IEA Bioenergy

Task 38

Greenhouse Gas Balances of Biomass and Bioenergy Systems

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

Wood pellets – Missouri photo gallery

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.

Amer Power plant, Essent Energy, Netherlands; courtesy of Essent Energy

Unloading pellets at Essent Energy Amer power plant; courtesy of Doug Bradley

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 CO_2e in 2006, including 205 000 t CO_2e from the power plant and 12 000 t CO_2e from heating. A project, to build and operate a pellet plant and substitute pellets for fossil fuels, has emissions of 22 000 t CO_2e in 2006, including 10 000 t CO_2e to build the plant, 2 600 t CO_2e annually to operate it, and 5 700 t CO_2e annually for ocean shipping of pellets. The project reduces net GHG emissions by 213 000 t CO_2e 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, CH_4 and N_2O emissions, and C stock changes is to reduce GHG emissions by 307 000 t CO_2e in 2006 (Bradley, 2006).

Ocean vessel; US Army Corps of Engineers

Premium Pellet Inc pellet plant, Vanderhoof, BC; courtesy of Norm Avison

Doug Bradley
Climate Change Solutions

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.

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 CH_4/N_2O emissions by incinerating bark
- C stock changes from incineration of sawmill residues and decay of a MPB infested stand

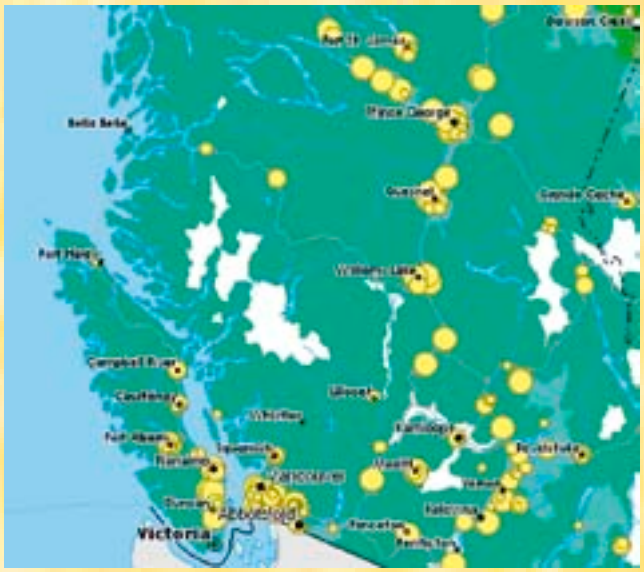

Figure 1. Plant Location at William's Lake BC (Yellow indicates size of sawmill)

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
- CH_4/N_20 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.

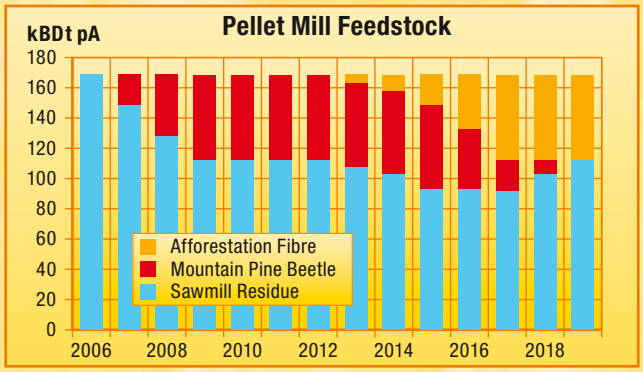

Figure 2. Pellet Mill Feedstock

Reference Case

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 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 coal. At 2.25 t CO_2e per tonne coal for a conventional boiler, plant emissions are 205 000 t CO_2e. Based on 0.1 t CO_2e/t coal produced, emissions from producing coal are 1 000 t CO_2e. Transporting coal on average 10 000 km emits 3 400 t CO_2e annually based on 400 tonnes marine heavy fuel oil per shipload, 2.67 loads and a factor of 3.14 t CO_2e/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 CO_2e/GJ for natural gas, 2006 emissions for North America are 11 600 t CO_2e. 168 000 BDt of mill residues are incinerated annually in beehive burners. CO_2 emissions from burning biomass are not counted, while CH_4 and N_2O emissions are. Emission factors in BC for burning wood waste are 0.00015 t CH_4/BDt waste and 0.00016 t N_2O/BD t waste, for a GHG emission of 13 500 t CO_2e.

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.

Table 1. Target Markets (k BDt)

Markets	2006	2007	2008	2009	2010	2011	2012
Europe	127	122	112	112	112	112	102
Canada	5	5	10	10	10	10	20
US West	0	5	10	10	10	10	10
Total	**132**	**132**	**132**	**132**	**132**	**132**	**132**

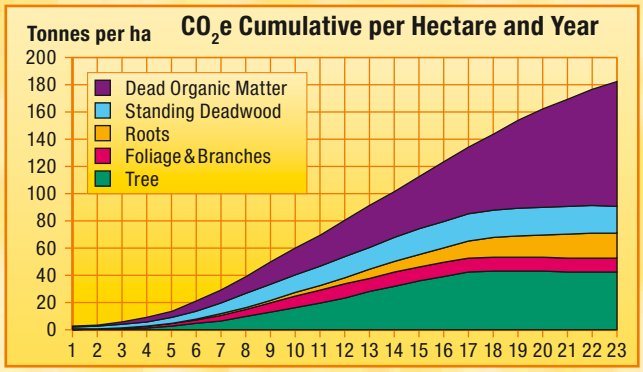

Figure 3. Cumulative CO_2e per Hectare and year (stand age)

Project Case

For plant construction an emission factor of 636 t CO_2e per $ million invested is used, thus a $ 15.5 million capital cost equates to emissions of 9 900 t CO_2e.

In the manufacturing process 1 650 MWh 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 CO_2e/GWh), for an average emission of 112 t CO_2e/GWh, or 2 300 t CO_2e 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 m^3 gas and 724 t carbon per kt gas, emissions are 300 t CO_2e. Thus plant emissions are 2 600 t CO_2e. The plant also burns 36 000 BDt of biomass to dry pellets. Using the same NH_4/N_2O factors as above, the plant emits 2 900 t CO_2e as NH_4 and N_2O.

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 600 t CO_2e. Pellets destined for Europe are transported 540 km to Vancouver on 100-tonne rail cars with emissions of 0.1 t CO_2e per carload, or 124 t CO_2e 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 CO_2e.

Table 2. Biomass and Emissions from 2004 Infestation followed by harvest 2007–16

Biomass (Bdt/ha)	2006	2007	2008	2009	2010	2011	2012
Base Case	368.4	360.4	353.0	346.3	340.2	334.7	329.8
Project	368.4	346.7	327.2	309.8	294.3	280.5	268.4
Harvest		13.7	12.1	10.7	9.4	8.2	7.2
Harvest Stock change (tCO_2e/ha)		25.1	22.3	19.6	17.3	15.1	13.1
Biomass Need (MBdt)		20.0	40.0	55.5	55.5	55.5	55.5
Change in C Stock (ktCO_2e)		-36.7	-73.3	-101.7	-101.7	-101.7	-101.7
Fossil Fuel Emissions (ktCO_2e)		1.7	3.4	4.7	4.7	4.7	4.7

Table 3. Afforestation Fibre Supply

	2013	2014	2015	2016	2017	2018
Harvest – needed (1000 m^3)	12.5	25.0	50.0	87.5	139.0	139.0
Harvest – modeled (1000 m^3)	15.6	31.1	46.7	109.0	140.0	140.0
Harvest area – needed (ha)	88	176	352	616	979	979
Harvest area – modeled (ha)	100	200	300	700	900	900

BC afforestation site; courtesy of Doug Bradley

As shown in Figure 2, harvesting MPB biomass will commence in 2007 at 20 000 BDt, rising to 55 500 BDt 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 2004 with harvest beginning in 2007 over 10 years. Table 2 shows changes in biomass and C stocks per hectare, and net emissions. Biomass loss is identical in the base case and project until harvest begins in the project. Though there is 360 BDt/ha of biomass per ha in 2007, only 13.7 BDt is harvested since so much of the biomass is woody debris, foliage or in soils. In 2008 harvesting 40 000 BDt will result in a stock change of 73 333 t CO_2e and GHG emission of 3 384 t CO_2e 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_2e 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_2e after 23 years. Carbon balances are shown in Table 4.

Table 4.

GHG Emissions					(kt CO_2e)
	2006	**2007**	**2008**	**2009**	**2010**
CO_2e Emissions from Fossil Fuel & Incineration					
Base Case (Coal fired Power Plant Gas Heating)					
Bark pile incineration CH_4 N_2O	13.55	11.94	10.32	9.08	9.08
Gas Heating (incl. Gas Production)	11.61	23.21	46.42	46.42	46.42
Coal Production	0.98	0.98	0.98	0.98	0.98
Coal Transport (at 10 000 km)	3.36	3.36	3.36	3.36	3.36
Coal burned in Power Plant	205.36	197.27	181.10	181.10	181.10
Total Baseline emissions	234.85	236.76	242.19	240.94	240.94
Project (Build pellet plant supply pellets to power plant for cofiring and gas substitution)					
FF – Build pellet plant	9.87	0	0	0	0
Truck Mill residue to pellet plant	0.61	0.49	0.37	0.28	0.28
Process & Truck MPB fibre to plant		0.58	1.16	1.61	1.61
Process & Truck Afforestation fibre to plant	(begins in 2013)				
Pellet Manufacturing – gas & power (CO_2)	2.57	2.57	2.57	2.57	2.57
Pellet drying (CH_4 N_2O)	2.90	2.90	2.90	2.90	2.90
Rail – pellets to port	0.12	0.12	0.11	0.11	0.11
Rail – pellets to US North West		0.01	0.02	0.02	0.02
Truck pellets Alta and BC	0.08	0.08	0.16	0.16	0.16
Ocean Transport (Van-Rotterdam)	5.73	5.50	5.05	5.05	5.05
Barge to Power plant	assume immaterial				
Total Project emissions	21.88	12.25	12.34	12.67	12.67
Net Fossil Fuel Emissions	-212.97	-224.51	-229.85	-228.25	-228.25
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					
Base Case (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
Net Emissions	-306.58	-310.83	-303.32	-293.62	-313.12

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 t CO_2e 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 t CO_2e. The project reduces GHG emissions by 213 000 t CO_2e in 2006.

In the base case mill residues are incinerated and C stocks decline by 308 000 t CO_2e, 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 t CO_2e 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 t CO_2e 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 t CO_2e in 2006, or 1.83 t CO_2e per tonne biomass used. The Dutch power plant yields 1.8 MWh/t pellets, thus emission reductions are 1.3 t CO_2e/MWh.

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/t CO_2e, 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

Bradley D 2006. GHG Impacts of Pellet Production from Woody Biomass Sources in BC, Canada – May 24 2006. Web accessible at www.joanneum.at/iea-bioenergy-task38/projects/task38casestudies/can2-fullreport.pdf

Bradley D and McCloy B. 2004. Estimated Production, Consumption and Surplus Mill Wood Residues in Canada – A National Report, Natural Resources Canada and FPAC – Aug 2005.

Kumar A, Sokhansanj S et al. 2005. British Columbia's Beetle Infested Pine: Biomass Feedstocks for Producing Power – April 2005. For BIOCAP and the Province of BC

Kurz W and Apps M. 1992. A 70-year Retrospective Analysis of Carbon Fluxes in the Canadian Forest Sector. Ecological Applications 9 (2) 1999, pp 526–547, section Dead organic matter dynamics.

Kurz W, Apps M et al. 1992. The Carbon Budget Model of the Canadian Forest Sector: Phase 1 – Forestry Canada 1992, Inf. Rep. NOR X-326 – pages 21–30.

Woodrising Consulting. 2005. Canadian Case Study on Mountain Pine Beetle (MPB) Infested Pine in BC 2005-08–09

Yemshanov D and McKenney D. 2006. Bioenergy Plantations Case Study: Williams Lake (BC) – Internal Report for CFS, May 2006.

Canada's Greenhouse Gas Inventory 1990–98 – Final Submission to the UNFCCC Secretariat – Aug 2000

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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.

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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