The cost relativity of New Zealand biomass heating fuel systems

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1. ABSTRACT

A study is described which defined the optimum harvesting, processing and transport system in terms of the cost per tonne of delivering biomass produced from a commercial short rotation coppice crop to a $10MW_e$ bioenergy conversion plant 25 km away. Harvesting the crop during one short seasonal period of the year results in the need to store most of the material for between one to 12 months in order to provide a continual supply of feedstock. Storage of large volumes of biomass is costly and also results in dry matter losses over time. An alternative system would be to harvest small areas as required every few weeks throughout the year. The results are compared with other fuels suitable for heat and power generation under New Zealand conditions.

2. INTRODUCTION

The production of short rotation forests to provide feedstock for producing heat, electricity or transport biofuels has reached the commercial stage in several bioenergy projects (Sims, 2002). However the costs of the biomass material in terms of $/GJ delivered to the conversion plant, remain relatively high compared with coal or natural gas. These costs must therefore be further reduced if bioenergy from these energy crop sources is to compete with fossil fuels or even with biomass from other sources such as wood process residues.

Typical harvestable yields from short rotation_forests of 10 to 24 tonnes of dry matter per hectare and year have been reported under warm temperate conditions (Sims *et al.*, 1990). Part of the delivered supply costs involve harvesting, transport and storage. These need to be minimised by optimising truck payloads (Hall *et al.*, 2001) and minimising dry matter losses when in store (Kofman and Spinelli, 1997).

The optimum time for harvesting a crop of short rotation forest is normally a compromise between maximising winter sprout production, avoiding cold winter temperatures on young regrowth stems, avoiding summer dry periods and gaining maximum summer growth (Sims *et al.*, 1994). Under conditions experienced in the central North Island of New Zealand, short rotation coppice *eucalyptus* is normally harvested in spring time during October/November when rainfall is common and the soil is warm enough to encourage plant regrowth. However long term field trials (including some harvested every three years for 15 years, yet to be published) in the central North Island of New Zealand, have shown that a stand can be harvested all year round without the occurrence of any significant agronomic problems such as increased stump mortality or yield losses (Lowe, 1994). Harvesting in January and February caused some yield reduction but conversely where harvesting was delayed for several months past the usual October/November harvest period, the additional growth which resulted was an added advantage. This was verified by Blake (1983) who reported that *E. obliqua* showed a decline in the number and length of sprouts when harvested in the summer.

The objective of the study reported here was to determine whether all-year-round harvesting of short rotation coppice *eucalyptus* could be a viable system of providing more secure and cheaper biomass fuel supplies compared with a single harvest operation conducted over a concentrated period of just three or four weeks and resulting in the biomass having to be stored for up to 12 months in large piles.

All-year-round harvesting enables favourable changes to be made to the supply chain in that:

- any change in heat and power demand with seasons can be met by harvesting a greater or lesser area each week;
- a more even labour and machinery requirement would occur throughout the year;
- additional growth would be obtained by leaving the trees standing as long as possible before requiring them to be harvested for the biomass;
- the storage period of the material would be greatly reduced leading to lower dry matter losses;
- the cost of storage, whether stored under cover or on a given area of land, would be reduced as smaller volumes can be stored at any given time; and
- smaller, cheaper machines could be used with lower performance capacities but optimised to match the harvest requirements.

3. METHODOLOGY

In this study the production yield data used were taken from a trial block of *E. saligna* planted at Massey University in November 1988, with 12 plots of single stems harvested monthly from February 1992 until January 1993. The coppice regrowth plots were then harvested exactly three, six and nine years later. It was assumed that in a commercial operation, one third of the land area would be planted in year 1 ready for first harvest in year four; another third planted in year two and first harvested in year five; and the final third planted in year three and first harvested in year six. Harvesting of the coppice regrowth would then begin in year seven.

It was further assumed that a 10 MW_e integrated gasification, combined cycle power plant, similar to that of ARBRE in the United Kingdom (Fardy, 2002) was to be constructed in the Manawatu region of the North Island of New Zealand and that several short rotation forest plantations would be established around the area to supply it. Assuming the plant operated at 33% efficiency for 7000 hours per year to meet a constant base load, the total energy requirement would be approximately 850 TJ of biomass per year. Full details of the assumptions are given in Sims and Venturi (2003).

The BIOTRANZ model used in the analysis (Sims and Culshaw, 1998) automatically accounts for moisture content changes over time and also for dry matter losses. To provide a fixed amount of useful energy at the plant the purchased volume of the material is increased to compensate for any losses which results in a higher total initial purchase price. Thus if 20 tonnes of biomass were required and a 10% loss was expected prior to use in the gasifier, then

22 tonnes would need to be purchased. In this study the purchase price of the biomass was set at \$NZ[1]10/t dry matter.

3.1 System options compared

Six options of the two harvest chain systems under evaluation were selected for analysis (Figure 1).

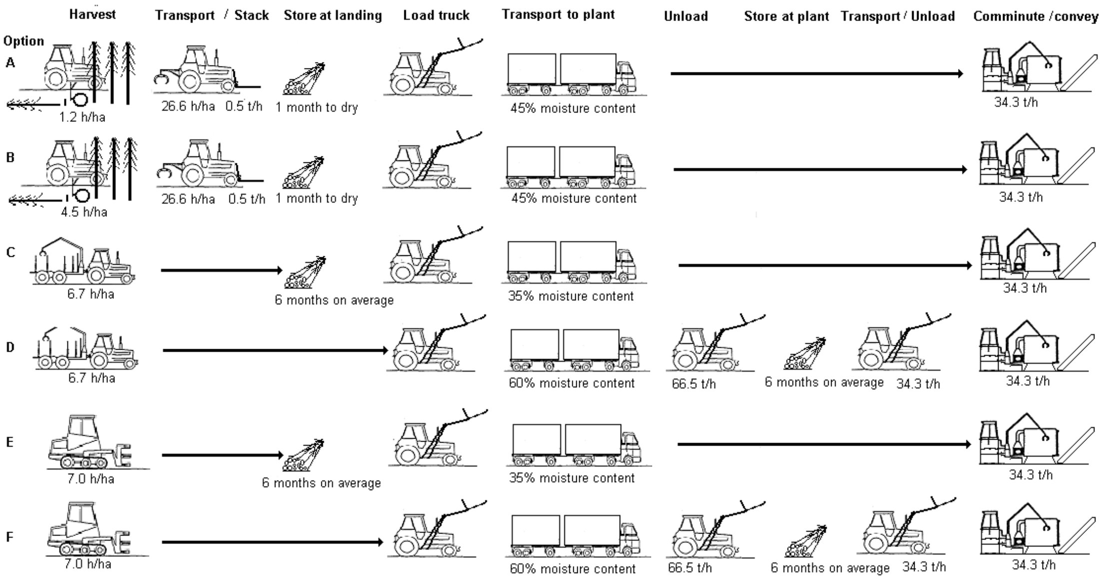

Figure 1. Harvest system chains as compared in the study: two options (A & B) for the all-year-round harvesting system and four options (C,D,E & F) for the single seasonal harvesting system

Options A and B were based on a simple, tractor mounted, circular saw harvester as developed by the Italian Research Institute for Agricultural Mechanisation (ISMA) in Rome (Pari, 2000). The 750 mm diameter blade was powered by the tractor hydraulics, mid-mounted on the tractor and positioned with a variable cutting angle depending on the crop characteristics. It was assumed the saw would be able to handle either single stem or multiple stem coppice regrowth with base stem diameters up to 200mm. The saw blade and drive mechanism is mid-mounted on the tractor when cutting, but designed to be carried behind the tractor during transport on the road. The actual field performance of the saw (in terms of hours per hectare) will vary with crop type and stemwood size and is not known. Therefore two options were analysed covering an assumed work productivity range of either 1.2 h/ha (A) or 4.5 h/ha (B).

The cut stems fall at right angles to the rows and are then gathered and collected by a tractor-mounted fork. The whole stems are then transported an average of 200 m to the landing at the edge of the field at a work rate of 26.6 h/ha. In order to match the output of the harvester and produce a balanced system to transport the large volumes of material, a simple spreadsheet was developed to calculate the number of machines needed (Sims and Venturi, 2003).

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[1] \$1 New Zealand = 0.5 Euro or \$0.5US approximately

For both Options A and B it was assumed the cut stems will be left stored on the farms to dry naturally for one month prior to transporting them by truck/trailer to the power plant (Figure 1). The material will be unloaded by a knuckle boom grab which also serves to feed the fixed tub grinder selected to comminute the material at a rate of around 34 t/hour in order to meet the conversion plant's fuel demand.

Options C, D, E and F were based on the more conventional seasonal harvesting method whereby all of the biomass material is cut in the late winter or early spring during a four week period, then stored either on the farm or at the conversion plant. The plant needs to be continually supplied with fuel.

4. RESULTS AND DISCUSSION

A summary of the harvest, transport and processing costs for each of the six system options compared is given in Figure 2.

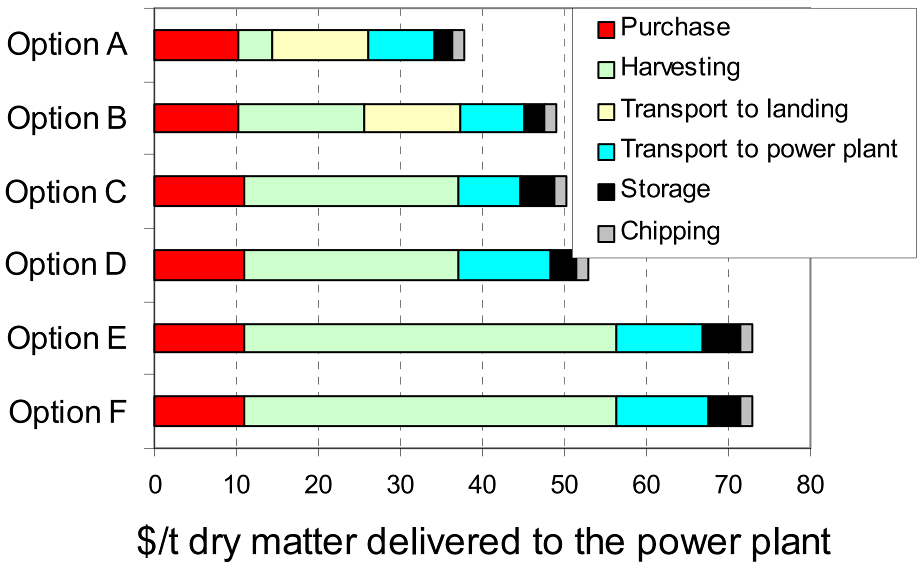

Figure 2. A comparison of the delivered cost of biomass to the conversion plant for all-year-round harvesting Options A and B, and for seasonal harvesting Options C and D based on using a forwarder, and E and F using a feller-buncher

The slightly higher biomass purchase costs for Options C,D,E and F are due to the greater volume needed to compensate for the dry matter losses when in longer term storage. In these four options the cost of transporting to the landing is included in the harvesting costs as it is all carried out in one operation, whereas for Options A and B the mechanised cutting by circular saw is separated from the collection by tractor and fork loader.

Transport costs over the 24.8 km distance to the power plant partly depend on the moisture content of the carted biomass. The storage costs are less for Options A and B than for the seasonal system options as the average storage time is relatively short. Chipping costs at the plant were the same for all options.

Overall the all-year-round harvesting options were \$37.90/t dry matter delivered for A and \$49.10 for B. These showed slight economic advantages over the seasonal harvest operations (which ranged from \$50.21 to \$72.98/t dry matter delivered), partly as a result of the reduction in dry matter losses due to the shorter storage period, and partly due to the cheaper harvesting costs due to the use of smaller scale machinery. Option A gave the lowest delivered costs which equated to \$1.98/GJ but this result was dependent on the assumption that the tractor-powered saw could cut the trees at the high assumed work rate of 1.2 hours per hectare which is yet to be proven in practice. Options C to F ranged from \$2.61 to \$3.80/GJ delivered. A sensitivity analysis was also conducted (Sims and Venturi, 2003) which showed the direct harvesting costs had the greatest impact on the delivered fuel costs.

Based on the yields recorded from field trials of coppiced eucalyptus in the Manawatu region of New Zealand over four rotations, the land area to supply a 10 MW_e base load power station was calculated to be around 2,800 hectares. Harvesting this area in a short season by using expensive high performance machinery and storing the biomass for an average of 6 months was shown to be a more expensive system than frequent harvesting of small areas throughout the year. The most expensive seasonal harvesting option (F) at \$3.80/GJ of delivered biomass was almost double the cost of the better of the two all-year-round systems evaluated. However several key assumptions regarding the use of the simple tractor-mounted circular saw followed by subsequent collection of the drying trees using a tractor and fork loader, need to be confirmed by field evaluation. If verified, then all year round harvesting of short rotation coppice eucalyptus in a temperate climate appears to be a feasible method of significantly reducing the delivered costs of the biomass fuel to a power plant located within a 20 to 70 km radius.

5. COMPARISON WITH OTHER FUEL OPTIONS

A similar analysis of forest arisings from *Pinus radiata* plantations under New Zealand conditions (Hall *et al., 2001*) gave a range of delivered costs from \$22 to \$65/t dry matter over a similar transport distance depending on collection and transport system used and assuming a purchase price of only \$2-3/tdm. This resource can be delivered cheaper than SRC which ranges from \$50 - \$75/tdm when harvested conventionally assuming a low growing cost of around \$10/tdm. Wood process residues produced on site by comparison can have a negative cost where there is a disposal problem. These figures are confirmed by a recent study (to be published in December 2003) undertaken for the Australian Greenhouse Office and RIRDC by the author in association with Enecon which indicated supply chain costs for SRC of around \$40-50/tdm when collecting over a 100 km radius.

This provides a comparison of delivered prices to be approximately \$0-4/GJ for wood process residues; \$2-5/GJ for forest arisings depending on road types and distances; and \$3.50 – 5/GJ for SRC. Currently by way of comparison coal can be delivered 100kms in New Zealand for around \$2-3GJ and natural gas retails for around \$2-4/GJ depending on contractual arrangements based on volume of use. The capital investment in combustion plant tends to be significantly greater /kW installed than for coal or gas. Therefore the fuel costs need to be significantly lower in order for a biomass project to compete. The carbon charge to be added to fossil fuels in 2007 (capped at \$25/t carbon dioxide) will serve to bridge the gap but probably insufficiently for biomass from SRC to compete.

Taking New Zealand as an example, the 30PJ Renewable Energy target consists of heat, power and transport fuels (Figure.3). Bioenergy options can compete for heat but less so for electricity and biofuels.

- Heat at around $4-7 /GJ competes with gas and coal at around $3-5/GJ.
- Electricity at around $10-30/GJ (or 4-10c/kWh) competes with combined cycle gas turbine plants at around 4c/kWh though rising to 5c/kWh as the gas price increases.
- Solar water heating compare well with the retail electricity at around 12c/kWh.
- Transport fuels from energy crops at over $35/GJ compare with the ex-refinery price of petrol and diesel (before excise taxes etc) at $12-13/GJ (but bioethanol from whey and biodiesel from tallow are close to competitive.

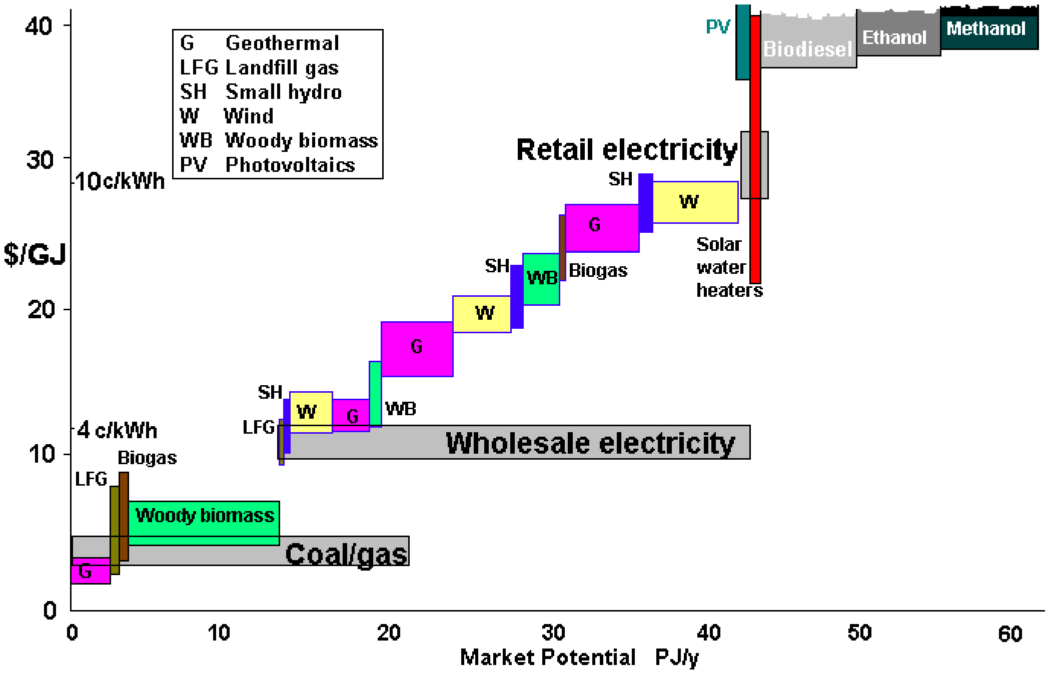

Figure 3. Potential supply of renewable energy to meet the New Zealand 30PJ target by 2012

6. CONCLUSIONS

The delivered costs of SRC using various supply chain options cannot compete with on-site biomass processing residues or collection of forest arisings unless they can be grown close to the bioenergy plant to reduce transport costs. Harvesting all year round may reduce storage costs and losses and is worthy of further evaluation. Under New Zealand conditions SRC cannot compete with fossil fuels except perhaps in the heat market. The cost of greenhouse gas emissions by way of a carbon charge on fossil fuels plus a carbon credit for biological carbon sequestration will help to bridge the gap and make biomass from SRC more competitive in terms of $/t of carbon equivalent avoided.

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