site (for example, an old airstrip) where a large stockpile of skid waste has been accumulated, after being transported by bin truck from a super skid. An excavator loader feeds the Ripper. A bucket front-end loader then clears the processed waste into a stockpile and loads bin trucks. Transport distance for this kind of operation can be up to 50km.

In a second operation at Napier, a Ripper is sited close to the boiler stockpile. Log processing yard waste is brought to the Ripper by dump truck (less than 1km lead distance). The central processing yard is located adjacent to the mill.

Fuel quality of forest residue

Calorific value
Calorific value is largely determined by fuel moisture content as well as the fuel type or species. The graph below shows the relationship between moisture content and energy content. As moisture content rises, energy content falls.

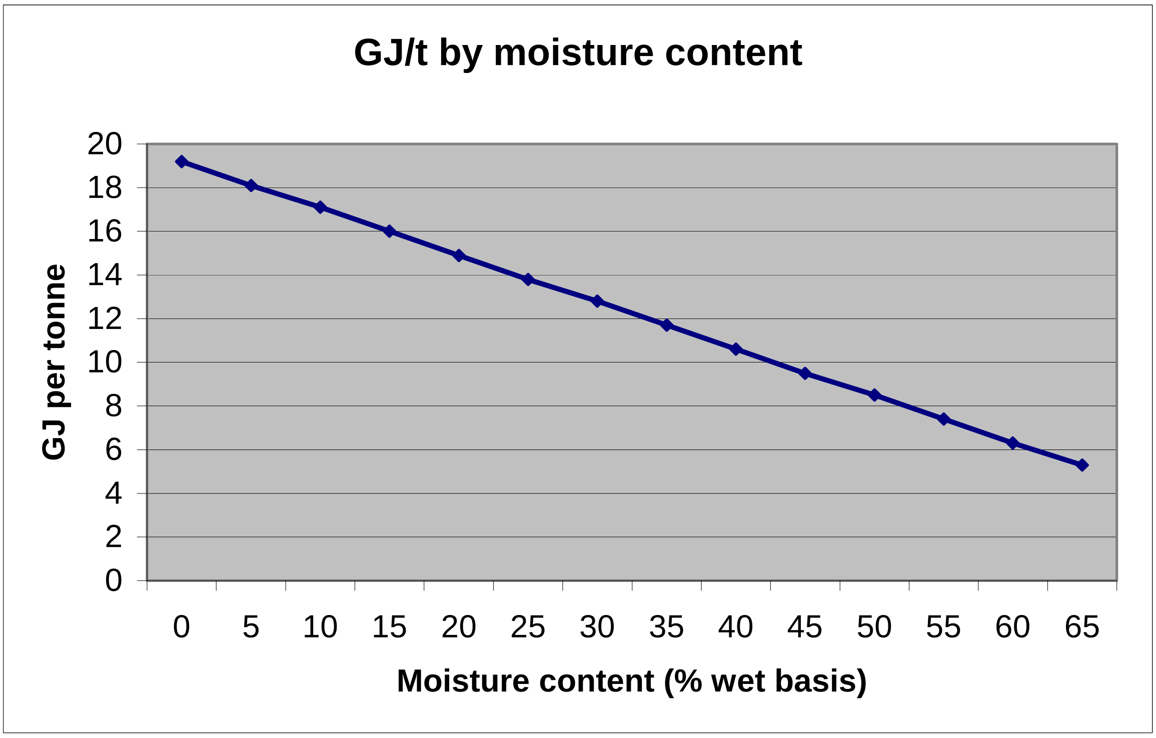

Figure 1 – Energy content by moisture content

Moisture content
NPI: Mostly radiata pine, Mean 51% Wet Basis (43% Summer, 55% Winter)
Pan Pac: 42–52 % dry solids (MC Wet Basis)
Norske Skog: 45–60% (MC Wet Basis)
CHH: March 2007, 3 week average value 57.5% (MC Wet Basis)

Ash content
NPI: Mostly radiata pine, Mean 12% (2006, 2007 data)
Norske Skog: Mean 3% (screening of some fuel at this site reduces dirt content)
CHH: Overall stream 3-5%

Industry issues

Payment
Currently, most waste processors are paid on their production in terms of tonnes of processed waste produced. As such, there is less incentive to produce fuel of greater quality (that is, reduced moisture content, reduced contamination), but greater emphasis on quantity. This seems counterintuitive to the notion that the value to end-user is based on the calorific value of the fuel used to generate heat, steam or power.

Moisture content is not generally one of the factors within the control of the processor. Another aspect of fuel quality is controllable to the extent that the producer can use screening to reduce the dirt content and fine fractions in the fuel produced. However, this reduces the production rate, so fuel produced will be more expensive. The fuel purchaser must consider the costs of reduced efficiency of the boiler system when deciding on a suitable payment system. High ash contents (> 6 to 8%) are highly undesirable.

Continuity of work
Large residue processing machines that are capable of producing processed waste at up to 100 m^3 per hour need customers with large annual requirements if the machines are to be effectively utilised. At present, most processors of forest residues move their machines and operations to different sites within a region, or to different parts of the country in search of work. This lack of significant single-site demand and the scattered resources may have had an effect on the willingness of processors to invest in capital equipment. In many cases the machines are still being trialled to test their suitability and cost on a particular raw material.

Currently in many of the New Zealand operations, forest residues often comprise only a small part of the waste the machines are processing. The owning and operating costs of machines costing up to $750,000 require machines to be fully utilised if costs are to be minimised.

Diversification
Most processors have structured their operations to produce more products than just boiler fuel. Compost, pulp chip, animal bedding products and landscaping bark are some of the products that can be sold if there are ready sources of raw material. At least one processor also processes green waste at a transfer station.

Cost of competing fuels
Biofuels are attractive to the user if the relative costs of competing fuels are high in terms of dollars per gigajoule. There may be non-financial benefits in terms of a triple bottom line as biofuels are effectively carbon neutral.

Fuel quality
One processor, not currently processing forest residue, raised the issue of fuel quality because a potential customer required a better standard of fuel with reduced contamination (and hence a lower ash content produced on combustion). This may not be a concern with other biofuel users but illustrates the need for producers to be flexible and possibly offer higher quality fuel on different terms.

Some forest harvesting systems, often ground-based, involve successive blading of the skid site working surface, adding to the soil and gravel content of waste wood. Some integration of residue harvesting with conventional log products would help the efficiency of the residue operation. However, this must not interfere with the primary function of the logging operation.

Modelling volume of supply and cost

A model based on a GIS system and the 2005 National Exotic Forest Description has been developed that allows the selection of a delivery location for which the model then calculates the volume of residues potentially available and the cost of delivery to the selected point. As the volume of residues delivered rises, the distance required to go to collect the residues rises, and hence the cost of delivery rises (see Figure 2 below). A 5MW electricity with 30 MW heat co-generation plant would require about 120,000 tonnes (at 30% moisture content) per annum of wood fuel.

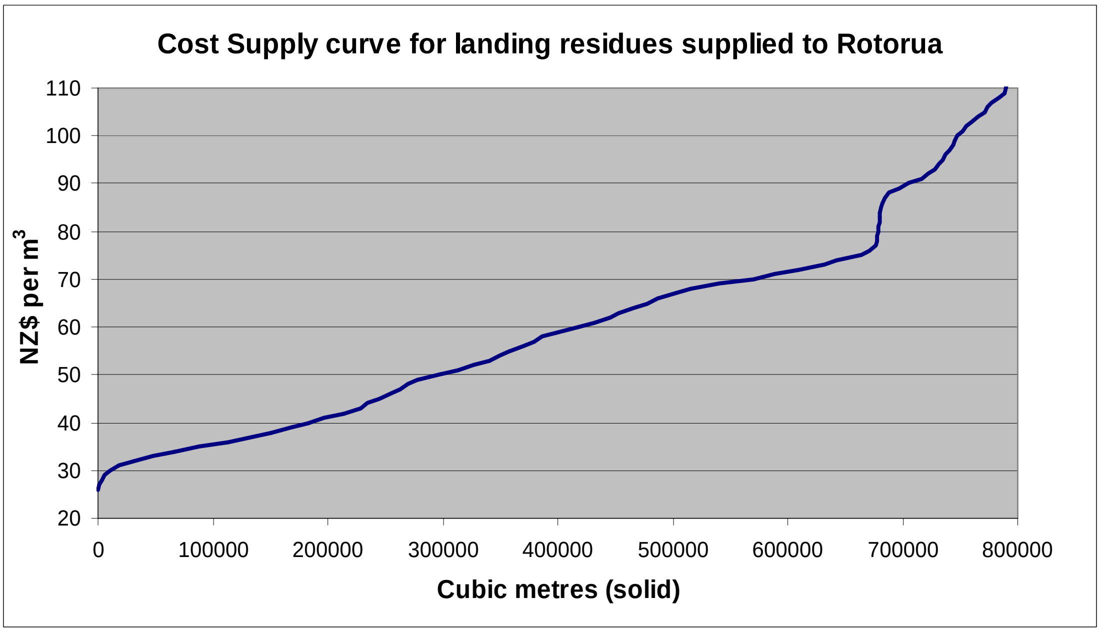

Figure 2 – Cost supply curve for delivering landing residues in fuel form to Rotorua.

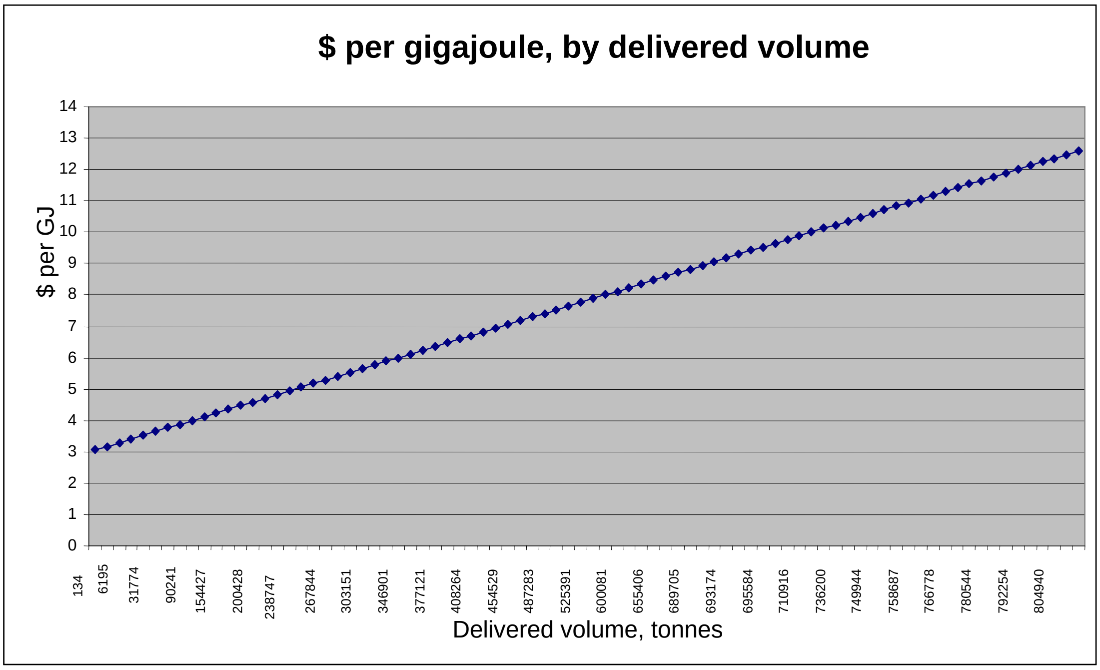

Figure 3 – Cost per gigajoule by delivered volume, for landing residues in fuel form to Rotorua

4. Case studies – summary

Three operations processing biomass in the CNI have been visited and data collected on their operations; these are summarised below. In addition, some information was collected on two other operations that have worked, or are currently working, within the CNI.

Processing machine	**Ripper**	**Woodweta**	**Crambo 6000**	**Morbark 1300**	**Wastepro**
Engine size kW	298	372	447	592	370
Approx cost	$640,000	$700,000	$800,000	$800,000	$500,000
Weight, tonnes	24	36	26.2	36.6	32
Height, m	3.9	4.2	3.155	4.11	
Width, m	3.04	3.05	2.95	3.65	
Length, m Transport Operating	 10.6 12.65	 15.85	 6.58 11.04	 12.2	 12+
Configuration	Vertical shaft, high speed oscillating disk, tip in-feed to bin above disk	Horizontal longitudinal shaft, high speed disk, walking deck into sloping rotary drum, onto disk	Horizontal shafts (2), low speed high torque augers, loader feeds directly into hopper above shafts.	Horizontal longitudinal shaft, high speed drum, loader direct in-feed to rotating tub above drum	Horizontal transverse shaft, high speed drum, walking in-feed deck with compaction/ feed roller.
Mounting	Tracks, remote control operation	Semi Trailer	Tracks, remote control operation	Semi trailer	Semi trailer
Production	25 to 30 t/hr	25 to 30 t/hr	20 to 40 t/hr	40+ t/hr	30 t/hr
Dollars per tonne, on truck	$22 to $24	$18 to $20	$18+	*A $20 to $21 *B $23 to $24	$18 to $19

*A = cost of hog fuel only
*B = cost of mixed hog fuel and panel board chip

All operating systems were variations on the same basic structure of:
1 20-tonne excavator to in-feed material to the processing machine
1 processing machine (hogger)
1 Rubber Tyred Front End Loader to clear the out-feed and load out

The costs of production presented in this report are average costs and reflect the cost of processing the material the machine typically works in. There appear to be differences between machines, but these can be attributed to the material being worked and the specifics of the site they were operating in, rather than any specific advantage one machine might have. In order to test one machine against another it would be necessary to put them all in very similar work situations, which was not possible.

The Morbark tubgrinder has its own self-loading crane, which requires all fuel to be brought within reach of the machine by truck or another loader.

For the Ripper, WoodWeta and Crambo machines, the in-feed excavator operator also controls the processing machine by a radio remote control. This can start, stop and control the in-feed as well as operaTE the tracks to move and position the machine.

Critical to any direct comparison of the machines is the particle size of the material produced. The smaller the particle size demanded by the end-user, the lower the production rate of any given equipment. Machines also vary in the shape and size distribution of the material produced and the machine chosen for the job should be one that can consistently produce a particle that meets the buyer's specification. Screening, handling and reprocessing of oversize material is costly, reduces throughput and increases the need for operating space.

Figure 3 - CWR's Ripper working in 9 year old radiatA pine, converting whole trees into boiler fuel (See Appendix I).

Figure 4 - Plateau Bark's WoodWeta converting reject logs and logging residues into boiler fuel (see Appendix II)

Figure 5 - Materials Processing's Crambo 6000 turning stem off-cuts, bark and packaging waste into boiler fuel (see Appendix III)

In the operation observed for the Ripper, an additional excavator was working ahead of the processing operation, piling and preparing the material to be processed. The material being processed was large windrows of whole (9-year-old) radiata pine. The densely packed windrows were being broken open and the tree lengths broken into two pieces. This made them easier to fit into the in-feed of the Ripper.

The Ripper and Crambo are both track mounted, and can quickly be moved by the operator along a windrow or pile of residues minimising the handling of materials being fed into the machine.

In some cases operational scale trials are being conducted to determine suitability and productivity of machines on a range of residue types. This includes logging landing residues and wood processing waste, including reject product.

In the operations observed, the most common approach is to get the hogging machine as close as is reasonably possible to the source of the residue. This is because of the difficulty in loading and transporting the unprocessed residues, which are frequently low density and of highly variable piece size. The processed residues are much more homogeneous and easier to handle and transport. However, due to the throughput of the machines and the down time and cost associated with moving them, some accumulation and/or aggregation of residues is necessary. Ideally the machines should have a minimum of two weeks' and preferably four weeks' work at one site.

Figure 6 - Truck and trailer rig used for transporting processed residues from the processor to the energy plant

Transport distances and truck configurations varied from operation to operation. In two cases the processor was close to the mill energy plant and so the fuel was loaded into a truck and taken a short distance to the fuel pile. These lead distances were so short that the use of a trailer was not advantageous. In one operation the fuel was being transported approximately 70km to the pulp mill's cogeneration plant, and so a large high volume truck and trailer unit was required to make this viable. In this instance the transport was by private forest road, and so the truck was able to run a much higher gross vehicle weight than if it had been running on public roads. This has significant cost implications for the delivered cost of the fuel.

In some operations the fuel was very high moisture content (57% wet basis); this means that transport operations have high payloads. When they are being paid by the tonne this is highly advantageous to the truck operator, but the fuel purchaser is paying for delivered weight that is water, not fuel.

Issues

In all the operations the product was being fed out of the machine and on to the ground and from there it was picked up and loaded into trucks. This is often done because of the difficulty of scheduling trucks for direct loading, or because of site restraints in terms of space and layout. However, where fuel is reloaded off the ground there are losses of hogged material, which can be as high as 10 to 12%, the risk of dirt contamination and the cost of the loader. Where it is viable, the hoggers should load directly into trucks as this will improve recovery and efficiency, and reduce cost. In most, but not all, cases the machines have out-feed conveyers that are capable of loading directly over the side of the trucks.

Payment by energy content of the delivered fuel is not happening at any of the operations observed. All operations were being paid by weight. This is not desirable when the product is a fuel and the commodity being bought is energy. The energy content of biomass varies with moisture content. High moisture content means a heavy load with low energy per tonne. Low moisture content means a light load but a higher energy content. When fuels are wet the processor wins as the buyer is paying more for less and when the fuel is dry the buyer wins as they are paying less for more. It would be preferable and fairer to pay by energy content and both sides get what they are expecting. One side effect of paying for fuel by weight is that it encourages the production of wet dirty fuel. An interim step to consider is payment by volume. The volume of the trucks being used is measurable and will not change (assuming the truck is loaded to its full volume capacity). This ensures that the truck operator is not disadvantaged by carrying very dry fuels which have high volume but low weight.

Testing of the fuel for moisture content is relatively simple, and is already being done at one site. However, the data are not being used to pay for the fuel, but as a record of what the fuel is like (quality). Records of ash content are also kept (by weighing ash produced and calculating it as a percentage of the fuel in). These are used as a quality control measure, not as a means of adjusting payment.

In two of the operations (one of which is no longer producing) the material coming out of the hogger was being screened and separated. It is also possible to debark and/or screen prior to hogging. These processes are suitable for operations which have high throughput and a variety of markets. In some cases the prices paid for landscaping products such as bark and mulch are higher than those paid for fuel, so it makes sense to segregate these products if it can be done economically. It is also preferable to screen out dirt and fines before the raw material goes into the hogger, as this improves efficiency and reduces wear. The dirt and fines can be used as clean fill or composting material.

The design of the machine can also influence its susceptibility to damage. Machines that have the ability to screen out tramp metal or stop when metal is encountered without major damage to the knives have better utilisation and productivity. Once metal is detected, the design of the machine can also influence how hard it is to get the metal out and the time taken to get restarted.

Fuel quality is an area that needs to be looked at carefully. The demands of the end-user will vary. Some combustion plants are capable of coping with fuels that have high moisture and ash contents. However, these fuels are low in value. In order to attract better prices from higher value end uses, the fuel needs to be as clean and dry as the economics allow.

This study has not looked at any mobile chippers, as these machines are not common, and not necessarily suited to producing hog fuel from dirty, highly variable, raw material.

Engineering issues identified

Handling/loading

- Cut-off saws on grapples. In two of the operations observed the addition of a cut-off saw to the excavator grapple would have enhanced the ability of the in-feeding loader to present material to the processing machine. The cut-off saw is a hydraulic chainsaw fitted to one side of the grapple which can be operated from the cab and allows the operator to cut larger sections into smaller pieces, improving load placement and improving the presentation of the material to the hogger face.

- Large volume buckets + hydraulic thumbs. In another operation the excavator was fitted with an earthmoving bucket with a hydraulic thumb to assist with accumulating and retaining a good scoop-full of material. Some modification to the bucket and the thumb would further enhance the ability of the machine to quickly and easily shift residue material that is made up of short sections such as stem wood off-cuts.

- By feeding from the hogger directly into the truck transporting the fuel a loading cost and a loss of materials during handling would be eliminated; this could potentially reduce the cost by 10%.

Figure 7 – Log-yard waste from a central processing yard showing small, medium, and large stem wood sections

Transport

- Load compaction (raw and processed residues). A key to making forest residues a viable biofuel is efficient transportation. This includes both having purpose-built trucks which are robust and high volume and having the loads in them of sufficient density for the truck to be able to reach its maximum gross vehicle weight and maximise its payload. For some unprocessed residues, simple and lightweight load compaction devices would be an advantage. Alternatively, specialist loaders fitted with high rise cabs to improve the driver's ability to view his load placement, along with a cut-off saw, would also improve the operator's ability to maximise load density. Compaction of comminuted residues is much more difficult to achieve and can lead to difficulties in getting the load to tip out.

- Transport costs contribute at least a third of the delivered cost of the fuel. Gains in transport efficiency will therefore have a marked impact on the total costs. Trucks should be designed for maximum payload on low moisture content hog fuel. These should be able to be loaded direct from the hogger where possible.

Processing

- Screening to remove dirt. This can occur either before the material is size reduced or after. Currently, two operations either have or can use a rotary drum-type screen to remove dirt, stones and loose bark prior to comminution. Screening after size reduction can also be used to remove fines and dirt.

- Screening to upgrade and segregate products. After size reduction screening can be used to segregate by size. Larger (over-sized) material may be reprocessed, and intermediate sizes can be used for boiler fuel and smaller sizes for mulch or composting.

- Processing (comminuting) contributes approximately a third of the total cost of the fuel. Having machines that are best suited to the material being processed, that are fully utilised and operated at best efficiency, is essential. Research on improved throughput from redesigned comminution machines would give productivity gains. This research is likely to be highly specialised, very expensive and time consuming. New Zealand's best approach may be to follow closely R&D effort on this topic in Europe, Scandinavia and North America.

Logistical

- Segregation before piling. In some instances a variety of wastes were being put into one pile and processed into one homogeneous pile. There was clearly room to segregate the differing raw materials and process them separately to produce different products.

- Loading. Having machines that are well suited in size and design is critical to getting good clean load-out of materials that are piled on the ground. Good driver skill and education are also essential. Contamination of fuel with dirt by poor machine operation has been observed.

- Processing into trucks, not piles. In many cases the processing machines were processing on to the ground. This means that up to 10 to 12% of the processed material can be left on, or mixed into, the ground. It can lead to problems with dirt contamination when loading out. It requires an extra machine to do the loading, which has a cost. It is often a challenge to get an even flow of trucks, and to keep the processor working efficiently enough to fill them quickly. However, this practice has been used successfully overseas (Australia and USA). There is also room for a mix of solutions, with the use of hook bins (for example, waste bins) to work into if a truck is not available.

Fuel quality

- To burn consistently fuels must be of a consistent quality, preferably high quality. In terms of forest residue-derived fuels this means low moisture content (30 to 35%), even particle size distribution with a minimum of fines and low dirt content. Dirt content lowers fuel energy value and increases ash production. Ash becomes a waste product that requires disposal and so minimising this has real value in avoided landfilling and transport costs.

5. Estimating the cost of recovering forest residues as fuel for energy production

This section provides a simple methodology for calculating the value of energy obtained by collecting, processing and delivering forest residue to a heat plant facility for conversion into energy. Design and operation costs of the heat plant are not covered. It must be stressed that the costs developed for this model are indicative only and additional, detailed, site-specific calculations will be required to prove a project's feasibility.

Harvesting methods

The method of recovery of the residue will dictate the quality, quantity and mix of the biomass available for processing into fuel:

1. Ground-based systems

As this is often carried out on flatter land, logging residues from both cut-over areas and from the landing areas are potentially available for collection although, as stated above, the preferred location for sourcing forestry-derived biofuel is the landing material.

On flat terrain specialised equipment allows de-limbing at the stump with the result that branch material is left in the forest. This can then be collected by specialised collection equipment. It is assumed that these forwarders are self-loading. Residue at the landing will mainly consist of stem off-cuts, but this will vary with crop and harvesting system, and large volumes of branches can occur.

2. Hauler systems

In steep terrain, hauler extraction may involve removal of trees intact up to the felling break point and smaller broken pieces, both of which have most of the branches still attached. As a result the landing residue may consist of stem off-cuts, branches and small diameter tops. In steep terrain there may be little recovery of cut-over residues. There will, however, be a larger amount of landing waste available with hauler systems. This is likely to increase the need for residues to be removed as harvesting occurs to allow adequate working space at the landing.

Biomass collection volumes

The quantity of forest residue likely to be available for collection and processing can be estimated from the figures in Table 1. These values give the number of tonnes per hectare for an average mature *Pinus radiata* forest in New Zealand. Terrain, location and variations arising from different harvesting methods will have an effect on the figures but this average information should be able to provide an indication of the amount of fuel which will be available.

	Ground-based logging flat to rolling terrain	**Hauler logging steep terrain**
Total extracted stem volume	500 to 700 m^3 per ha	500 to 700 m^3 per ha
Stem waste at landing - Manual log making - Mechanised log making	 20 to 28m^3 per ha (4%) 30 to 42m^3 per ha (6%)	 25 to 35m^3 per ha (5%) 30 to 42m^3 per ha (6%)
Branch waste at landing	2.5 to 3.5m^3 per ha (0.5%)	15 to 21m^3 per ha (3%)
Total waste at landing	22 to 32m^3 per ha (4.5%)	40 to 56m^3 per ha (8%)
Stem waste on cut-over	25m^3 per ha (5%)	49m^3 per ha (10%)
Branch waste on cut-over	52m^3 per ha (10%)	58m^3 per ha (11%)
Total waste on cut-over	77m^3 per ha (15%)	107m^3 per ha (21%)
Total in forest waste	100 to 130m^3 per ha (ca 20%)	140 to 160m^3 per ha (ca 28%)

Table 1 - Tonnes of residues per hectare available for conversion into biomass fuel

The use of computer-based value optimisation systems does not significantly alter the percentage of waste produced during log making, although it may affect the average length of the pieces.

Processing options

Most biomass fired energy plants require that forest residues be either chipped or hogged to provide an easily managed fuel source. The processing of residue into chipped or hogged fuel can be carried out at four possible sites.

The options are: at the stump (cut-over); at the landing; at a central point in the forest (may be the roadside or a point central to a number of landings or plantations); or at the utilisation/conversion plant. Choice will depend on type of residue (composition, volume, density, distribution, piece size), location, logistical difficulties, handling and transport costs. It is likely that, due to the cost and low economies of scale of moving a chipper between individual landings, residue will be taken to a central point for processing.

For simplicity only processing at a central site or at point of use is considered in this exercise. The term ‘comminute’ is used to cover either chipping or hogging of the material. Comminution will generally be by passing the residue through a large chipper, tub grinder, horizontal or rotary hog or other similar specialist equipment which could be mobile or stationary.


Figure 8 – Self-loading disc chipper


Figure 9 – Horizontal hogger with excavator loader


Figure 10 – Self-loading tubgrinder

Figure 11 – Horizontal rotary hogger, self-propelled, requires loader to infeed raw material

As a result of residue collection and processing there will be a quantity of "green" biomass that is available as a fuel. It is likely that the moisture content will need to be reduced before combustion. This may be achieved by natural drying by storing for three to six months or by passing through a dryer at the combustion site. This report does not consider the cost of storage or forced drying. (Refer BANZ Information Sheet 8, *Woody Biomass Fuel Drying*, for forced drying options.)

	Low cost	**High cost**
Chipping at central site using mobile plant. (CC)	\$7 to \$9	\$10 to \$12
Chipping at point of use using fixed plant (CM)	\$3 to \$5	\$6 to \$9

Table 2 - Range of costs for chipping residue ($ per tonne)

Transport

Off-highway transport costs are likely to be lower than those for transport on the highways due to the higher gross vehicle weights allowed on some private forest roads. The reduced costs may only be able to be realised if the destination does not involve any highway travel. It is probable that heavier loads may be possible when transporting processed residues on highways due to the increased density of chips. This would give lower transport costs per tonne for processed residues.

Due to transport costs, the distance between plantations and the heat plant is likely to be the major consideration in determining the feasibility of forest residue collection.

	Low Cost – long haul	**High Cost – short haul**
Off-highway uncomminuted (TL)	\$0.17	\$0.51
On-highway uncomminuted (TN)	\$0.22	\$0.65
On-highway comminuted (TC)	\$0.17	\$0.45

Table 3: Range of costs for off- and on-highway transport ($ per tonne per km)

Note: The $ per tonne per km costs need to multiplied by the haul distance to give the total transport cost. For very short haul distances (<5km) the costs may be in the order of $1 per tonne per kilometre.

Delivered energy costs

While the characteristics of each source of residue being considered for recovery and processing into a fuel will vary for individual locations, a range of typical costs has been established. These are based on a combination of actual and theoretical costs. They are adequate for an initial study of the viability of recovering residue as a fuel source, but a full costing analysis using site-specific data is recommended prior to committing to any project.

No allowance has been made for the cost of storage in the forest or at the combustion site. If residue or chips are delivered to the plant un-dried there may be the need to add drying costs to the model if the fuel is to be used immediately.

It is also assumed that there is no fee for the residue itself. If the forest owner wanted a fee for the residue this would need to be added to the calculations.

Costing model

A typical collecting and processing model is shown in Figure 12. This is based around a simple scenario but with minor modification can be adopted for other scenarios. The model assumes residue is collected from 15 to 20 landing sites, delivered to a central site and then transported to the mill for use as fuel. Comminution may be carried out at the central site or at point of final use. This model can be modified to cover other scenarios.

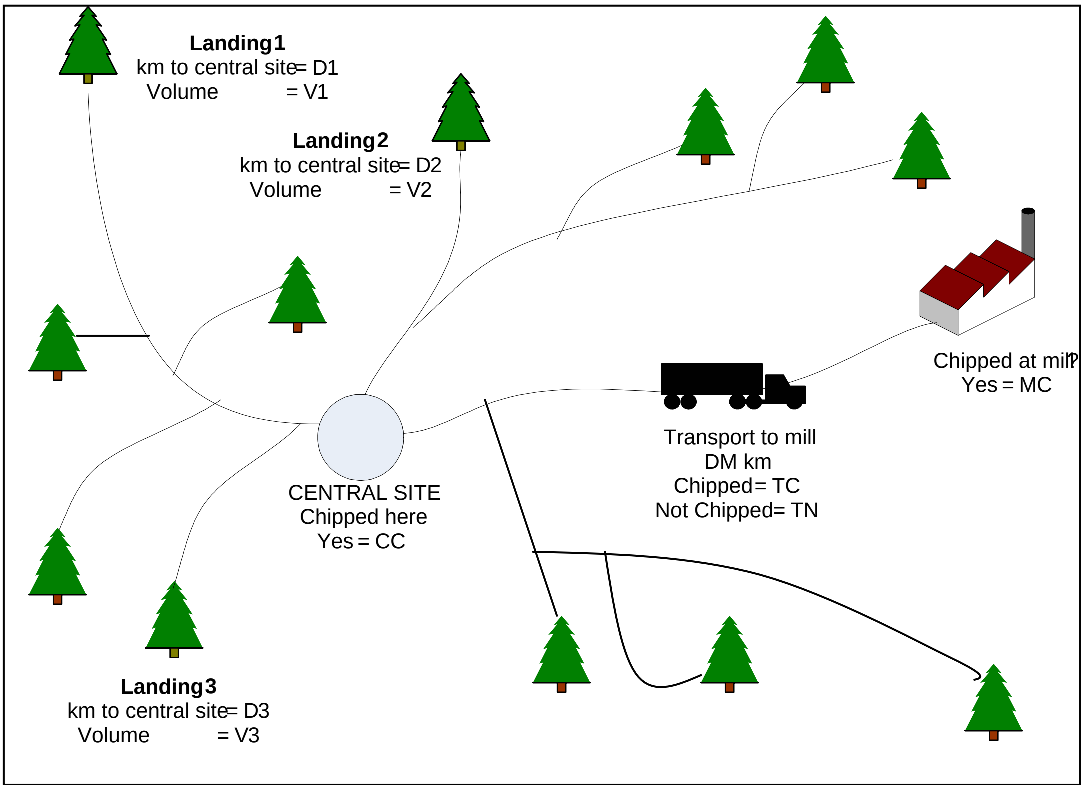

Figure 12 – Schematic of possible biomass system

The formula is: DC = (TL x DL) + (CC or MC) + (DM x TC or TN) * DMLf

Where:
DC = delivered cost of forest residues ready for use as fuel ($/tonne)
TL = $ cost per km of loading and transporting residue to the central site (Table 3)
D1, D2 & D3 are the distances between individual landings and the central site (km)
DL = D1 + D2 + D3 / (No. landings (km))
DM = distance from central site to the mill
CC = cost per tonne of chipping at the central site ($) (Table 2)
TC = cost per tonne of on-road transport for chipped residue ($) (Table 3)

TN = cost per tonne of on-road transport for unchipped residue ($) (Table 3)
MC = cost per tonne of chipping at point of use ($) (Table 2)
DMLf = dry matter loss factor (suggest 0.97)

In order to compare costs with those of alternative fuels, the energy output of the biomass residue should be calculated. On average, one tonne of comminuted residue will provide 10 gigajoules (GJ) of energy. Therefore cost per GJ is DC/10. This cost can be compared with other fuels to show the economic feasibility of recovering forest residues for use as fuel.

Likely costs are in the range of $2.5 to $5 per GJ, with the range of variation largely driven by the transport distance, system used and amount of in-forest drying that is achieved.

In February 2007 at the time of writing, comparative costs of alternative fuels were:

- Split firewood for home use	$9 to 10 per GJ
- Briquettes	$15 to $18 per GJ
- Wood pellets	$24 to $25 per GJ (domestic supply)
- Coal, bulk supply	$5 to $7 per GJ
- Gas, bulk supply	$10 to $15 per GJ
- Diesel	$23.5 to $28 per GJ

The total costs are made up of various handling, processing and transport costs. Looking at the proportion of the total which comes from each step is a useful way of looking at where there are potential gains to be made. Table 4 below shows the percentage attributable to the four biggest cost contributors for the system described in Figure 12.

Transport distance, km	25	45	65	85
Comminute (hogging)	36%	31%	29%	27%
2nd stage transport	25%	33%	38%	42%
1st stage transport	11%	10%	9%	9%
Handling/storage losses	7%	7%	7%	7%

Table 4 - percentage of delivered cost attributable to various steps in the process, by variable transport distance

These figures show that there is potential for significant cost reduction by gains in the transport and comminution phases. Any reduction in handling losses is a direct saving. Each loading operation contributes around 6%. Altering the operations to reduce handling and associated losses, as well as improving truck design, would potentially reduce costs by at least 10%.