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Biopower generation from mountain pine infested wood in Canada: An economical opportunity for greenhouse gas mitigation

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Abstract

Biomass is considered carbon neutral, and displacement of fossil fuel-based power by biomass-based power is one means to mitigate greenhouse gases. Large forest areas in British Columbia (BC), Canada, are infested by the mountain pine beetle (MPB). Dead wood from the infestation is expected to vastly exceed the ability of the pulp and lumber industry to utilize it; current estimates are that 200–600 million m^3 of wood will remain unharvested over the next 20 years. Regions where the damaged wood is not harvested will experience loss of jobs in the forestry sector, increased risk of forest fire hazard, carbon emissions from burned or decaying wood, and uncertainty about timing of replanting since this usually occurs at harvest. This paper reports the results of a detailed preliminary techno-economic analysis of producing power from MPB killed wood. Power plant size and location are critical factors affecting overall power cost. Overall cost of power rises steeply at sizes below 300 MW net power output. By locating the power plant in an area of high infestation, transportation distances can be minimized. A 300 MW power plant would consume 64 million m^3 of wood over a 20-year lifetime, and hence is a significant sink for otherwise unharvestable wood. Cost estimates are based on harvesting of whole dead trees with roadside chipping and transport to a central power plant located in either the Nazko or Quesnel regions of BC. A circulating fluidized bed boiler with a conventional steam cycle is a currently available technology demonstrated at 240 MW in Finland. The estimated power cost is $68 to $74 per MWh, which is competitive with other "green power" values in BC. Given recent values of export power in the Pacific Northwest, a 300 MW MPB power plant is viable with a carbon credit below $15 per tons of CO_2.

Keywords: Biomass power; Direct combustion; Power cost; Mountain pine beetle; Lodgepole pine

1. Background and overview

Mountain pine beetle (MPB) infestation of lodgepole pine is creating a crisis for the forestry industry of British Columbia (BC), Canada. An estimated 10 million hectares is currently infested, and models predict the ultimate volume of otherwise merchantable timber lost to MPB will be 960 million m^3 [1]. Some parts of Alberta have also been infected, and the potential exists for a trans-species jump to jackpine which would spread the infestation across Canada.

Regions where the damaged wood is not harvested will experience loss of jobs in the forestry sector with an impact on the viability of communities. Unharvested areas may not be replanted in a timely manner since replanting occurs shortly after harvest. The unharvested biomass is a fire hazard to regenerating species and hence a risk of even more future economic damage. This unharvested wood, if left to decay in the stands, would release carbon into the atmosphere. Using surplus MPB killed trees to generate power would contribute to Canada's efforts to reduce fossil carbon emissions while helping sustain the forestry industry in BC.

Many plants around the world burn biomass to make heat, power or a combination of the two. Many of these plants are based on mill residues, for example bark, sawdust and trimmings, and hence are built at a small size that reflects the source of the biomass. An example of this is the 65 MW plant in Williams Lake, BC that uses about

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600,000 tons of sawmill residue per year. California has 28 direct combustion biomass power plants with a generation capacity of 558 MW and an additional 70 MW of generating capacity from cofiring of municipal waste; many other plants are located across the US. Europe has many biomass power plants, including several using straw as a fuel [2–5].

Several authors have noted that the cost of power from a biomass-based plant is dramatically lower for plants as size increases, even up to 500 MW (see, for example, [6–9]); capital efficiency outweighs increased transportation cost, with the biomass yield per gross area being a critical determinant of optimum size [8]. However, because many biomass projects to date are constrained by mill residue supply or by their demonstration nature, only one plant over 100 MW has been built, the 240 MW Alholmens power plant in Pietarsaari, Finland capable of running on 100% coal or 100% biomass [10].

The objective of this study is a preliminary techno-economic assessment of using a portion of BC's surplus MPB killed pine to generate power. Based on a preliminary study [11], two plant sizes in each of two locations in BC were analyzed: gross generation of 330 (Case 1) and 240 (Case 2) MW at West Road/Nazko River (N) and Quesnel (Q). The 240 MW size is identical to the Alholmens plant, and the 330 MW size was chosen as a reasonable scale up. The Nazko location is remote and in an area of very high concentration of MPB stands; the Quesnel site is an existing urban area closer to construction and operating labor but with a somewhat lower gross density of MPB trees in the surrounding area [12]. Internal power consumption reduces net output to 300 MW and 220 MW. All cost factors from wood harvesting with replanting through delivery of the power to the main BC transmission grid are included in the estimated power costs below [13].

2. Biomass source and characteristics

The Province of British Columbia has a total land area of 94 million hectares. Timber productive forestland area is about 55% of the total land area. Timber productive volume for the province is about 10,595 million m^3 [14]. As of August 2003, the annual allowable cut for the province was about 74.4 million m^3/year of wood [15]. British Columbia's forest consists of both coniferous and deciduous tree species; coniferous species include lodgepole pine, Douglas fir, spruce, hemlock, cedar, and true firs. Lodgepole pine is most susceptible to MPB attack, with mature trees being most vulnerable because their larger diameter and thicker bark protects the beetle from predators. The beetles have a symbiotic relationship with the blue stain fungus, which actually causes the death of the tree [16]. Infestation leaves relatively dense stands of dead trees. Fig. 1 shows the study area and the two study locations. The yield of surplus MPB killed trees for 60 year or older lodgepole pine stands is estimated from reports and discussions with the BC Ministry of Forests and Range (MoFR) [12,17]. Actual amounts of MPB killed trees and the fraction that are surplus to existing forestry operations is under current re-evaluation within the MoFR, and yield figures may be adjusted in the future.

In this study we assume that MPB killed trees are cut and skidded to the roadside. At the roadside the whole tree is chipped and chips are transported to the plant by large chip vans; hence limbs and tops are recovered as fuel. In this study we have assumed a value of 20% for the residues, and hence actual yield is 25% higher than merchantable volume. The final average standing yield per gross hectare for lodgepole pine is estimated at 64.1 m^3 for the West Road/Nazko River location and 37.5 m^3 for Quesnel location. Gross hectares include all other land uses such as other forest species and non-forestland use.

3. Fuel properties

Moisture content of wood is one of the most important characteristics for its use as fuel. For a dead tree, water in the wood has a tendency to reach equilibrium with the surrounding air. The equilibrium moisture content (EMC) of wood stored outdoors is a function of the surrounding temperature and relative humidity of the air. In this study we estimated the EMC of the wood based on equations developed by W. Simpson of the United States Department of Agriculture Forest Service [18]. The temperature and relative humidity of Williams Lake, which is approximately in the center of the study area, are assumed to be representative of the study area. Based on 20 years of data [19], the estimated average daily temperature and relative humidity used in this study are 4.2 °C and 67.6%, respectively. The calculated value of EMC is 13% (dry basis); other assumed fuel properties are given in Table 1. The value of EMC has a critical impact on the available lower heating value (LHV) of the wood.

4. Scope and cost

Note: All currency figures in this report are expressed in 2004 Canadian dollars unless otherwise noted. Costs from the literature have been adjusted to the year 2004 using historical inflation rates; an inflation rate of 2% is assumed for 2005 and beyond. MW refers to electrical megawatts unless otherwise noted. Cost factors are developed in detail for each element of the scope [13].

4.1. Components of delivered cost of biomass

This study is based on the existing practices in the forest industry of western Canada including clear cutting and skidding of whole trees to the edge of the logging road. Trees are drawn from throughout the long-term harvest area, giving a constant average transportation distance to the power plant over the life of the plant. Trees are cut by a feller-buncher, moved to the side of a logging road by a grapple skidder, chipped and loaded into 48 foot trailers