GHG Impacts of Pellet Production from Woody Biomass Sources in BC, Canada

Summary

This case study quantifies the greenhouse gas (GHG) impacts of manufacturing wood pellets, transporting them to Europe, US and Canada, and replacing fossil fuels in these markets. It also assesses long-term potential biomass supply from mill residues, trees killed by the Mountain Pine Beetle (MPB) infestation, and afforestation, to support pellet plant development in British Columbia (BC) Canada.

A reference case, which reflects fossil fuel usage in a European coal power plant and North American heating applications, has GHG emissions of 235 000 t CO₂e in 2006, including 205 000 t CO₂e from the power plant and 12 000 t CO₂e from heating. A project, to build and operate a pellet plant and substitute pellets for fossil fuels, has emissions of 22 000 t CO₂e in 2006, including 10 000 t CO₂e to build the plant, 2 600 t CO₂e annually to operate it, and 5 700 t CO₂e annually for ocean shipping of pellets. The project reduces net GHG emissions by 213 000 t CO₂e in 2006. The net carbon (C) stock change from mill residues is zero since they are incinerated in the base case and burned for energy in the project. Afforestation increases C stocks, while MPB harvesting reduces C stocks. The net of fossil fuel GHG emissions, CH₄ and N₂O emissions, and C stock changes is to reduce GHG emissions by 307 000 t CO₂e in 2006 (Bradley, 2006).
Scope

The objectives are to assess long-term supply of biomass for BC pellet plants, and to quantify GHG impacts of building and operating a pellet manufacturing plant. The study considers three biomass sources, all of interest to the forest industry, governments, communities undergoing economic hardship and NGOs:

- **Mill Residue**: BC has considerable surplus sawdust, shavings and bark from sawmills and pulp mills, currently incinerated in beehive burners, thus wasting bioenergy fuel (Bradley, McCloy, 2004).
- **Standing Deadwood**: Dead wood as a result of MPB, which by 2004 infested 7 million hectares, will be a major fire hazard and economic value will be lost unless utilized for bioenergy.
- **Afforestation Fibre**: The Canadian Forest Service (CFS) is assessing potential for afforestation of hybrid poplar for long-term fibre supply.

The project assumes:

- One-time emissions from construction of a pellet plant in William’s Lake BC
- Annual emissions from fossil fuel to transport sawmill residues to the plant; to harvest, chip and transport MPB standing deadwood and afforestation wood; to manufacture pellets; transport them by rail to the port of Vancouver and by ship to Rotterdam, and by rail to markets in the US and Canada
- \( \text{CH}_4/\text{N}_2\text{O} \) emissions from burning biomass to dry pellets
- C stock changes of burning biomass in the pellet plant and pellets for energy, harvesting MPB wood, and growth and harvest of afforestation fibre

The plant is modeled on an existing pellet plant, Premium Pellet Ltd. of Vanderhoof BC, which produces 132 000 BDt (Bone dry tonnes = oven dry tones) pellets annually. The case considers a similar plant constructed at William’s Lake in central BC, which has numerous sawmills that can supply surplus residue, as indicated by the circles in Figure 1. William’s Lake, at the southern end of the area infested with MPB, has this supply at close proximity. In addition, nearby tracts of land identified by the Canadian Forest Service are appropriate for afforestation.

Plant feedstock is shown in Figure 2. 168 000 BDt wood residues are needed annually, of which 36 000 BDt are used as fuel to dry 132 000 BDt, which are made into pellets. The main source is low-cost residue from nearby sawmills, of which there was 1.2 million BDt annual surplus in 2004. Trees killed by MPB will be the next major supply, followed by afforestation fibre in the long-term.

Illustrated in Table 1, three markets for pellets are considered; co-firing in a Netherlands coal power plant, home heating in BC, Alberta and Saskatchewan and pulp and paper mills in BC to replace natural gas, and heating applications in California also to replace natural gas.

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**Methodology**

The study compares GHG emissions and C stock changes of a base (reference) case with a project. The base case includes:

- Annual emissions from: mining and transporting coal to the power plant, burning coal for power production, producing and burning natural gas for industry and home heating applications, and \( \text{CH}_4/\text{N}_2\text{O} \) emissions by incinerating bark
- C stock changes from incineration of sawmill residues and decay of a MPB infested stand

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![Figure 1. Plant Location at William’s Lake BC (Yellow indicates size of sawmill)](image1)

![Figure 2. Pellet Mill Feedstock](image2)
A 600 MW coal power plant can burn biomass in the boiler, reducing GHG emissions. The power plant will use 127,000 t pellets in 2006 with a heat value of 19.8 GJ/t, for a total of 2,515 TJ. Since coal is 27.56 GJ/t, the pellets will displace 91,240 tonnes of coal. At 2.25 t CO₂e per tonne of coal for a conventional boiler, plant emissions are 205,000 t CO₂e. Based on 0.1 t CO₂e/t coal produced, emissions from producing coal are 1,000 t CO₂e. Transferring coal on average 10,000 km emits 3,400 t CO₂e annually based on 400 tonnes marine heavy fuel oil per shipload, 2.67 loads and a factor of 3.14 t CO₂e/t oil.

5,000 t of pellets are sold in Canada in 2006, while sales reach 20,000 t in Canada and 10,000 t in the US by 2012. 5,000 t pellets is 99,000 GJ. Using 0.117 t CO₂e/GJ for natural gas, 2006 emissions for North America are 11,600 t CO₂e. 168,000 BDt of mill residues are incinerated annually in beehive burners. CO₂ emissions from burning biomass are not counted, while CH₄ and N₂O emissions are. Emission factors in BC for burning wood waste are 0.00015 tCH₄/BDt waste and 0.00016 t N₂O/BDt waste, for a GHG emission of 13,500 t CO₂e.

Assuming Canada includes the managed forest in carbon accounting, the base case must include carbon stock changes from decaying trees killed by MPB, covered below.

### Reference Case

### Project Case

For plant construction an emission factor of 636 t CO₂e per $1 million invested is used, thus a $15.5 million capital cost equates to emissions of 9,900 t CO₂e.

In the manufacturing process 1,650 MW are used monthly to run electric motors to convey biomass. In BC, new incremental power will be mostly from renewable sources. We assume 85% renewable with no GHG emissions, and 15% coal (750 t CO₂e/GWh), for an average emission of 112 t CO₂e/GWh, or 2,300 t CO₂e annually. To sustain the dust burner flame, the plant utilizes 6,000 GJ of natural gas annually. Using factors of 34.9 GJ per 1,000 m³ gas and 724 t carbon per kt gas, emissions are 300 t CO₂e. Thus plant emissions are 2,600 t CO₂e. The plant also burns 36,000 BDt of biomass to dry pellets. Using the same NH₃/N₂O factors as above, the plant emits 2,900 t CO₂e as NH₃ and N₂O.

The plant is built beside a sawmill. 66,000 BDt of sawdust is blown from the sawmill planer and 102,000 BDt is trucked in from other sawmills with an average distance of 46 km. 36,000 BDt comes by B-train and 66,000 BDt by diesel Van, with emissions of 0.016 t CO₂e per carload, or 124 t CO₂e in 2006. Pellets for the US travel by rail on average 1,000 km. Pellets for Canada travel by truck at 28 BDt/load, with emissions of 80 t CO₂e.

### Table 1. Target Markets (kBDt)

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<td>5</td>
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<td>10</td>
<td>10</td>
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<td>US West</td>
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<td>10</td>
<td>10</td>
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<td>132</td>
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### Table 2. Biomass and Emissions from 2004 Infestation followed by harvest 2007–16

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<tr>
<th>Biomass</th>
<th>(Bdt/ha)</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<td>368.4</td>
<td>360.4</td>
<td>353.0</td>
<td>346.3</td>
<td>340.2</td>
<td>334.7</td>
<td>329.8</td>
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<td>Project</td>
<td>368.4</td>
<td>346.7</td>
<td>327.2</td>
<td>309.8</td>
<td>294.3</td>
<td>280.5</td>
<td>286.4</td>
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<td>Harvest</td>
<td>13.7</td>
<td>12.1</td>
<td>10.7</td>
<td>9.4</td>
<td>8.2</td>
<td>7.2</td>
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<tr>
<td>Harvest Stock change (tCO₂e/ha)</td>
<td>25.1</td>
<td>22.3</td>
<td>19.6</td>
<td>17.3</td>
<td>15.1</td>
<td>13.1</td>
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<td>Biomass Need</td>
<td>(MBdt)</td>
<td>20.0</td>
<td>40.0</td>
<td>55.5</td>
<td>55.5</td>
<td>55.5</td>
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<tr>
<td>Change in C Stock (ktCO₂e)</td>
<td>-38.7</td>
<td>-73.3</td>
<td>-101.7</td>
<td>-101.7</td>
<td>-101.7</td>
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<tr>
<td>Fossil Fuel Emissions (ktCO₂e)</td>
<td>1.7</td>
<td>3.4</td>
<td>4.7</td>
<td>4.7</td>
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### Table 3. Afforestation Fibre Supply

<table>
<thead>
<tr>
<th>Harvest – needed (1000 m²)</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tr>
<td>Harvest – modeled (1000 m²)</td>
<td>15.6</td>
<td>31.1</td>
<td>46.7</td>
<td>109.0</td>
<td>140.0</td>
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<td>Harvest area – needed (ha)</td>
<td>88</td>
<td>176</td>
<td>352</td>
<td>616</td>
<td>979</td>
<td></td>
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<tr>
<td>Harvest area – modeled (ha)</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>700</td>
<td>900</td>
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</tbody>
</table>

### Figure 3. Cumulative CO₂e per Hectare and year (stand age)
As shown in Figure 2, harvesting MPB biomass will commence in 2007 at 20,000 BD t, rising to 55,500 BD t in 2009. MPB attacks mature pine trees with thick bark. The MPB population has undergone an unprecedented explosion in BC, spreading to over 7 million ha in 2004. By the projected peak in 2008 an estimated 450 million m$^3$ will be dead. It is estimated that 200 million m$^3$ will be available for bioenergy in 2004–07 alone (Kumar et al., 2005).

Three years after the leaves turn red there is a high risk of fire, however the dynamics of fire in the MPB forest is still subject to speculation and therefore the benefits of harvesting before it burns are not taken into account here.

The Gorcam Model was used to compare impacts of MPB on all relevant carbon pools, including above-ground biomass, roots, litter, and soils. Stands affected by MPB are assumed to be 60% Pine and 40% Douglas Fir and Spruce, with MPB only affecting the Pine. In each stand 80% of the pine is killed (Woodrising Consulting, 2005). In the base case the stand decays according to a pest decay rate from the Canadian Forest Service (CFS) (Kurz et al., 1992) and standing deadwood hinders new growth, however eventually the stand regenerates. The project case assumes MPB infestation in the base case and project until harvest begins in the project. Though there is 360 BD t/ha of biomass per ha in 2007, only 13.7 BD t is harvested since so much of the biomass is woody debris, foliage or in soils. In 2008 harvesting 40,000 BD t will result in a stock change of 73,333 t CO$_2$e and GHG emission of 3,384 t CO$_2$e from harvest operations.

The data considers establishment of plantations annually over 20 years starting in 1998. Plantings are identical to the required annual hectares needed in 2013+, based on harvest at age 16. Cumulative carbon stock in each pool is shown in Figure 3 (Yemshanov et al, 2006). C stock in trees reaches 42 t CO$_2$e in year 18, leveling off as new growth matches biomass harvested. Foliage and branches, roots, standing deadwood and dead organic matter remain on the site and decay over time. More carbon is stored in non-tree than tree carbon pools, reaching 140 t CO$_2$e after 23 years. Carbon balances are shown in Table 4.

### Table 4.

<table>
<thead>
<tr>
<th>GHG Emissions</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tr>
<td>CO$_2$e Emissions from Fossil Fuel &amp; Incineration</td>
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<tr>
<td>Base Case (Coal fired Power Plant Gas Heating)</td>
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<tr>
<td>Bark pile incineration CH$_4$, N$_2$O</td>
<td>13.55</td>
<td>11.94</td>
<td>10.32</td>
<td>9.08</td>
<td>9.08</td>
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<td>Gas Heating (incl. Gas Production)</td>
<td>11.61</td>
<td>23.21</td>
<td>46.42</td>
<td>46.42</td>
<td>46.42</td>
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<tr>
<td>Coal Production</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
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<td>Coal Transport (at 10,000 km)</td>
<td>3.36</td>
<td>3.36</td>
<td>3.36</td>
<td>3.36</td>
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<td>Coal burned in Power Plant</td>
<td>205.36</td>
<td>197.27</td>
<td>181.10</td>
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<td>Total Baseline emissions</td>
<td>234.85</td>
<td>236.76</td>
<td>242.19</td>
<td>240.94</td>
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<td>Project (Build pellet plant supply pellets to power plant for cofiring and gas substitution)</td>
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<tr>
<td>FF – Build pellet plant</td>
<td>9.87</td>
<td>0</td>
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<td>Truck Mill residue to pellet plant</td>
<td>0.61</td>
<td>0.49</td>
<td>0.37</td>
<td>0.28</td>
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<td>Process &amp; Truck MPB fibre to plant</td>
<td>0.58</td>
<td>1.16</td>
<td>1.61</td>
<td>1.61</td>
<td>1.61</td>
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<tr>
<td>Process &amp; Truck Afforestation fibre to plant</td>
<td></td>
<td></td>
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<tr>
<td>Pellet Manufacturing – gas &amp; power (CO$_2$)</td>
<td>2.57</td>
<td>2.57</td>
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<tr>
<td>Pellet drying (CH$_4$, N$_2$O)</td>
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<td>2.90</td>
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<td>Rail – pellets to port</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
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<td>Rail – pellets to US North West</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
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<td>Truck pellets Alta and BC</td>
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<td>0.08</td>
<td>0.16</td>
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<td>Ocean Transport (Van-Rotterdam)</td>
<td>5.73</td>
<td>5.50</td>
<td>5.05</td>
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<tr>
<td>Barge to Power plant</td>
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<tr>
<td>Total Project emissions</td>
<td>21.88</td>
<td>12.25</td>
<td>12.34</td>
<td>12.67</td>
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<tr>
<td>Net Fossil Fuel Emissions</td>
<td>-212.97</td>
<td>-224.51</td>
<td>-229.85</td>
<td>-228.25</td>
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### Stock Changes

1) **Mill Residues**

Baseline (incinerated): 308.00 308.00 308.00 308.00 308.00

Case (burned for energy): 308.00 308.00 308.00 308.00 308.00

Net Stock Change 0 0 0 0 0

2) **Mountain Pine Beetle fibre**

Stock Change MPB fibre 0 -36.67 -73.33 -101.69 -101.69

3) **Afforestation fibre**

Baseline (No Afforestation) 0 0 0 0 0

Project 93.61 122.99 146.80 167.06 186.56

Net Stock Change 93.61 86.32 73.47 65.38 84.87

Results

Table 4 summarizes net GHG emissions and C stock changes. In the base case, mining and transporting coal, running the coal power plant and natural gas heat applications in North America, and incinerating bark in BC incur emissions of 235,000 tCO₂e in 2006. In the project, constructing and operating the plant, trucking in mill residues, MPB biomass and afforestation fibre, transporting pellets to port and North American consumers, and shipping pellets to Europe cause emissions of 22,000 tCO₂e. The project reduces GHG emissions by 213,000 tCO₂e in 2006.

In the base case mill residues are incinerated and C stocks decline by 308,000 tCO₂e, however in the project C stocks decline an equal amount since all residues are burned for energy either in the pellet plant or the power plant. For MPB biomass, the loss in carbon stock averages 101,700 tCO₂e at peak harvest in 2009. With afforestation, tree growth as a result of plantings begun in 1998 results in a C stock increase of 94,000 tCO₂e in 2006. Cumulative C stock continues to rise. When harvest begins in 2013, annual tree carbon loss from harvest is offset with carbon uptake in the remaining trees so that stem carbon is essentially in equilibrium. However, overall carbon stock continues to grow, primarily in dead organic matter, including soils.

The net of GHG emission reductions and stock changes is a 307,000 tCO₂e in 2006, or 1.83 tCO₂e per tonne biomass used. The Dutch power plant yields 1.8 MWh/t pellets, thus emission reductions are 1.3 tCO₂e/MWh.

Acknowledgements

The case was reviewed by Ken Byrne, Terry Hatton, Kimberly Robertson and Andre Faaij of Task 38. Modeling work by Neil Bird of Woodrising Consulting and D. Yemshanov and D. McKenney of the Canadian Forest Service is gratefully acknowledged. The study was funded by IEA Bioenergy Task 38 participation fees.

Discussion

While the project results in considerable GHG emission reductions, the project proponent owns few of them. The plant owner actually causes emissions by manufacturing and transporting pellets. Contrastingly, the power plant owner would receive 205,000 in Emission Reduction Credits now valued at €20/tCO₂e, and also would receive a feed-in-tariff of €6.4/KWh for production of power in the Netherlands from renewable sources. The owner of the afforestation project would get credit for carbon stock changes under the Kyoto Protocol, which will have value when the Canadian Offset Trading System is implemented.

As of May 2006, Canada has not decided whether to include the managed forest for carbon accounting nor has it established forest carbon ownership. Although harvesting MPB stands for energy is sensible, opting to include the managed forest will require an entity to absorb the C stock loss from harvesting MPB trees. Canada will establish whether MPB harvesting reduces fire losses.

While selling pellets in North America reduces transportation costs, the impact of EU ERCS and feed-in-tariffs likely will continue draw pellets into the European market.

The full report can be downloaded from the Joanneum website (www.joanneum.at/iea-bioenergy-task38/projects/task38casestudies/can2-fullreport.pdf) or the website of the author at www.climatechangesolutions.net

References

Canada’s Greenhouse Gas Inventory 1990–98 – Final Submission to the UNFCCC Secretariat – Aug 2000
IEA Bioenergy Task 38

IEA Bioenergy (www.ieabioenergy.com) is an international collaborative agreement, set up in 1978 by the International Energy Agency (IEA) to improve international cooperation and information exchange between national bioenergy research, development and demonstration (RD&D) programs. IEA Bioenergy aims to realize the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, thereby providing a substantial contribution to meeting future energy demands.

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IEA Bioenergy Task 38 brings together the work of national programs in 13 participating countries on GHG Balances for a wide range of biomass systems, bioenergy technologies and terrestrial carbon sequestration. As one example of work, case studies have been conducted by applying the standard methodology developed by the Task 38. The case studies have assessed and compared GHG balances of different bioenergy and carbon sequestration projects in the participating countries, and the Canadian case study is one example.

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