Biomass Energy Production Opportunities From Large Scale Disturbances in Western Canada

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Abstract

A variety of economic and policy vehicles have been deployed in European and North American jurisdictions designed to facilitate investment in biomass energy production. This paper discusses a number of these vehicles and their impact on investment decisions. The biomass energy options of direct fired feedstock, co-firing of thermal energy production and fuel pellets are discussed in detail. The potential for carbon credits to encourage investment in biomass energy is examined. The context for much of the analysis presented is the large mountain pine beetle epidemic in British Columbia. This forest pest outbreak, which has spread through an area of almost 10 million hectares of mature pine forests, may be a leading indicator of the scale of future natural disturbances supported by a more benign climate.

This paper provides an economic perspective to the financial feasibility of biomass energy, an overview to a selection of public policy vehicles used to promote biomass energy production, and an examination of the economic potential for biomass energy to serve as option to capture value from the legacy of standing dead timber from a large mountain pine beetle epidemic in British Columbia. The paper concludes with a brief discussion on select barriers to biomass energy.

Keywords: bioenergy, biomass energy, mountain pine beetle

1. Introduction

The use of woody biomass for commercial energy production has considerable physical potential on a global scale – commercial is defined here as an industrial process converting wood to energy or heat. The key impediment to increased production has generally been economic, with the costs of gathering and centralizing feedstock being uncompetitive with comparable fossil fuel energy sources. Northern Europe, choosing to stimulate investment

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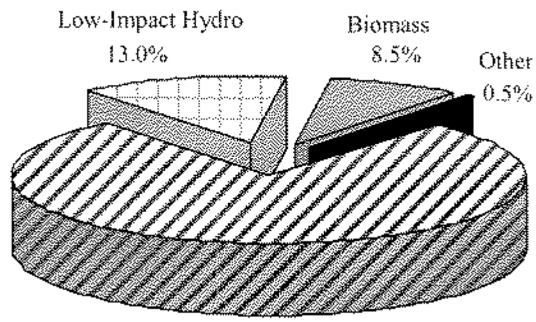

Figure 1. Total renewable energy capacity in Canada (2003) by resource type (percentage of total 93,000 MW). Source: Nyboer *et al.* (CCIEEDAC) 2004.

through a wide array of economic incentives, likely has the most advanced biomass energy production sector. Canada also has significant biomass energy capacity in place but the bulk is integrated within established forest products manufacturing – most notably for energy production in pulp mills and heat for dry kilns in sawmills.

The most important constraint to the economic feasibility in biomass energy production is the cost associated with the collection, handling, transportation and storage of feedstock. Variability in procurement costs between feedstock sourced from mill residues versus some form of market purchase contributes to a wide range in cost estimates. For many of the energy investments integrated with mills the opportunity cost of the feedstock is zero or even negative (benefit) as tipping fees (i.e., disposal) or treatment costs are avoided. The aggregate cost of collecting, treating and transporting feedstock for an independent energy production facility are generally prohibitive given the market price for energy.

Renewable energy capacity in Canada is 93,000 MW if large-scale or "conventional" hydro projects are included (Figure 1). In this definition, biomass energy comprises 8.5% of renewable energy in Canada (Nyboer et al. 2004). It is worth noting the small contribution of the 'Other' sources – wind, biogas, municipal solid waste, solar photovoltaics, tidal, solar, thermal, biodiesel, earth energy, geothermal and ethanol. Of the total biomass energy produced, most is produced by forest product companies for their own use – mostly as cogeneration in pulp mills. The feedstock is either in the form of residues (bark, shavings and sawdust) or black liquor, a by-product of the pulping process at kraft pulp mills.

2. Review of Feedstock Costs – Western US

There is an increased recognition in the western US, although not without opposition, that large areas of public forest are in need of hazardous fuels reduction to minimize the risk of wildfire (NFP 2001, etc.). This shift to so-called "proactive" wildfire management has led to numerous studies on options to utilize this often sub-commercial source of fibre, usually small diameter forest thinnings. This research provides useful information on examining certain alternatives is biomass energy production. The estimated biomass feedstock costs from a number of these studies are summarized in Table 1 (converted to Canadian $/Bone

Table 1. Biomass Feedstock Costs – Western US in 2002 $BDt^{-1}.

	Roadside			Delivered		
	Low	High	Mean	Low	High	Mean
Ince et al. (1984)	56.81	137.83	74.60	72.76	154.39	90.08
McNeil (2003)	39.45	65.39	55.95	-	-	-
Zachritz et al. (2000)	-	-	-	50.40	59.11	54.75
Whittier and Hease (1994)[a]	-	-	-	50.40	71.69	61.05
Lynch and Mackes (2002)[b]	93.59	145.76	119.68	-	-	-
Klepac and Rummer (2002)[b]	96.99	130.91	113.95	-	-	-

[a] As reported in Zachritz et al. (2000)
[b] As reported in McNeil Technologies (2003)

Dry tonne [$BDt^{-1}]). These estimates are generally provided as a range of costs, and estimate the roadside costs, the delivered costs or both. The distribution of costs and the average costs are provided in the table.

The cost estimates are the result of forest thinnings, with the exception of Ince et al. (1984), which examined the costs of salvage harvesting Lodgepole pine following a mountain pine beetle (MPB) outbreak. In order to equalize across the two types of costs $10 BDt^{-1} is added to the roadside cost for transport and the simple average across roadside and delivered costs in Table 1 is $87.60 BDt^{-1}.

3. The Mountain Pine Beetle Epidemic in British Columbia – Feedstock Potential

Early estimates of the potential impact on fibre supply (beetle killed timber) resulting from the MPB epidemic are approximately 500 million m^3 (mill. m^3) of timber killed in the short- to medium-term (BC Ministry of Forests 2004). In addition to large this volume, the outbreak is spread over a considerable area as illustrated in Figure 2. It is anticipated that existing processing mills will use much of this timber volume, but approximately 200 mill. m^3 of the total killed is expected to remain unsalvaged in the absence of creative (new) options to utilize this fibre. Although this indicates a large "potential" supply of feedstock for biomass energy, the question on the economics of investing in this potential remains to be tested. The supply potential of this feedstock will be defined by two economic margins – the intensive and extensive margins. Supply availability at the intensive margin is defined as that arising from more fully utilizing fibre on a given area of land (i.e., increase utilization). Supply availability arising from the extensive margin refers to expanding the area harvested. Most of the available "economic" supply of feedstock for energy is that available at the intensive margin, including post processing co-products (i.e., residuals), and low-valued timber within stands with a mix of higher quality stems not of sufficient grade to justify manufacturing activities. Supply arising from extending the extensive margin is still more financially challenging.

A further complication is that the longer beetle-killed timber remains standing, the less options are available for using the fibre. In other words, the decomposition of this dead

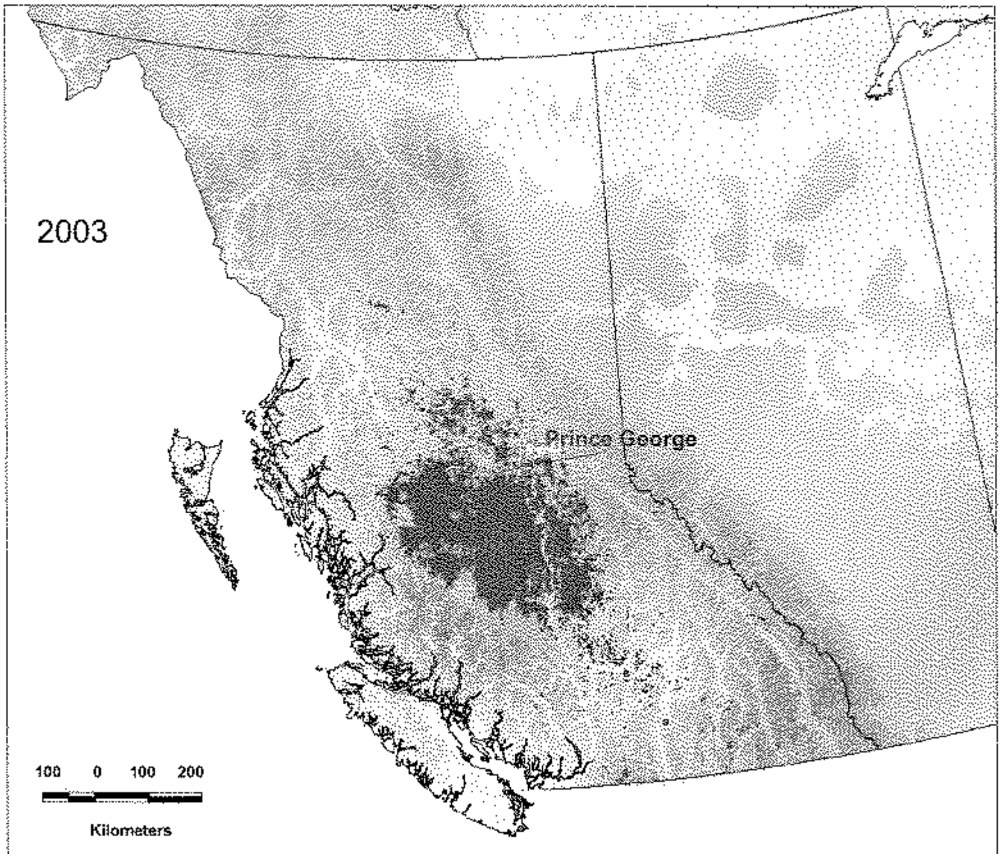

Figure 2. Area affected by MPB in British Columbia. Source: Natural Resources Canada/Canadian Forest Service.

timber renders it commercially useless after a period of time, even for energy production, the notion of 'shelf life'. Therefore, as stands are salvage harvested over time for processing into lumber or other traditional forest products, the supply of non-suitable timber per hectare will increase as higher proportions of trees within a stand degrade beyond merchantability.

In response to the shelf life constraint the allowable harvests on public lands in the most heavily impacted regions of BC have been increased with a focus on existing forest firms and "traditional" manufacturing activities. The harvest increase to date is 5.3 (mill. m^3) or 42% of the pre-outbreak base of 13.2 mill. m^3 (BC Ministry of Forests 2004(a)). There have also been increases outside this region. This up-lift volume is supplying a combination of increased capacity at existing sawmills (i.e., adding a third shift to mills) and increased capacity from a number of new investments. There are a number of constraints on how much additional commodity can be produced including the price impact on markets. The residuals associated with this manufacturing increase are the lowest cost fibre because they have already been transported to and concentrated at sawmill locations. At this point in time (2004) much of these residuals are in surplus, in fact, some are still burned in beehive burners, a cost with no associated benefit in terms of heat or energy produced.

It should be noted that increases in the supply of residuals are a temporary source of feedstock that is only available as long as the harvesting up-lifts remain. BC Ministry of

Table 2. Estimated Wood Pellet Production Costs - $Cdn.

Cost Category	$/tonne Pellets
Energy	14.94
Labour	8.16
R&M	4.61
Other	0.53
Carrying Costs	2.67
Total Variable Costs	30.91
Total Fixed (Capital) Costs	13.03
Pellet Costs pre Feedstock	43.94

Source: Hirsmark 2002, Converted to $Cdn at 2002 Exchange Rate.

Forests' projections forecast a reduction in timber supply after approximately 15 years from the onset of the MPB, with a total harvest reduction at approximately 14% below the pre-outbreak allowable harvests by the 2015–2017 period. This represents a harvest reduction of 7.1 mill. m^3 when compared to the supply levels prior to the beetle response up-lifts.

The financial feasibility of investing in biomass energy facilities is fundamentally challenged by both the lack of long-term feedstock supplies and a source of low-cost feedstock. This raises a series of questions. Are there opportunities to provide feedstock in this region past the anticipated time period when harvest reductions take hold? Assuming some of the beetle-killed timber is still harvestable, what is the cost of a long-term feedstock supply through dedicated harvest? What is the potential to provide post-MPB feedstock through aforestation of appropriate marginal lands in the region with fast-growth plantation fibre?

4. Options for energy from forest biomass

The next section examines the potential for converting mill residues into wood pellets. The is followed by a discussion of policy measures taken to promote biomass energy and a pair of case studies examining options to convert beetle salvage timber to biomass energy.

An alternative use of processing residuals, rather than direct energy production, is to create a value-added product such as wood pellets, or products based on other innovative conversion technologies such as enzymatic ethanol or bio-oil. There are a number of pellet production facilities currently operating in BC, making use of processing residuals, and the capacity is rapidly expanding with increased timber processing. A recent Swedish study (Hirsmark 2002) estimated the costs to produce pellets at a commercial scale (80,000 tonnes/year) at about $44 per tonne (see Table 2). However, this estimate did not include any provision for the cost of the feedstock.

Feedstock supply resulting from direct harvest of MPB killed trees will be more costly than fibre from processing residuals. The early estimate of available feedstock in BC resulting from the MPB outbreak is at least 200 mill. m^3. Although harvesting for lumber production can provide sufficient financial returns to develop harvest areas, transport the fibre, reforest and pay economic rents, it is not the case with biomass feedstock. A simple example examining the costs to procure feedstock through direct harvest in the northern interior of BC is given in Table 3.

Table 3. Costs to harvest, haul and chip timber in Northern BC.

	Traditional Logging, Hauling then Chipping	Whole-Tree Chipping On Site
	$/BDt	
Logging Costs (Tree to Truck)[a]	40.71	33.73
Development Costs[b]	9.49	7.86
Overhead[c]	16.67	13.82
Basic Silviculture[c]	8.57	7.10
Total Log Costs Pre-Hauling	75.44	62.51
Hauling[a]	17.16	17.16
Chipping[d]	8.00	8.00
Total Delivered, Chipped Prices	100.60	87.67
Tree to Truck + Haul + Chip	65.87	58.89

Sources. [a] BC Ministry of Forests 2001
[b] Peter 2004
[c] BC Ministry of Forests 2004(b)
[d] McNeil (2003) converted to $Cdn

It must be noted that the $101/tonne value estimated in Table 3 assumes all of the costs (including reforestation) to deliver and chip logs are accounted for in the biomass feedstock costs. The only cost not included is payments to the resource owner (i.e., stumpage to the provincial government). This omission reflects the lack of economic rents in the energy production example. A tonne of wood chips (dry) delivered to existing facilities can generate approximately 1,330 kWh of electricity (net), which means the imputed value of electricity in a BDt wood is $66/tonne, using a price of $0.05 kWh^{-1}. Prior to accounting for any of the capital or operating costs of a generating facility, the $101 estimated for the direct costs of providing the feedstock exceeds the value of the energy being produced which is $66/tonne of feedstock.

There is potential to reduce the feedstock costs to some degree if on-site chipping of whole trees is feasible. This will increase the yield for a given volume of logs by 20.7% (accounting for non-bole biomass, Nagle 1990). The delivered cost of the chips drops to $88/BDt in this system, or to $59/BDt if development and reforestation costs are not included.

The following sections examine these costs by comparing them with feedstock costs in other regions and are used to examine markets, instruments and/or policy that could make direct salvage harvest of feedstock an attractive option for beetle-killed timber.

5. Possible Measures to Increase Biomass Energy Uptake

In the example presented above, it is clear that accounting for energy prices alone (at current levels) will not support woody biomass energy production from the beetle salvage, even with the lowest cost feedstock option. However, the challenge of a biomass energy option deserves further examination because there are additional benefits to producing energy from wood. For example, one major benefit is predicated on the fact there are costs to leaving large volumes of woody biomass on landscapes vulnerable to large-scale disturbances. These costs include any additional risk of wildland fire, habitat alteration and reduced growth rates in subsequent stands. The rate of stand growth may be very important to regions with forest-dependent communities, although most of these costs will accrue in the future.

A frequently cited benefit to biomass energy production is the displacement of emissions from burning fossil fuels. This is especially valid in cases such as wood waste where carbon is released (generally through beehive burners) whether or not energy is produced. Many domestic, regional and international programs recognize the benefits of renewable energy production in general, and biomass energy production in particular, designing various economic/policy instruments to promote its uptake.

The European Union (EU) adopted a directive in 2001 to promote renewable energy production in internal electricity markets (IEA Renewable Database 2004). The target is to generate 22.1% of electricity and 12% of all energy consumed from renewable sources by the year 2010. In the EU directive renewables include wind, solar, geothermal, wave, tidal, hydro, biomass, landfill gas, sewage treatment gas and biogas. Although this is very much a regulated target, individual countries within the EU were given country specific targets and discretion on how to meet the targets, many choosing to use market incentives. There are many programs to support green energy development throughout the EU, most notably feed-in tariffs which guarantee a price premium for renewable energy production. It should also be noted that many of these countries had well entrenched systems in place prior to this directive, most notably the Nordic countries.

Carbon taxes on non-renewable energy sources have been used in the Nordic countries and the Netherlands since the early 1990s. Countries with specific taxes on CO_2 include Denmark, Finland, Italy, Norway, the Netherlands and Sweden (IEA 2005). Finland was the first country to institute carbon taxes in 1990 and Sweden followed suit in 1991. In the case of Sweden, CO_2 emissions have risen since 1990, although at a slower rate than would have been the case without the taxes (Bohlin 1998). The effectiveness of the carbon tax in Sweden has been weakened by a reduction in the rates paid by industrial users. Carbon taxes were instituted in Sweden in 1991 with an initial rate of $US 133/tonne C. This was changed two years later to a differential rate with industry charged $US43/tonne and consumers $US160/tonne. In addition to a carbon tax, Sweden also levies taxes on energy and sulphur, although for competitiveness reasons, industry is exempt from the energy tax. Biomass energy is exempt from all of these taxes in Sweden, leading to a relative cost advantage versus the case in an instrument-free market situation. There are many other programs in Sweden that are aimed at increasing biomass energy uptake as well including (IEA 2005):

- Green certificates scheme in which tradable certificates are generated by select green energy sources, with certificates produced for MWh's of production. Consumers are required to purchase a certain number of certificates or face a fine.
- Tax breaks to individual homeowners who install pellet or wood burning furnaces.
- Feed-in tariffs, which guarantee additional support above the market price of electricity for small independent power producers using wind or biomass.

In Canada, institutions are under development, such as carbon credits and associated markets, which should help close the gap between current market costs and benefits to carbon-neutral energy production in the future. In the March 2005 federal budget Canada introduced a program (The Renewable Power Production Initiative) to promote investment in renewable energy. This program provides 1 cent per kWH for eligible non-wind, renewable energy projects.

Two simple case studies are developed below to examine the required value of carbon credits for a direct harvest for a) dedicated direct-fired biomass electrical production in BC, and b) co-firing with coal in neighbouring Alberta. The models assume the carbon benefits from each of the systems is equal to the carbon emissions not released due to the reduction in fossil fuel use minus the carbon emissions arising from the collection and transport of the biomass feedstock. The metric used for this analysis is the \$/tonne value of CO_2, generated by the proposed facility that would make a decision-maker indifferent between the reference system and the proposed biomass facility. In order to complete this analysis the costs of producing energy from the biomass and the reference systems to be displaced must be fully accounted for.

Case Study 1 – Carbon Credit Values Required for Direct-Fired Electrical Production from Salvage-Harvested Pine.

This case study is based on direct-fired energy production using feedstock harvested solely for producing biomass energy. The costs for feedstock from the previous section (Table 3) are used in addition to energy production parameters developed from recent studies by the National Renewable Energy Laboratory (Bain et al. 2003, Spath and Mann 2000). The costs (pre-feedstock) are modeled here based on the parameters (capital costs and operating costs) given in that study, although converted to \$Cdn. The carbon credits that are generated from biomass energy production are based on displacing generation from a Combined-Cycle Natural Gas (CCNG) system (assumed to be the baseline, *or reference system*) on the basis of life cycle global warming potentials. The assumed costs for this reference system are those used by BC Hydro in their 2004 Integrated Electricity Plan (BC Hydro 2004), which form a cost range of 5.6 to 8.1 cents per kWh for average annual costs. The levelised costs of CCNG in the BCHydro analysis formed this range on the basis of size and the assumed future prices for natural gas. The cost estimates were replicated using the BCHydro assumptions at 250 and 500MW capacities and the estimated costs are closer to 5 cents kWh-1 using a natural gas price of \$4.80 GJ-1, a discount rate of 7.5% (real) and the BCHydro assumed operating and capital costs. The analysis is based on a biomass energy facility of 100 MW. It is further assumed that the location of this facility is such that the transport distances are the same as is the case for the representative (average) sawmill in the Prince George region, the underlying assumption in the transport costs used in Table 3. The key parameters for the two systems are outlined in Table 4.

The annualized costs for the biomass plant are approximately \$48 MWh^{-1} prior to the costs of delivered feedstock being included, and rise to \$124 MWh^{-1} using the feedstock costs derived in Table 3. This is substantially higher than for the reference natural gas system costs. The cost range used by BC Hydro for biomass power production is \$56 to \$190 MWh^{-1} (BC Hydro 2004(a)). Our estimate of \$124 MWh^{-1} falls close to the centre of this range. The value of carbon credits required to bring the biomass energy system costs to the \$56 to \$81 MWh^{-1} range for the CCNG reference is \$90.76 to \$143.72 per tonne CO_2. Sensitivity analysis estimating carbon credit values by varying feedstock costs and natural gas prices are summarised in Table 5.

Although the analysis examines the use of carbon credits as the instrument to narrow the cost gap between biomass and natural gas power generation, there are a host of instruments that can be used for this purpose including subsidies to collecting and/or transporting the feedstock or guaranteed price premiums for the electricity produced. It is clear the energy biomass from direct salvage requires financial assistance for any level of feedstock costs above zero in the absence of substantial increases in natural gas prices.

Case Study 2 – Carbon Credit Values Required for Feasible Transport and Co-firing Feedstock from Salvage-Harvested Pine.

The co-firing of biomass with coal in existing facilities is generally the low-cost option for electrical generation. This is an interesting opportunity for MPB fibre considering the *relatively* short distance from the Prince George region to the area west of Edmonton where the bulk of Alberta's coal generating capacity is located (approximately 780 km by road).

Table 4. Case study parameters – direct biomass energy from salvage harvest versus greenfield combined cycle natural gas (CCNG) energy.

	Biomass 100MW Plant	CCNG Reference > 59 MW
	Per MWh	
Emissions Associated Providing Feedstock (tonnes)	0.027[a]	0.125
Total GHG Emissions (tonnes)	0.027	0.499
Feedstock Costs ($)	75.8	n.a.
Total Generation Costs ($)	123.8	56 to 81

Notes:

[a] Based on emissions in Sambo 2002, for the Prince George region whole tree harvest and haul.

Any carbon sequestration associated with additional growth due to removing the standing dead pine is not included here. Biomass facility capacity use is 7000 hours. Wood is converted to energy at 1.33 MWh BDT^{-1}

Table 5. Sensitivity analysis on feedstock costs and carbon credit values ($ $tonne^{-1}$ CO_2) to make biomass energy from direct harvest competitive to CCNG reference.

Natural Gas Prices $ $mmbtu^{-1}$	Feedstock Costs in $ BDT^{-1} 0	25	50	75	100
	$ tonne CO_2				
5	-6.7	33.2	73.1	112.9	152.8
7	-33.1	6.8	46.7	86.6	126.5
9	-59.4	-19.5	20.0	60.3	100.2
11	-85.7	-45.8	-5.9	34.0	73.9
13	-139.3	-72.1	-32.2	7.7	47.6

Note: Shaded region indicates biomass energy is low cost option.

Alberta has in excess of 5,000 MW of capacity in coal-fired electrical plants. At 10% biomass use in co-firing, this would represent greater than 500 MW of wood-fired capacity, nearly equivalent to the total used in BC at this time. The second case study is harvesting salvage pine, chipping on-site and transporting directly to the coal plants in Alberta where the chips are co-fired with coal to produce electricity. The key parameters necessary for the analysis, and the sources of this data, are provided in Table 6.

The incremental costs of displacing coal (per MWh) are the delivered costs associated with three quarters of a tonne of chips, plus the annual capital costs of upgrading the plant to accept biomass, less the delivered costs of 0.468 tonnes of coal. The incremental costs of displacing coal with biomass feedstock using the parameters outlined in Table 6 would be $72.41 MWh^{-1}. Again, as in the previous section if we examine the costs of CO_2 credits necessary to make this an economically efficient alternative, it would be $71 $tonne^{-1}$ CO_2. Sensitivity analysis is again performed on these results varying the delivered cost of chips and the delivered coal price (see Table 7).

The combinations of coal prices and feedstock costs that generate negative values in the table indicate combinations where biomass co-firing lowers the overall generation costs of the electrical facilities. If feedstock can be delivered at $50 per BDt or less, and coal prices achieve $50 per tonne or more, displacing coal with biomass in these facilities would work with carbon credits at > $17 per tonne CO_2. Although such increases in delivered coal prices

Table 6. Case study parameters – co-firing salvage harvested with whole-tree chipping in existing Alberta thermal generating facilities.

	Biomass	Displaced Coal
	Per MWh	
Total GHG Emissions (tonnes)	0.046[a]	1.02[b]
Feedstock Required BDt	0.753	0.468[c]
Delivered Feedstock Costs ($)	85.51[d]	15.44[e]
Annualized Upgrading Costs ($)	2.08[f]	0

[a] Same as the estimate in Table 5 with the additional emissions associated with fuel use to move chips 780 km to Alberta.
[b] Life cycle emissions of thermal (coal) electrical production from Spath et al 1999.
[c] The 0.468 coefficient is the average coal per MWh for US thermal generation (EIA 2003).
[d] This is with the whole-tree system, chipped on-site and loaded into chip trucks for delivery in Alberta, thus the $17.16 BDt^{-1} to move feedstock to a central location from the previous case study is not incurred in this case. The overall transport costs are $43.03 BDt^{-1} to move the chips to Alberta (based on costs in Webb 2003).
[e] The delivered coal price is 33/tonne which is the value used by BCHydro 2004(b)
[f] This is the annualized costs of the capital upgrades to existing thermal facilities to co-fire with biomass. These are from Bain et al. 2003, and the total is $218.60 kW^{-1} of installed capacity

Table 7. Sensitivity analysis on coal costs and carbon credit values ($ $tonne^{-1}$ CO_2) to make salvage harvest, whole-tree chipping co-firing competitive to thermal (coal) reference.

Coal Costs $ $tonne^{-1}$	Feedstock Costs in $ BDT^{-1} 25	50	75	100
		$ tonne CO_2		
25	10	29	48	68
50	-2	17	36	56
75	-14	5	24	44
100	-26	-7	12	31

Note: Shaded region indicates biomass/thermal blend is low cost option.

seem excessive given historic prices, coal prices which set highs in 2004 may be indicative of the rapid increase in Chinese demands for metallurgical coal dragging along the relatively low-valued thermal coal.

In order to co-fire biomass on a large scale in Alberta's thermal power generation sector would require planning on feedstock streams "post-MPB". The region in which much of this thermal capacity is located in some of the best potential aforestation sites in the country. If contractual arrangements with local private landowners could be initiated to examine the potential to grow fibre for energy, and the costs were not prohibitive, the possibility for co-firing biomass and coal would be complemented.

6. Discussion

One of the more obvious barriers to biomass energy projects has been the competition from low cost natural gas combined cycle systems. Recent spikes in natural gas prices mean that biomass generation is cost competitive if feedstock is available for free. The problem is that standing biomass is spread across regions, especially in the context of the MPB, which results in high feedstock procurement and transport costs that drive energy production costs much higher than those based on natural gas. In addition, the pay back period to recover the costs of these facilities is a longer term (20 to 30 years) and the availability of MPB feedstock is almost certainly less than this. It appears unlikely that a new facility to produce energy from MPB fibre would be feasible without being able to extend or substitute with another fuel source after the (approximately) 15-year window.

If a large-scale project using MPB fibre is initiated, a strategy to phase-in the use of an alternative feedstock source would be required to substitute as the MPB fibre disappeared. One such example could be dedicated energy crops such as fast growing plantation fibre. For the case study of using MPB fibre for co-firing in Alberta thermal power plants, this would seem to be a logical extension, as sufficient land base and growing conditions exist for such plantations in the region of Alberta where most of the coal capacity is located. Strategies such as this, that involve using existing facilities, with lower capital requirements, and shorter pay back periods offer the greatest potential for a biomass energy option to capturing value from the post-MPB salvage.

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