CLIMATE CHANGE SOLUTIONS
"CONSULTING IN STRATEGY, ISSUES, MECHANISMS"

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

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Fig 1. Wood Pellet Plant- Premium Pellet- Vanderhoof BC

1. Summary

This case study quantifies the GHG impacts over 15 years of a project involving different supply options for a wood pellet manufacturing plant in British Columbia (BC) Canada. It also assesses whether there is a sufficient long-term supply of surplus fibre to warrant investment in pellet plants in the province. The biomass supply mix includes mill residues, fibre from trees killed by the Mountain Pine Beetle (MPB) infestation, and afforestation fibre. The study also quantifies the GHG impacts of manufacturing the pellets, transporting them in Canada, to Europe and the US, and replacing fossil fuels in these markets.

The study reflects emission reductions from fossil fuels, and stock changes in biomass carbon pools. The **base case** includes GHG emissions from a coal-fired power plant in the Netherlands and heating applications in North America, methane and N_20 emissions from residue incineration, and stock changes in decaying stands in BC as a result of mortality from MPB. The **project** includes emissions from building a wood pellet plant, transporting fibre from the above sources to the plant, manufacturing wood pellets and transporting the pellets to market, and reflects carbon stock increases from afforestation. For illustrative purposes only, the case reflects that Canada includes the managed forest in its Kyoto accounting, and thus includes stock impacts of harvesting MPB trees.

The base case has GHG emissions of 235,000 tCO_2e in 2006, including the coal power plant (205,000 tCO_2e) and North American heating applications (12,000 tCO_2e). Project emissions in 2006 are 22,000 tCO_2e, including a one-time emission of 10,000 tCO_2e to build the pellet plant. 12,000 tCO_2e annual emissions include fossil fuel emissions of 2,600 tCO_2e to operate the plant, 5,700 tCO_2e for ocean shipping of pellets to Rotterdam, and 2,900 tCO_2e in methane and N_2O emissions to burn residues to dry pellets. The net impact of the project is to reduce GHG emissions by 213,000 tCO_2e in 2006.

Changes in carbon stock of the forest and the wood products associated with the forest must be reflected in net emissions. The net C stock change from mill residues is zero since residues are incinerated in the base case and burned for energy in the project. C stock increases from afforestation vary each year, but average 172,000 tCO_2e annually over 15 years. C stock changes from MPB harvesting, relevant only if Canada opts to include the managed forest in its carbon accounting, average 51,000 tCO_2e in C stock reductions annually. The net of fossil fuel GHG emissions, CH_4 and N_2O emissions, and carbon stock changes is to reduce net GHG emissions by 307,000 tCO_2e in 2006, or 1.83 tCO_2e/tonne biomass used.

While the project results in considerable reduction in GHG emissions, few of them are actually credited to the project proponent. The pellet plant owner actually causes emissions of 11,000 tCO_2e, while the owner of the power plant is credited with just less than 200,000 tCO_2e emission reductions annually due to fuel substitution. The operator of the afforestation initiative has emission reductions, while the entity harvesting Mountain Pine Beetle fibre must account for net emissions.

2. Scope

The objective of this study is to compare GHG impacts of different supply options for a wood pellet manufacturing plant, and also to assess whether there is a sufficient long-term supply of surplus fibre to warrant investment in pellet plants in the province of British Columbia (BC) Canada. The case also reflects GHG impacts of manufacturing the pellets, transporting them in Canada and to Europe and the US, and replacing fossil fuels in these markets. The case is viewed over 20 years.

The study considers three woody biomass sources of extreme interest to stakeholders, including forest industry, governments, communities in economic difficulty and NGOs:

- Mill Residue: BC has considerable surplus sawdust, shavings and bark from sawmills and pulp mills. The approved method of disposal is incineration in beehive burners, thus wasting a considerable amount of bioenergy fuel.
- Standing Deadwood: Critical to BC is the fate of standing deadwood as a result of the Mountain Pine Beetle (MPB), which as of 2004 has infested 9 million hectares of forest in BC. This wood will be a major fire hazard and it's economic value will not be realized unless it can be utilized for bioenergy or other bio-products.
- Afforestation Fibre: The Canadian Forest Service (CFS) is assessing potential for afforestation of hybrid poplar for long-term fibre supply.

The base case is primarily burning fossil fuel in coal-fired power plants in the Netherlands. This base case considers the following:

- GHG emissions from mining and transporting coal to the power plant
- GHG emissions of burning the coal for power production
- GHG emissions to produce natural gas and burn it in residential and industrial heating applications in the US and Canada's western provinces
- CH_4 and N_2O emissions from bark incineration in beehive burners
- Stock changes from the forest; continued incineration of sawmill residues in BC, projected decay of a MPB infested stand, and no afforestation

The project assumes the following

- One-time GHG emissions from construction of a 168 TPD (tonne per day) pellet plant in William's Lake BC
- GHG emissions from fossil fuel used to truck sawmill residues to the plant
- GHG emissions from harvesting, chipping and transporting standing deadwood as a result of the MPB infestation
- GHG emissions from harvesting and transporting afforestation wood
- GHG emissions from fossil fuels used in the manufacture of pellets
- CH_4 and N_2O emissions from burning biomass to dry the pellets
- Emissions to transport the pellets by rail to Vancouver and by ship to Rotterdam, by rail to the US Northwest, and by truck to Canada's western provinces
- Stock changes from the forest; including burning mill residues in the pellet plant, harvesting MPB wood, and growth and subsequent harvest of afforestation fibre

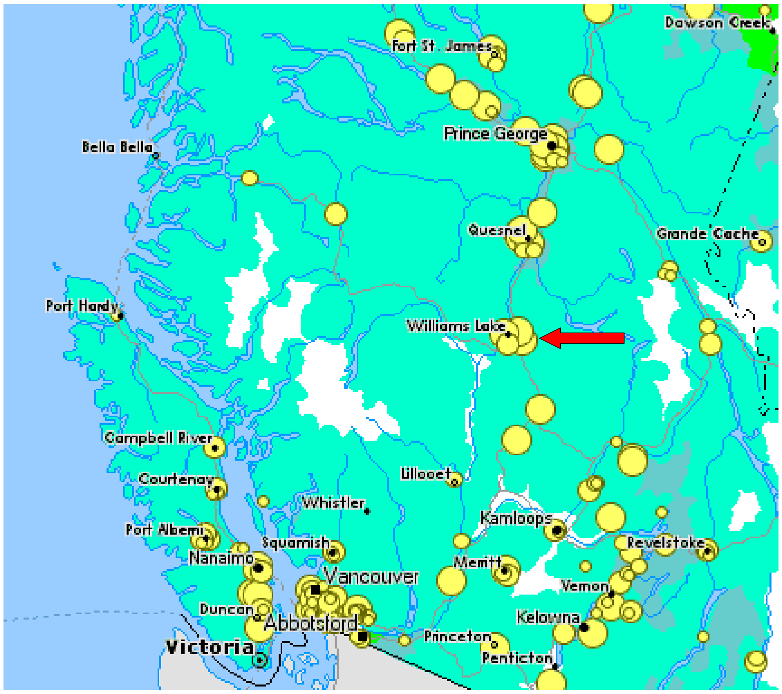
Gelöscht:

3. Methodology

The plant is modeled on an existing pellet plant, Premium Pellet Ltd of Vanderhoof BC. The Vanderhoof plant produces 132,000 BDt pellets per year[1]. For feedstock, 5,500 BDt[2]/month of sawdust are blown in from the planer in an adjacent sawmill, while 8,500 BDt/mo are trucked in from other mills. It is common for pellet plants to obtain a portion of feedstock from an adjacent sawmill. An additional 3,000 BDt of wood dust and sawdust are burned to dry the remaining feedstock for pelletizing. 500 GJ of natural gas is burned monthly to sustain the dust burner flame, and the plant uses 1,650,000 KWh/mo to run electric motors. Pellets are transported to the port of Vancouver in 100 tonne rail cars, and then 11,000 tonnes of pellets on average are loaded onto ships with capacity of 35-40,000 tonnes to be shipped with pulp or lumber to Rotterdam via the Panama Canal.

In the case study we consider a plant constructed at William's Lake in the Caribou region of central BC that will produce 132,000 BDt pellets per year. William's Lake has numerous sawmills in the area that can supply surplus residue, as indicated by the circles in Fig 2. William's Lake is in the southern part of the area infested with Mountain Pine Beetle, and thus has supply from this biomass source at close proximity. In addition, there are tracts of land identified by the Canadian Forest Service as being appropriate for afforestation activity (see section 3.4.3 Afforestation).

Fig 2- Plant Location at William's Lake BC
[Circles reflect size of BC sawmills]



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[1] All Vanderhoof data was provided by Premium Pellet.

[2] BDt = Bone Dry (metric) tonnes = Oven Dry tonnes = weight with zero moisture

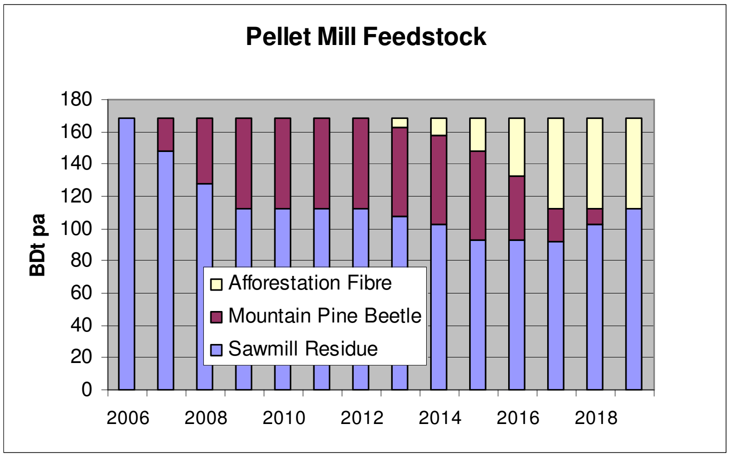
3.1. Biomass Supply

Projected fibre supply for pellet manufacture is shown in Table 3.1 and in Fig 3, a hypothetical mix of residues from local sawmills, harvested wood killed by MPB and fibre from afforestation based on fibre availability (detailed in Section 3.4 Feedstock).

Table 3.1- Biomass Feedstock

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pellet Production (000T/y)	132	132	132	132	132	132	132	132	132
Biomass Feedstock:									
Feedstock (000 GT/y)	315	315	315	315	315	315	315	315	315
Feedstock (000BDt/y)	168	168	168	168	168	168	168	168	168
Sawmill Residues									
Blown in from sawmill	66	66	66	66	66	66	66	66	66
Trucked in	102	82	62	46.5	46.5	46.5	46.5	41.5	36.5
Sawmill Residue	168	148	128	112.5	112.5	112.5	112.5	107.5	102.5
Mountain Pine Beetle	0	20	40	55.5	55.5	55.5	55.5	55.5	55.5
Afforestation Fibre	0	0	0	0	0	0	0	5	10
Total	168	168	168	168	168	168	168	168	168
Used for drying	36	36	36	36	36	36	36	36	36
Used for pellet mfgr	132	132	132	132.0	132.0	132.0	132.0	132.0	132.0

Fig 3. Pellet Mill Feedstock



3.2. Pellet Markets

Table 3.2 shows the planned destination of the pellets, mostly to coal-fired power plants in Europe, and some to North American applications. Projections are based on experience of the Premium Pellet plant, and a request by Task 38 to include US and domestic uses.

Table 3.2- Pellet Markets (000BDt)

Markets:	2006	2007	2008	2009	2010	2011	2012	2013	2014
Europe	127	122	112	112	112	112	102	102	102
Canada	5	5	10	10	10	10	20	20	20
US West	0	5	10	10	10	10	10	10	10
Total	132	132	132	132	132	132	132	132	132

3.3. Fossil Fuel and Incineration Emissions

3.3.1. Pellet Plant (Project)

The plant will cost $15.5 Cdn million to build[3]. To determine the GHG emissions for plant construction a GHG emission factor of 636 tCO_2e per $million invested is used[4]. This factor reflects many types of plants including brick and mortar, though a pellet plant possibly would be constructed of lighter materials with lower emissions. Ideally GHG emissions would be estimated by calculating actual emissions from fabricating the building components, transporting them to the site, and constructing the plant.

The plant requires 168,000 BDt wood residues annually. 36,000 BDt are used as fuel to dry the remaining 132,000 BDt, which are made into pellets. Burning the 36,000 BDt of drying residues causes no incremental CO_2 emissions, since emissions are deemed to have occurred on harvest.

The pellet manufacturing plant will use 1.65 GWh monthly to run electric motors to convey biomass. Most of BC's current electricity generation is zero-emission hydro. Half of excess needs are coal-based power imported from the US, however the emission factor for imported power is zero[5]. Following a recent Request for Proposals process, BC is expected to be power self-sufficient. New generation is targeted to be 50% renewable (no GHG emissions) and will in all likelihood be much higher[6]. For purposes of this report it is assumed 85% renewable sources and 15% from new domestic coal (750 tCO_2e/GWh). An average rate of 112 tCO_2e/GWh yields emission of 2,227tCO_2e pa.

To sustain the dust burner flame the plant utilizes 500Gigajoules/month (GJ/mo) natural gas, or 6,000 GJ annually. The emissions are calculated as [6,000GJ / 34.856GJ per1000M^3 gas * .000724 t gas/M^3 * 74% tC per t gas * 44/12 = 338 tCO_2e]. Thus manufacturing pellets results in 7,425 + 338 = 7,763 tCO_2e emissions annually.

3.3.2. Coal Power Plant (Base Case)

The base case considers a 600MW coal-powered power plant in the Netherlands. The plant can burn up to 25% biomass in the boiler, thus reducing GHG emissions from coal. The pellet plant will supply the power plant with 112,000 t pellets in 2008. Pellets have a heat value of 19.8 GJ/t for a total of 2,613,600 GJ. Since coal is 27.56 GJ/t, on a heat equivalent basis the pellets will displace 94,842 tonnes coal annually. The GHG emissions for the base case using this coal are 94,842 t coal * 2.25 tCO_2e/t coal[7] = 213,775 tCO_2e, for a conventional boiler. For producing coal a factor per tonne is used of 0.1 t CO_2e/tonne coal produced (Appendix 4).

3.3.3. North American Applications (Project)

It is assumed that 15% of production is sold in North America: 10,000 t in the US and 10,000 t in Canada, rising to 20,000 in 2012. In the US there are home heating

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[3] Based on data from Premium Pellet

[4] Woodrising Consulting 2002

[5] UNFCCC ACM0002, Mar 3, 2006

[6] BW McCloy and Associates

[7] Woodrising Consulting- 2005

applications in Pacific region, primarily in California, but the prime market at the moment is home heating in the east coast states. It is assumed US exports are destined for California to replace natural gas heating. Pellets are assumed to be transported on 100 Tonne rail cars on average 1000 km. Emissions are .181 tCO_2e/carload[8]. In Canada the western pellet market comprises home heating in BC, Alberta and Saskatchewan, and pulp and paper mills in BC. This case assumes pellets are used in heating applications to replace natural gas, either for home heating or in pulp mills. Delivery distance for 80% of these volumes is assumed to be 200 km, returning empty, and 20% is transported 800 km, returning on a back haul, for a GHG emission of 159 tCO_2e annually for 10,000t.

3.3.4. Biomass Incineration

In the base case, 168,000BDt in mill residues are incinerated annually in beehive burners. While CO_2 emissions from burning biomass are not counted, CH_4 and N_2O emissions are. The accepted emission factors in BC[9] for burning wood waste are .00015 t CH_4/BDt waste * 21 (CO_2e factor) and .00016 t N_2O/BDt waste * 310 (CO_2e factor).

In the project case, the pellet plant uses 36,000 BDt of the incoming biomass to dry pellets. The same factors as above are applied to biomass burned for drying.

3.4. Feedstock GHG Impacts

3.4.1. Mill Residue-

It is assumed that the plant will be beside a sawmill and that 66,000 BDt of sawdust will be blown from the planer, using electricity, not fossil fuel. Initially 102,000 BDt pa will be trucked in from other sawmills with an average transportation distance of 46 km. Of this supply, 36,000 BDt will come by B-train, which carries 20 t/load, or 1,800 loads p.a. and makes 2.14 km per litre of diesel fuel. The remaining 66,000 BDt of residue arrives by 53' Van, which carries 14 t/load and makes 2.87km/litre diesel. The residue cost, including transportation is $18/Bdt on average. GHG emission is 608 tCO_2e annually.

The lowest cost biomass source is surplus bark, sawdust and shavings from surrounding sawmills, which is currently incinerated. A shown in Table 3.3 there is sufficient surplus mill residue near William's Lake and in the Prince George region to supply the plant.

Table 3.3[10]

Wood Residue Surpluses- 2005
000 BDt

	Surplus
Caribou (Williams Lake)	206,500
Prince George	1,073,800
Prince Rupert	284,000
Kamloops	204,900
Nelson	45,700
BC total	1,814,900

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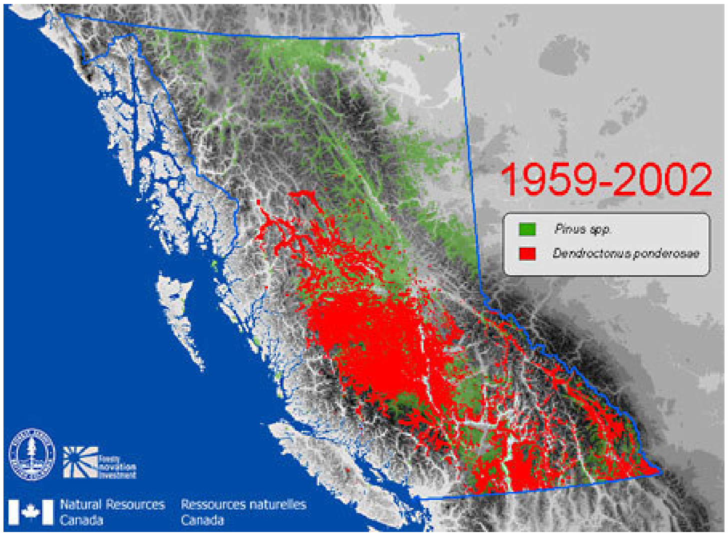
[8] Douglas Bradley- 2004, CN rail estimate of transporting BioOil/char from Val D'Or to Montreal.
[9] Canada's GHG Inventory 1990-98- Final Submission to UNFCCC Secretariat- page 106
[10] D. Bradley and BW McCloy- 2005, page vii

3.4.2. Mountain Pine Beetle Fibre-

It is assumed that demand for mill residue by pellet and board plants and cogeneration installations will increase and that eventually this source will become scarce and more costly. Harvesting standing deadwood from stands infested with Mountain Pine Beetle (MPB) in the William's Lake area is estimated to be costly, and to prevent its loss from fire it is surmised that government will apply incentives to use this wood for bioenergy. In the long-term the fibre may be too decayed for energy. As shown in Table 3.1, above, it is assumed that harvesting from MPB stands will commence in 2007 at 20,000 Bdt pa, rising to 55,500 BDt pa in 2009.

The Mountain Pine Beetle is a pest that attacks mature pine trees that have thick bark. The MPB population has undergone an unprecedented explosion in BC, spreading from 25,000 hectares (ha) in 1994 to over 7 million ha in 2004[11]. Of this area, 26% suffered moderate mortality and 11% suffered severe mortality[12]. The estimated dead timber in 2004 as a result of the outbreak is 170 million M^3[13]. The annual kill is projected to peak in 2008 at 70 million M^3 with over 450 million M^3 projected to be killed by this time[14]. The outbreak may last for 10 years and kill 80% of merchantable pine. The extent of infestation in 2002 is shown in Fig 4 below. Williams Lake is at the current southern end of the infestation area.

Fig 4 -Mountain Pine Beetle Infestation by 2002



In response, the BC government has increased the annual allowable cut (AAC) to allow the capture of economic value from dead trees in a way that maintains the highest environmental standards possible, speeds up regeneration, and restores the productivity of impacted forests. AAC will increase by 27% to 23.4 million M^3 in three north-central BC

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[11] COFI Mountain Pine Beetle Task Force

[12] Beetle Information Bulletin- Government of BC website

[13] BC Ministry of Forests- Brad Stennes, Natural Resources Canada

[14] Mountain Pine Beetle Project Team, Summary of year 1 report

timber supply areas[15]. Although cuts have been increased for the production of lumber and pulp, it is anticipated that 200 million M^3 over 2004-07 will remain unharvested. This includes timber unsuitable for lumber and also reflects that traditional uses for timber in the region (lumber, pulp and paper) will be at capacity. Excess timber could be a viable resource for bioenergy[16].

The shelf life for MTB timber is undecided, but as the dead wood decays after a period it will not be viable for construction lumber, and then not viable for pulp, and ultimately not viable for energy. However there are other factors, namely, the cost of leaving the deadwood standing. Three years after the stage where the leaves turn red, there is a very high risk factor for fire[17]. In addition, standing deadwood does not promote new growth.

A reasonable assumption for the base case is that within 7 years 30% of the forest will undergo a stand clearing fire and thus experience a carbon loss to atmosphere, though some carbon will be retained in some stems and some in the litter pool. Harvesting the fibre before it burns would result in a considerable carbon stock benefit compared with the base case. However, the dynamics of fire in the MPB forest is still subject to speculation and therefore fire effects are **not taken into account in this projection**. It is anticipated that as MPB fibre is harvested and fire experience is better known, that the base case would be adjusted for this data and the carbon benefit of harvesting improved.

A study prepared by Neil Bird, Woodrising Consulting[18], compares the carbon impacts on a base case and harvest case. In the base case, the stands affected by MPB are assumed to be 60% Lodge Pole Pine and 40% Douglas Fir and Spruce. MPB only affects the pine. The base case assumes 80% of the pine is affected, and 100% of the affected pine dies. The dead trees are left to decay using a pest infestation decay data from the Canadian Forest Service[19]. The base case stand eventually regenerates. For simplicity, the modeled project case in the Bird study assumed a mountain pine beetle fibre infestation in 2003 and harvest over 10 years 2006-15, as shown in the Table 3.4 below.

Table 3.4

Biomass and Emissions from 2003 Infestation followed by harvest 2006-15*

	2003	2004	2005	2006	2007	2008	2009	2010
Biomass (Bdt / ha)								
Baseline Biomass	386.9	377.3	368.4	360.4	353.0	346.3	340.2	334.7
Project Biomass	386.9	377.3	368.4	346.7	327.2	309.8	294.3	280.5
Harvest	0.0	0.0	0.0	13.7	12.1	10.7	9.4	8.2
Emissions (t CO2e / ha)								
Baseline Biomass	-8.9	17.7	16.2	14.8	13.5	12.3	11.1	10.1
Project Biomass	-8.9	17.7	16.2	39.9	35.8	31.9	28.4	25.2
Net Biomass Emissions	0.0	0.0	0.0	25.1	22.3	19.6	17.3	15.1

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[15] BC Ministry of Forests news release Sept 14, 2004

[16] A. Kumar, S. Sokhansanj et al April 2005

[17] Conversation with W. Kurtz, Canadian Forest Service, Victoria, BC

[18] Woodrising Consulting- 2005

[19] Kurz and Apps- 1999, pp 526-547, and Li, Kurz, Apps & Beukema- 2003, 126-136

Baseline and project biomass per hectare reflect declining biomass stocks due to decay and emission to atmosphere as a result of mortality from MPB. In the Bird study, harvesting MPB fibre begins in 2006. The net reduction in biomass per hectare due to the project is 13.7 BD t in 2006, equivalent to a carbon stock change of 25.1 tCO$_2$e

Biomass pools include above-ground biomass (AGB) from trees and vegetation, roots, litter, and soils. Biomass data is shown in Appendix 2. The harvest in 2006 is only 13.7 Bdt/ha even though there is 360 Bdt/ha of biomass. The reason is that for each hectare only 45.3 BDt is in the above ground tree bole, 10 BDt is roots and 23.2 BDt is foliage. Total woody debris is 137 BDt/ha and soils 76.2 BDt/ha, as shown on Table 3.5.

Table 3.5

Biomass 2006 (Bdt/ha)

	Above Ground	Below Ground	Total
Tree	45.3	10.0	55.3
Other Vegetation	4.9	1.1	6.0
Foliage	23.2		23.2
Woody debris	137.1		137.1
F Root		11.6	11.6
W Root		30.2	30.2
Other	16.9	3.7	20.6
Soils		76.2	76.2
	227.4	132.8	360.2

Using the data from the Bird study (a 2006 harvest from a stand killed in 2003), Table 3.6 estimates the higher harvest available if taken from stands infested in 2004-07.

Table 3.6

Biomass Harvest Per Hectare if take fibre from stands infested in 2004-07

	2004	2005	2006	2007	2008	2009	2010	2011	2012
2003 infestation	17.5	15.5	**13.7**	**12.1**	**10.7**	**9.4**	**8.2**	**7.2**	**6.2**
2004 infestation		17.5	15.5	13.7	12.1	10.7	9.4	8.2	7.2
2005 infestation			17.5	15.5	13.7	12.1	10.7	9.4	8.2
2006 infestation				17.5	15.5	13.7	12.1	10.7	9.4
2007 infestation					17.5	15.5	13.7	12.1	10.7
Suggested Available Fibre (Bdt/ha)				**17.5**	**17.5**	**15.5**	**12.2**	**10.8**	**9.5**

Table 3.7 translates MPB feedstock requirements (Table 3.1), harvest per hectare (Table 3.6), and emissions per hectare (Table 3.4) into a net carbon stock change from harvesting all required MPB biomass. For example, in 2008 harvesting 40,000 BDt of MPB biomass will result in a stock change of -73,333 tCO$_2$e.

Table 3.7- Carbon Stock Change for Mountain Pine Beetle

	2007	2008	2009	2010	2011	2012
Biomass Need (000 Bdt)	20,000	40,000	55,467	55,467	55,467	55,467
Biomass Harvest per hectare	17.5	17.5	15.5	12.2	10.8	9.5
Hectares	1,142	2,284	3,576	4,551	5,157	5,867
Processing- N. Bird (KgCO2e/t)	22.7	22.7	22.7	22.7	22.7	22.7
Trucking- N. Bird (KgCO2e/t)	6.3	6.3	6.3	6.3	6.3	6.3
Emissions (tCO2e/t)	0.029	0.029	0.029	0.029	0.029	0.029
Emissions	580	1,160	1,609	1,609	1,609	1,609
Change in Carbon Stock (tCO2e)	-36,667	-73,333	-101,689	-101,689	-101,689	-101,689

Fossil fuel emissions from getting this biomass include processing of 22.7 kg CO_2e/t (chipping 6.6, forwarding 4.6, harvesting 11.5) and transportation of 6.3 kg CO_2e/t[20]. Net fossil fuel emissions are thus 1,609 tCO_2e in 2008.

3.4.3. Afforestation-

Mountain Pine Beetle Fibre will eventually burn or decay, or otherwise run out. Mill residue, while potentially available, could be a costly commodity in the future. To secure a long-term fibre source at a known cost, the plan is to look at establishing fast-growing plantations to supply fibre. Accordingly, a study[21] was prepared by the Canadian Forest Service to assess plantations of fast-growing clones of hybrid poplar within a 300-km access radius of Williams Lake. The CFS study modeled carbon balances in all relevant carbon pools from afforestation activity. Results are summarized in Table 4.1.

The CFS study utilized a new real-time Forest Bioeconomic Model (CFS-FBM) to evaluate the economic feasibility of forestry projects with non-timber values (carbon sequestration in this case). CFS-FBM is a spatial model that simulates the annual progression of timber production, carbon sequestration and economic returns. The model generates measures of economic potential for forestry projects, including net present values, break-even prices and land availability. The CFS team used regional growth and yield tables from previous work within CFS including the development of a spatial site suitability model/map developed at CFS-Edmonton. Biophysical assumptions such as carbon sequestration and biomass decay are embedded in the model. Existing hybrid poplar studies (i.e., van Kooten et al. 1999; Guy and Benowicz 1998) were used as a starting point to formulate biophysical assumptions. CFS-FBM uses real-time annual carbon tracking algorithms and biophysical parameters similar to CBM-CFS2 carbon budget model[22].

Using the afforestation fibre required (Table 3.1), the CFS study (Yemshanov, below) calculated harvest area of 15,600 ha around William's Lake, and a resulting harvest profile. Agricultural land available was delineated from SPOT, VGT and AVHRR imagery. As shown in Table 3.8, the peak need is 139,000 M^3 annually, which is harvested from 979 hectares at 142 M^3/ha. (Modeling constraints require harvests in 100-hectare units, so adjustments were made accordingly in this case.)

Table 3.8- Afforestation Fibre Supply

	2013	2014	2015	2016	2017	2018	2019	2020	2021
Harvest (M3)- needed	12,500	25,000	50,000	87,500	139,000	139,000	139,000	139,000	139,000
Harvest (M3)- modeled	15,600	31,100	46,700	109,000	140,100	140,100	140,100	140,100	138,300
Harvest area (ha)- needed	88	176	352	616	979	979	979	979	979
Harvest area (ha)- modeled	100	200	300	700	900	900	900	900	900

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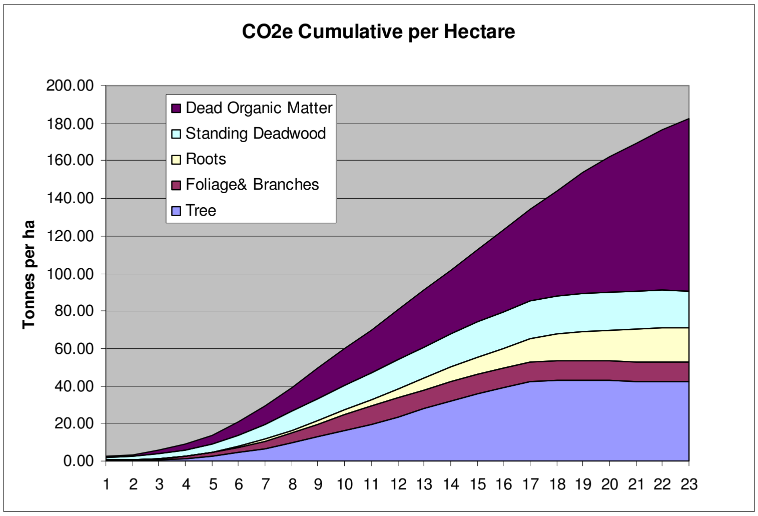
[20] Woodrising Consulting- 2005

[21] D. Yemshanov, D. McKenney, May 2006

[22] Kurz , Apps et al- 1992, and Kurz, Apps- 1999

The CFS modeled annual establishment of plantations over 20 years beginning in 1998 that match the required hectares needed in 2013 and beyond, based on harvest at age 16. The model examines all relevant carbon pools for forest stands, illustrated in Fig 5. As shown, the stock of carbon in biomass from trees reaches 42 tCO$_2$e/ha in year 18, and then levels off as new growth matches harvest requirements. The harvest only takes the gross merchantable and non-merchantable timber. Foliage and branches, roots, standing deadwood and dead organic matter remain on the site and decay over time. In fact, more carbon is stored in non-tree than tree carbon pools, reaching 140 tCO$_2$e/ha after 23 years, also shown on Fig 5. Decay rate coefficients and a discussion of dead organic matter dynamics are found in publications from CFS. The new model uses complex algorithms calculating the decay rate as a function of mean annual temperature and total biomass[23]. Annual plantings and carbon balances 2005-20 are shown in Appendix 3.

Fig 5- Cumulative CO$_2$e per Hectare



4. Results

As shown in Table 4.1, co-firing with pellets in a European power plant and replacing natural gas in North American heating applications causes a net reduction in GHG emissions of 307,000 tCO$_2$e in 2006, with reductions varying in each year after that.

In 2006 total base case emissions are 235,000 tCO$_2$e including: 205,000 tCO$_2$e to run the coal power plant, 16,000 tCO$_2$e to mine and transport coal and burn natural gas in home and industrial heating applications in western North America, and 14,000 tCO$_2$e in methane and N$_2$O emissions by incinerating mill residues in beehive burners.

Project emissions are 22,000 tCO$_2$e including a one-time emission of 9,900 tCO$_2$e to construct the pellet plant, and annual fossil fuel emissions of 2,600 tCO$_2$e to operate the plant, 5,700 tCO$_2$e for ocean shipping of pellets to Rotterdam, and 2,900 tCO$_2$e in methane and N$_2$O emissions to burn residues to dry pellets. Minor emissions include:

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[23] Kurz and Apps- 1999, pp 526-547, and Li, Kurz, Apps & Beukema- 2003, 126-13603

processing and trucking raw biomass to the plant, and shipping pellets to Western ports and markets. Thus the project reduces net GHG emissions by 213,000 tCO_2e.

Table 4.1- Net GHG Balances (tCO_2e)

						Emissions tCO2e			
	2006	2007	2008	2009	2010	2011	2012	2013	2014
Plant- CO2e Emissions from Fossil Fuel									
Base Case (Coal fired Power Plant, Gas Heating):									
Bark pile incineration CH4, N20	13,549	11,936	10,323	9,076	9,076	9,076	9,076	8,673	8,269
Gas Heating (incl. Gas Production)	11,606	23,212	46,424	46,424	46,424	46,424	69,637	69,637	69,637
Coal Production	976	976	976	976	976	976	976	976	976
Coal Transport (at 10,000 km)	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361
Coal burned in Power Plant	205,359	197,274	181,104	181,104	181,104	181,104	164,934	164,934	164,934
Total Baseline emissions	234,851	236,759	242,188	240,941	240,941	240,941	247,983	247,580	247,177
Project (Build pellet plant, supply pellets to power plant for cofiring, and gas substitution):									
FF- Build pellet plant	9,870								
Truck Mill residue to pellet plant	608	489	370	277	277	277	277	248	218
Process & Truck MPB fibre to plant		580	1,160	1,609	1,609	1,609	1,609	1,609	1,609
Process & Truck Afforestation fibre to plant								145	290
Pellet Manufacturing- gas & power (CO2)	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566
Pellet drying (CH4, N2O)	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903
Rail- pellets to port	124	119	110	110	110	110	100	100	100
Rail- pellets to US North West		9	18	18	18	18	18	18	18
Truck pellets Alta and BC	80	80	159	159	159	159	319	319	319
Ocean Transport (Van-Rotterdam)	5,730	5,504	5,053	5,053	5,053	5,053	4,602	4,602	4,602
Barge to Power plant	assume immaterial								
Total Project emissions	21,881	12,250	12,339	12,695	12,695	12,695	12,393	12,509	12,624
Net Fossil Fuel Emissions	-212,970	-224,509	-229,850	-228,246	-228,246	-228,246	-235,590	-235,071	-234,553
	2006	2007	2008	2009	2010	2011	2012	2013	2014
Forestry (Assuming the Managed Forest is IN Canada's accounting):									
Stock Change:									
1) Sawmill Residues	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000
Baseline (incinerated at source):	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000
Net Stock Change	0	0	0	0	0	0	0	0	0
2) Mountain Pine Beetle fibre									
Stock Change MPB fibre		-36,667	-73,333	-101,689	-101,689	-101,689	-101,689	-101,689	-101,689
3) Afforestation fibre									
Base Case (No Afforestation)									
Baseline Stock Change	0	0	0	0	0	0	0	0	0
Project(Afforest 15,600 ha 1998-2017, harvest 2013+):									
Tree	25,414	35,695	44,752	53,434	62,553	72,527	82,097	80,729	75,973
Foliage& Branches	13,702	17,816	18,839	18,282	16,867	15,180	13,200	10,523	7,968
Roots	3,920	5,988	8,584	12,030	16,023	20,497	25,520	29,157	30,991
Standing Deadwood	19,921	23,676	25,920	26,946	28,123	29,737	30,653	28,336	25,260
Dead Organic Matter	30,657	39,816	48,708	56,371	62,993	71,133	77,587	92,294	101,919
Afforestation Stock Change	93,614	122,991	146,802	167,064	186,560	209,073	229,057	241,039	242,110
Net Stock Change	93,614	86,324	73,469	65,375	84,871	107,384	127,368	139,350	140,421
Net Emissions	-306,584	-310,833	-303,319	-293,621	-313,117	-335,630	-362,958	-374,422	-374,974

Carbon stock changes must also be included in carbon accounting. There is no net stock change for mill residues, as shown in Table 4.1, since in the base case mill residues are incinerated, and in the project they are burned for energy, either in the pellet plant or by the final consumer. For MPB fibre, the carbon stock falls 101,700 tCO_2e annually after peak harvest in 2009. Afforestation carbon stock is shown on Table 4.1 (2006-14) and in Appendix 4 (2006-20). Tree growth as a result of plantings begun in 1998 result in 94,000 tCO_2e in carbon stock increases 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.

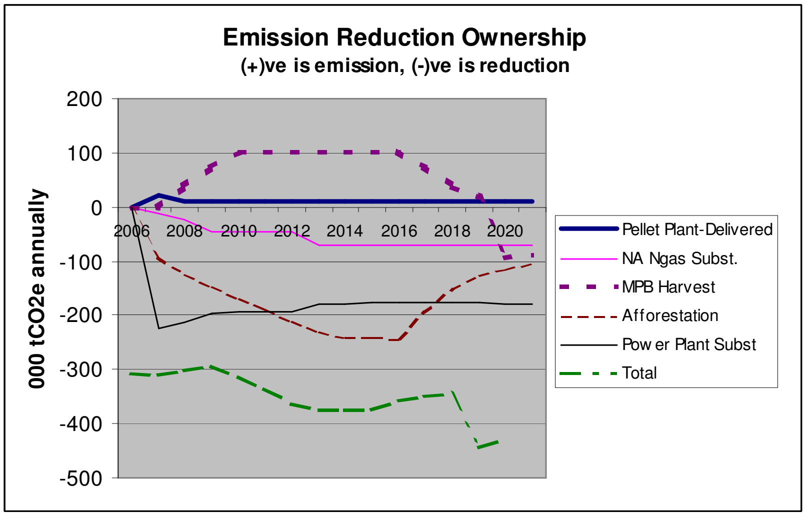
In 2006, the combined GHG reduction from emissions and stock change is 307,000 tCO$_2$e from 168,000 t biomass utilized, or 1.83 tCO$_2$e/t biomass. Since 132,000 tonnes pellets are produced, emissions reductions are 2.32 tCO$_2$e/t pellets.

The Dutch power plant produces 600 MW power and 350 MW heat on average from 1.5 million tones coal. Power plant experience[24], reflecting maintenance downtime and energy conversion efficiency, is to produce 105 kWh from 1 GJ pellets, where pellets provide 17 GJ/tonne, or 1.8 MWh power from 1 tonne pellets. Emission reductions are therefore 2.32 tCO$_2$e per 1.8 MWh, or 1.3 tCO$_2$e/MWh.

5. Discussion

While the project results in considerable reduction in GHG emissions, in excess of 300,000 tCO$_2$e annually, few of them are actually credited to the project proponent. As illustrated in Fig 6 below, the pellet plant owner actually causes <u>emissions</u> of 11,000 tCO$_2$e by manufacturing pellets. The owner of the power plant is credited with just less than 200,000 tCO$_2$e emission <u>reductions</u> annually due to fuel substitution, and would receive the EU Emission Reduction Credit currently valued at €20/tCO$_2$e, and a feed-in-tariff of €6.4/KWh for production of power in the Netherlands from renewable sources. North American pellet consumers would be credited with 56,000 tCO$_2$e emission <u>reductions</u> on average, but may or may not get value for these reductions.

Fig. 6



The owner of the afforestation would get credit for carbon stock enhancements under the 1997 Kyoto Protocol, peaking at 240,000 tCO$_2$e, which will have monetary value if the Canadian Offset Trading System is implemented later in 2006.

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[24] Data from Essent Energie, Netherlands

Canada has not decided whether to include the managed forest in its carbon accounting nor has it established ownership of carbon from forests if it does. Although harvesting MPB stands for energy is unquestionably a good thing, if Canada opts for the managed forest, a Canadian entity will have to absorb the carbon stock reduction of harvesting MPB trees. The Canadian Forest Service or the BC Ministry of Natural Resources will establish whether MPB harvesting reduces fire losses. If that is the case, the carbon benefit of this case will improve.

While transportation costs are considerably lower by selling pellets in North America, the combined impact of EU ERCs and feed-in-tariffs will continue draw pellets into the European market. Should all the pellets be used domestically, a further emission reduction of 3,800 tCO_2e could be achieved.

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Appendix 1

Emission Factors for Various Applications

Production - Fossil Fuels						**Base Fuel**		**BioOil**	**Char**	**NCG**
		CO_2	CH_4	N_2O	Total	t_{CO_2}/t_{fuel}	t_{CO_2}/GJ	t_{CO_2}/t_{BioOil}	t_{CO_2}/t_{Char}	t_{CO_2}/t_{NCG}
Light Fuel Oil Production	kg_{CO_2}/l_{fuel}	0.1459	1.01472		1.161	1.38	0.030	0.50	0.91	0.23
Heavy Oil Production	kg_{CO_2}/l_{fuel}	0.0642	7.75215		7.816	7.87	0.187	3.07	5.66	1.43
Natural Gas Production	kg_{CO_2}/m^3	0.07766	1.66047	0.6975	2.436	N/A	0.066	1.08	1.99	0.50
Open Pit Coal Mines	kg_{CO_2}/kg_{fuel}	-	0.01029		0.010	0.01	0.000	0.01	0.01	0.00

Applications - Liquid and Gaseous Fuel						**Base Fuel**		**BioOil**	**Char**	**NCG**
Industrial Boilers		CO_2	CH_4	N_2O	Total	t_{CO_2}/t_{fuel}	t_{CO_2}/GJ	t_{CO_2}/t_{BioOil}	t_{CO_2}/t_{Char}	t_{CO_2}/t_{NCG}
Light Fuel Oil	kg_{CO_2}/l_{fuel}	2.830	0.000	0.004	2.834	3.38	0.074	1.21	2.23	0.56
Heavy Fuel Oil	kg_{CO_2}/l_{fuel}	3.090	0.003	0.004	3.097	3.12	0.074	1.22	2.24	0.57
Natural Gas	kg_{CO_2}/m^3	1.891	0.001	0.010	1.902	N/A	0.051	0.84	1.55	0.39
Internal Combustion		CO_2	CH_4	N_2O	Total	t_{CO_2}/t_{fuel}	t_{CO_2}/GJ	t_{CO_2}/t_{BioOil}	t_{CO_2}/t_{Char}	t_{CO_2}/t_{NCG}
Stationary Diesel	kg_{CO_2}/l_{fuel}	2.730	0.005	0.124	2.859	3.41	0.074	1.21	2.23	0.57
On Road HD Diesel	kg_{CO_2}/l_{fuel}	2.730	0.003	0.031	2.764	3.29	0.071	1.17	2.16	0.55
Off Road HD Diesel	kg_{CO_2}/l_{fuel}	2.730	0.003	0.341	3.074	3.66	0.079	1.30	2.40	0.61
Rail Diesel	kg_{CO_2}/l_{fuel}	2.730	0.003	0.341	3.074	3.66	0.079	1.30	2.40	0.61
Marine Diesel	kg_{CO_2}/l_{fuel}	2.730	0.003	0.310	3.043	3.62	0.079	1.29	2.38	0.60
Marine Light Fuel Oil	kg_{CO_2}/l_{fuel}	2.830	0.006	0.022	2.858	3.40	0.074	1.22	2.24	0.57
Marine Heavy Fuel Oil	kg_{CO_2}/l_{fuel}	3.090	0.006	0.025	3.121	3.14	0.075	1.23	2.26	0.57
Applications - Coal										
Boilers		CO_2	CH_4	N_2O	Total	t_{CO_2}/t_{fuel}	t_{CO_2}/GJ	t_{CO_2}/t_{BioOil}	t_{CO_2}/t_{Char}	t_{CO_2}/t_{NCG}
Conventional Boiler	kg_{CO_2}/kg_{fuel}	2.254	-	-	2.254	2.25	0.082	1.34	2.47	0.63
Fluidized Bed Boiler	kg_{CO_2}/kg_{fuel}	2.254	-	-	2.254	2.25	0.082	1.34	2.47	0.63

Combined Production and Application - Liquid, Gaseous and Solid Fuels						**Base Fuel**		**BioOil**	**Char**	**NCG**
		CO_2	CH_4	N_2O	Total	t_{CO_2}/t_{fuel}	t_{CO_2}/GJ	t_{CO_2}/t_{BioOil}	t_{CO_2}/t_{Char}	t_{CO_2}/t_{NCG}
Light Fuel Oil	kg_{CO_2}/l_{fuel}	2.976	1.015	0.004	3.995	4.76	0.104	1.70	3.14	0.80
Heavy Fuel Oil	kg_{CO_2}/l_{fuel}	3.154	7.755	0.004	10.913	10.99	0.262	4.29	7.90	2.00
Natural Gas	kg_{CO_2}/m^3	1.969	1.661	0.708	4.338	N/A	0.117	1.92	3.54	0.90
Bituminous Coal	kg_{CO_2}/kg_{fuel}	2.254	0.010		2.264	2.26	0.082	1.35	2.48	0.63

Source: DynaMotive Energy Systems

Appendix 2

Base Case- Decay from Mountain Pine Beetle Infestation

Baseline Biomass (t/ha)

		AGB			Roots			Litter									Biological
Year	**Age**	**Trees**	**Other Veg**	**Total**	**Trees**	**Other Veg**	**Total**	**Foliage**	**Woody**	**F. Root**	**W. Root**	**Other AG**	**Other BG**	**Total AG**	**Total BG**	**Soil**	**Total**
2001	86.0	193.0	1.5	194.5	42.9	0.3	43.2	20.5	23.2	12.6	4.0	8.7	1.9	52.4	18.6	72.0	380.7
2002	87.0	194.1	1.5	195.5	43.1	0.3	43.4	20.6	23.4	12.7	4.0	8.6	1.9	52.6	18.6	72.0	382.1
2003	88.0	39.0	5.1	44.1	8.7	1.1	9.8	36.3	164.0	14.3	36.2	8.4	1.9	208.8	52.4	71.9	386.9
2004	89.0	41.1	5.0	46.1	9.1	1.1	10.2	31.1	154.4	13.2	34.1	11.9	2.6	197.5	49.9	73.5	377.3
2005	90.0	43.2	5.0	48.2	9.6	1.1	10.7	26.8	145.5	12.4	32.1	14.7	3.2	187.0	47.7	74.9	368.4
2006	91.0	45.3	4.9	50.2	10.0	1.1	11.1	23.2	137.1	11.6	30.2	16.9	3.7	177.2	45.6	76.2	360.4
2007	92.0	47.4	4.9	52.3	10.5	1.1	11.6	20.2	129.2	11.1	28.5	18.7	4.1	168.1	43.6	77.4	353.0
2008	93.0	49.5	4.8	54.3	11.0	1.1	12.1	17.7	121.9	10.6	26.8	20.1	4.4	159.7	41.8	78.4	346.3
2009	94.0	51.6	4.8	56.4	11.5	1.1	12.5	15.7	114.9	10.2	25.3	21.1	4.6	151.8	40.1	79.4	340.2
2010	95.0	53.8	4.7	58.5	11.9	1.0	13.0	14.1	108.5	9.9	23.8	21.9	4.8	144.5	38.6	80.2	334.7
2011	96.0	55.9	4.7	60.6	12.4	1.0	13.5	12.7	102.4	9.7	22.5	22.5	5.0	137.7	37.1	80.9	329.8
2012	97.0	58.1	4.6	62.8	12.9	1.0	13.9	11.7	96.7	9.5	21.2	23.0	5.1	131.3	35.7	81.6	325.3
2013	98.0	60.3	4.6	64.9	13.4	1.0	14.4	10.8	91.3	9.4	20.0	23.3	5.1	125.4	34.5	82.1	321.3
2014	99.0	62.5	4.5	67.0	13.9	1.0	14.9	10.1	86.3	9.3	18.9	23.5	5.2	120.0	33.3	82.6	317.7
2015	100.0	64.6	4.5	69.1	14.3	1.0	15.3	9.6	81.6	9.2	17.8	23.6	5.2	114.9	32.2	83.0	314.5
2016	101.0	66.8	4.4	71.3	14.8	1.0	15.8	9.2	77.3	9.1	16.8	23.7	5.2	110.1	31.2	83.4	311.7
2017	102.0	69.0	4.4	73.4	15.3	1.0	16.3	8.9	73.2	9.1	15.9	23.6	5.2	105.7	30.2	83.7	309.2

Project- Begin harvesting in 2006

Project Biomass (t/ha)

		AGB			Roots			Litter									Biological
Year	**Age**	**Trees**	**Other Veg**	**Total**	**Trees**	**Other Veg**	**Total**	**Foliage**	**Woody**	**F. Root**	**W. Root**	**Other AG**	**Other BG**	**Total AG**	**Total BG**	**Soil**	**Total**
2001	86.0	193.0	1.5	194.5	42.9	0.3	43.2	20.5	23.2	12.6	4.0	8.7	1.9	52.4	18.6	72.0	380.7
2002	87.0	194.1	1.5	195.5	43.1	0.3	43.4	20.6	23.4	12.7	4.0	8.6	1.9	52.6	18.6	72.0	382.1
2003	88.0	39.0	5.1	44.1	8.7	1.1	9.8	36.3	164.0	14.3	36.2	8.4	1.9	208.8	52.4	71.9	386.9
2004	89.0	41.1	5.0	46.1	9.1	1.1	10.2	31.1	154.4	13.2	34.1	11.9	2.6	197.5	49.9	73.5	377.3
2005	90.0	43.2	5.0	48.2	9.6	1.1	10.7	26.8	145.5	12.4	32.1	14.7	3.2	187.0	47.7	74.9	368.4
2006	91.0	45.3	4.9	50.2	10.0	1.1	11.1	23.2	123.4	11.6	30.2	16.9	3.7	163.5	45.6	76.2	346.7
2007	92.0	47.4	4.9	52.3	10.5	1.1	11.6	20.2	103.4	11.1	28.5	18.7	4.1	142.3	43.6	77.4	327.2
2008	93.0	49.5	4.8	54.3	11.0	1.1	12.1	17.7	85.4	10.6	26.8	20.1	4.4	123.2	41.8	78.3	309.8
2009	94.0	51.6	4.8	56.4	11.5	1.1	12.5	15.7	69.2	10.2	25.3	21.1	4.6	106.0	40.1	79.1	294.3
2010	95.0	53.8	4.7	58.5	11.9	1.0	13.0	14.1	54.6	9.9	23.8	21.9	4.8	90.6	38.6	79.8	280.5
2011	96.0	55.9	4.7	60.6	12.4	1.0	13.5	12.7	41.5	9.7	22.5	22.5	5.0	76.8	37.1	80.4	268.4
2012	97.0	58.1	4.6	62.8	12.9	1.0	13.9	11.7	29.8	9.5	21.2	23.0	5.1	64.5	35.7	80.9	257.8
2013	98.0	60.3	4.6	64.9	13.4	1.0	14.4	10.8	19.3	9.4	20.0	23.3	5.1	53.5	34.5	81.3	248.5
2014	99.0	62.5	4.5	67.0	13.9	1.0	14.9	10.1	10.0	9.3	18.9	23.5	5.2	43.7	33.3	81.5	240.4
2015	100.0	64.6	4.5	69.1	14.3	1.0	15.3	9.6	1.8	9.2	17.8	23.6	5.2	35.0	32.2	81.8	233.4
2016	101.0	66.8	4.4	71.3	14.8	1.0	15.8	9.2	2.2	9.1	16.8	23.7	5.2	35.0	31.2	81.9	235.2
2017	102.0	69.0	4.4	73.4	15.3	1.0	16.3	8.9	2.6	9.1	15.9	23.6	5.2	35.1	30.2	82.0	237.0

Appendix 3

Afforestation Carbon Stock Change

Year from Planting	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Harvest (M3)- needed															12,500	25,000	50,000	87,500
Harvest (M3)- modeled															15,600	31,100	46,700	109,000
Harvest area (ha)- needed															88	176	352	616
Harvest area (ha)- modeled															100	200	300	700
Plantings (ha)	600	700	900	900	900	900	900	900	1,100	1,100	1,100	1,000	1,000	1,000	900	800	600	300
Cumulative Planted (ha)	600	1,300	2,200	3,100	4,000	4,900	5,800	6,700	7,800	8,900	10,000	11,000	12,000	13,000	13,900	14,700	15,300	15,600
									tCO2e									
CO2e Balances per ha (cumulative)															1st harvest			
Tree	0.26	0.48	0.84	1.50	2.64	4.33	6.67	9.57	12.80	16.24	19.80	23.69	27.76	31.94	35.68	38.90	42.09	42.97
Foliage& Branches	0.18	0.33	0.59	0.99	1.72	2.71	4.03	5.54	7.04	8.29	9.20	9.90	10.34	10.56	10.63	10.60	10.60	10.52
Roots	0.04	0.04	0.07	0.15	0.29	0.48	0.81	1.28	1.87	2.60	3.52	4.66	5.98	7.48	9.09	10.71	12.43	13.93
Standing Deadwood	1.28	1.61	2.35	3.37	4.77	6.38	8.21	10.08	11.70	13.16	14.41	15.66	16.83	17.89	18.77	19.47	20.17	20.24
Dead Organic Matter	0.70	1.03	1.76	2.79	4.51	6.75	9.50	12.80	16.10	19.58	23.06	26.69	30.40	34.03	38.46	43.30	48.80	56.50
	2.46	3.48	5.61	8.80	13.93	20.64	29.22	39.27	49.50	59.88	70.00	80.59	91.30	101.90	112.64	122.98	134.09	144.17
Annual Stock Change- tCO2e/ha																		
Tree	0.26	0.22	0.37	0.66	1.14	1.69	2.35	2.90	3.23	3.45	3.56	3.89	4.07	4.18	3.74	3.23	3.19	0.88
Foliage& Branches	0.18	0.15	0.26	0.40	0.73	0.99	1.32	1.50	1.50	1.25	0.92	0.70	0.44	0.22	0.07	-0.04	0.00	-0.07
Roots	0.04	0.00	0.04	0.07	0.15	0.18	0.33	0.48	0.59	0.73	0.92	1.14	1.32	1.50	1.61	1.61	1.72	1.50
Standing Deadwood	1.28	0.33	0.73	1.03	1.39	1.61	1.83	1.87	1.61	1.47	1.25	1.25	1.17	1.06	0.88	0.70	0.70	0.07
Dead Organic Matter	0.70	0.33	0.73	1.03	1.72	2.24	2.75	3.30	3.30	3.48	3.48	3.63	3.70	3.63	4.44	4.84	5.50	7.70
one ha	2.46	1.03	2.13	3.19	5.13	6.71	8.58	10.05	10.23	10.38	10.12	10.60	10.71	10.60	10.74	10.34	11.11	10.08
Cumulative CO2e all Hectares 000tCO2e																		
Tree	0.2	0.6	1.9	4.7	10.6	21.2	38.7	64.1	99.8	144.6	198.0	260.6	333.1	415.2	495.9	571.9	644.0	670.4
Foliage& Branches	0.1	0.4	1.3	3.1	6.9	13.3	23.4	37.1	54.9	73.8	92.0	108.9	124.1	137.3	147.8	155.8	162.1	164.2
Roots	0.0	0.0	0.2	0.5	1.2	2.3	4.7	8.6	14.6	23.2	35.2	51.2	71.7	97.2	126.4	157.4	190.2	217.4
Standing Deadwood	0.8	2.1	5.2	10.5	19.1	31.3	47.6	67.6	91.2	117.2	144.1	172.2	202.0	232.6	260.9	286.2	308.6	315.7
Dead Organic Matter	0.4	1.3	3.9	8.6	18.0	33.1	55.1	85.7	125.6	174.3	230.6	293.6	364.8	442.3	534.6	636.6	746.7	881.5
	1.5	4.5	12.3	27.3	55.7	101.2	169.5	263.1	386.1	532.9	700.0	886.5	1,095.6	1,324.7	1,565.7	1,807.8	2,051.6	2,249.1
Annual Stock Change- All ha- 000 tCO2e																		
Tree	0.15	0.47	1.24	2.81	5.90	10.64	17.50	25.41	35.70	44.75	53.43	62.55	72.53	82.10	80.73	75.97	72.15	26.36
Foliage& Branches	0.11	0.32	0.86	1.78	3.82	6.40	10.10	13.70	17.82	18.84	18.28	16.87	15.18	13.20	10.52	7.97	6.36	2.04
Roots	0.02	0.03	0.11	0.29	0.72	1.16	2.34	3.92	5.99	8.58	12.03	16.02	20.50	25.52	29.16	30.99	32.79	27.18
Standing Deadwood	0.77	1.33	3.07	5.29	8.61	12.20	16.38	19.92	23.68	25.92	26.95	28.12	29.74	30.65	28.34	25.26	22.34	7.19
Dead Organic Matter	0.42	0.92	2.54	4.77	9.40	15.02	22.02	30.66	39.82	48.71	56.37	62.99	71.13	77.59	92.29	101.92	110.13	134.76
	1.47	3.05	7.81	14.94	28.45	45.42	68.34	93.61	122.99	146.80	167.06	186.56	209.07	229.06	241.04	242.11	243.77	197.53

Appendix 4

Emissions

tCO2e

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Plant- CO2e Emissions from Fossil Fuel															
Base Case (Coal fired Power Plant, Gas Heating):															
Bark pile incineration CH4, N20	13,549	11,936	10,323	9,076	9,076	9,076	9,076	8,673	8,269	7,463	7,500	7,452	8,259	9,065	9,065
Gas Heating (incl. Gas Production)	11,606	23,212	46,424	46,424	46,424	46,424	69,637	69,637	69,637	69,637	69,637	69,637	69,637	69,637	69,637
Coal Production	976	976	976	976	976	976	976	976	976	976	976	976	976	976	976
Coal Transport (at 10,000 km)	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361
Coal burned in Power Plant	205,359	197,274	181,104	181,104	181,104	181,104	164,934	164,934	164,934	164,934	164,934	164,934	164,934	164,934	164,934
Total Baseline emissions	234,851	236,759	242,188	240,941	240,941	240,941	247,983	247,580	247,177	246,370	246,408	246,360	247,166	247,973	247,973
Project (Build pellet plant, supply pellets to power plant for cofiring, and gas substitution):															
FF- Build pellet plant	9,870														
Truck Mill residue to pellet plant	608	489	370	277	277	277	277	248	218	158	161	157	217	277	277
Process & Truck MPB fibre to plant		580	1,160	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,160	580	290	0	0
Process & Truck Afforestation fibre to plant								145	290	580	1,015	1,612	1,612	1,612	1,612
Pellet Manufacturing- gas & power (CO2)	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566	2,566
Pellet drying (CH4, N2O)	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903	2,903
Rail- pellets to port	124	119	110	110	110	110	100	100	100	100	100	100	100	100	100
Rail- pellets to US North West		9	18	18	18	18	18	18	18	18	18	18	18	18	18
Truck pellets Alta and BC	80	80	159	159	159	159	319	319	319	319	319	319	319	319	319
Ocean Transport (Van-Rotterdam)	5,730	5,504	5,053	5,053	5,053	5,053	4,602	4,602	4,602	4,602	4,602	4,602	4,602	4,602	4,602.0
Barge to Power plant	assume immaterial														
Total Project emissions	21,881	12,250	12,339	12,695	12,695	12,695	12,393	12,509	12,624	12,854	12,843	12,857	12,627	12,397	12,397
Net Fossil Fuel Emissions	-212,970	-224,509	-229,850	-228,246	-228,246	-228,246	-235,590	-235,071	-234,553	-233,516	-233,564	-233,502	-234,539	-235,576	-235,576

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Forestry (Assuming the Managed Forest is IN Canada's accounting):															
Stock Change:															
1) Sawmill Residues	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000
Baseline (incinerated at source):	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000	308,000
Net Stock Change	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2) Mountain Pine Beetle fibre															
Stock Change MPB fibre		-36,667	-73,333	-101,689	-101,689	-101,689	-101,689	-101,689	-101,689	-101,689	-73,333	-36,667	-18,333	91,718	86,357
3) Afforestation fibre															
Base Case (No Afforestation)															
Baseline Stock Change	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Project(Afforest 15,600 ha 1998-2017, harvest 2013+):															
Tree	25,414	35,695	44,752	53,434	62,553	72,527	82,097	80,729	75,973	72,149	26,356	0	-2,860	-2,288	-3,432
Foliage& Branches	13,702	17,816	18,839	18,282	16,867	15,180	13,200	10,523	7,968	6,358	2,035	-572	-572	-1,144	0
Roots	3,920	5,988	8,584	12,030	16,023	20,497	25,520	29,157	30,991	32,791	27,181	21,736	17,732	15,444	12,012
Standing Deadwood	19,921	23,676	25,920	26,946	28,123	29,737	30,653	28,336	25,260	22,341	7,194	-1,144	-1,144	-1,144	-1,144
Dead Organic Matter	30,657	39,816	48,708	56,371	62,993	71,133	77,587	92,294	101,919	110,132	134,761	132,132	115,544	105,820	98,956
Afforestation Stock Change	93,614	122,991	146,802	167,064	186,560	209,073	229,057	241,039	242,110	243,771	197,527	152,152	128,700	116,688	106,392
Net Stock Change	93,614	86,324	73,469	65,375	84,871	107,384	127,368	139,350	140,421	142,082	124,194	115,485	110,367	208,406	192,749