An Inventory of the Bioenergy Potential of British Columbia

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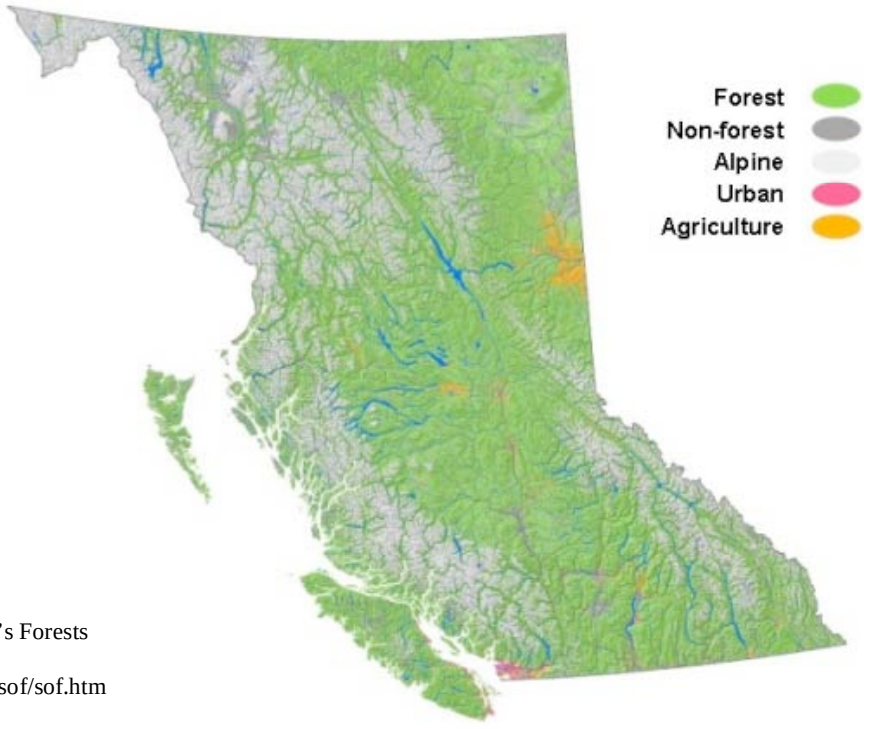


Image from British Columbia's Forests and Society: An Overview, http://www.for.gov.bc.ca/hfp/sof/sof.htm

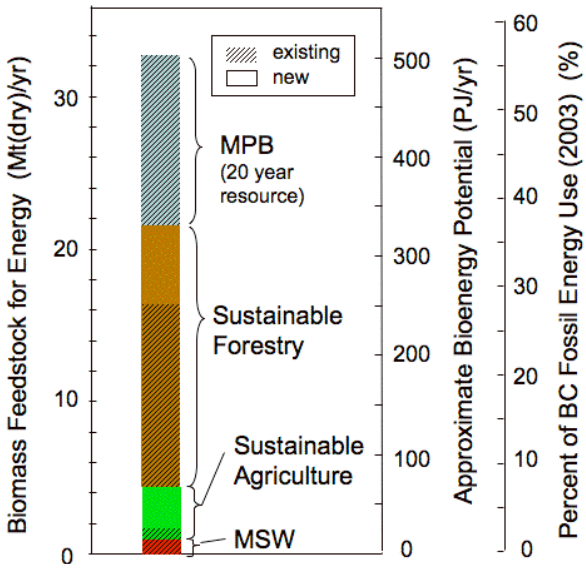
Executive Summary

The province of British Columbia has the potential to create a bioenergy resource sufficient to provide over 50% of its current fossil energy needs (920 PJ/yr). The 32 million dry tonnes of biomass per yr (Mt(dry)/yr) needed to achieve this goal could come from existing and new biomass resources associated with forestry, agriculture and municipal waste streams.

Potential biomass sources include:

- Municipal wastes from larger communities could provide about 948 Kt(dry)/yr or about 1.6% of the provincial fossil energy demand;
- Animal manure and residues from existing crop production systems could provide about 532 Kt of biomass per year (0.9% of energy demand);
- The planting of new biomass crops (e.g. switchgrass, miscanthus, willow, hemp) on converted or new agricultural lands could provide 2.7 Mt (dry)/yr, sufficient to provide about 4.8% of the province's fossil energy demand;
- Forest residues from the existing sustainable forestry operations in the province were estimated to be able to contribute about 12 Mt(dry).yr, sufficient to contribute almost 21% of the provinces's fossil energy demand;
- Improved silvicultural practices to increase forest productivity by 20% would provide an additional 5.1Mt(dry)/yr, or about 9% of energy demand even when half the enhanced productivity was directed to traditional forest products;
- Accessing new residues and unusable dead trees associated with the mountain pine beetle infestation was estimated to be able to provide an additional 11 Mt(dry)/yr for the next 20 years, sufficient to provide about 19% of the province's energy needs.

The bioenergy potential of British Columbia



Developing the policies, infrastructure, technologies and investment climate to access this major resource would have a number of benefits including:

- Reduced greenhouse gas emissions associated with fossil fuel use;
- Improved air and water quality associated with the use of biofuels and by keeping organic materials out of landfill sites;
- Enhanced energy security for the province, nation and continent as a result of more home-grown energy;
- Stimulated rural economy

Introduction

This study was carried out to provide an estimate of the potential that British Columbia has for the sustainable production of biomass as a source of renewable energy. Four sources were considered: Municipal Solid Waste, Sustainable Agriculture, Sustainable Forestry and the supply of dead forest biomass that has resulted from the mountain pine beetle infestation.

For each resource an estimate has been made of the magnitude of the accessible existing resource, as well as what could be produced as a result of new initiatives over the next 20-30 years given known management strategies and technologies. The estimates of existing biomass feedstocks have been discounted to allow for what is likely to be accessible and the estimates of new biomass feedstock potential are conservative given concerns about impacts on biodiversity and other values for forest and agricultural ecosystems.

Methods

Peer-reviewed publications, government (provincial and federal) reports, the Statistic Canada website (www.statscan.ca) and a number of web sites from industry groups and non-governmental organizations were used to generate the values reported here. The sources for data and conversion factors were as reported in footnotes to the text and tables included in this document. The software program, Microsoft Excel, was used for the calculations.

In this study, the thermal energy content of biomass was estimated as the Lower Heat Values (LHV), thereby taking into account the adverse effect of tissue water content on extractable thermal energy. The LHV values were calculated from Higher Heat values (HHV) and estimates of the elemental and water composition of biomass using the equations provided in van der Broek *et al.* (1995)[1]. For example, assuming a HHV for wood of about 20 GJ/t(dry)[2], and 44% water content, LHV was estimated to be 16 GJ/t(dry)[2]. In contrast, agricultural crops with a HHV of about 18 GJ/t(dry) and 16% water content[3] had an estimated LHV that was also 16 GJ/t(dry)[2]. LHV values for other biomass feedstocks such as municipal wastes or manure were drawn from the literature and will be discussed and referenced when relevant.

For comparative purposes, the LHV for energy content in biomass has been compared to total current fossil energy demand in the province, estimated as 920 PJ/yr[4] where 1 PJ = 10^{15} J = 10^{6} GJ.

Inventory Assumptions and Results

A. Municipal Solid Waste

The province of British Columbia generated approximately 2.6[5] Mt of MSW in 2002, of which 2.1 Mt was linked with larger communities and therefore potentially accessible for collection and energy conversion (Table 1).

A 28% recycling rate was assumed for the potentially accessible MSW, and the remainder of the material was assumed to be 80% combustible. Finally, assuming this combustible biomass has 22.5% water, we calculated that about 948 Kt(dry) MSW per year could be made available for energy conversion.

Assuming 16 GJ/t(dry) the calculated bioenergy potential of BC MSW was **15.2 PJ/yr**, or about 1.6% of the fossil fuel energy demand of the province.

Table 1. The bioenergy potential of Municipal Solid Waste

Item #		Units	Value
To enhance production of traditional forest products			
a	Total MSW Generated in BC (in 2002)	t/yr	2,598,558
b	MSW Generated in larger communities	t/yr	2,124,664
c	Recycling Rate	%	28.0%
d	Proportion Combustable in non-recycled	%	80.0%
e	Water Content in non-recycled	%	22.5%
f	Available MSW	t(dry)/yr	948,450
g	Energy Content	GJ/t(dry)	16
h	Bioenergy Potential	PJ/yr	15.2

a From Source: BC Municipal solid waste tracking report 2001/2002- http://www.solidwastemag.com/PostedDocuments/PDFs/2005/AugSep/BCwastetracking2000.pdf#search=%22BC%20municipal%20tracking%20report%22.
b limited to >25K persons/community and a density of >10 persons/km2
c Assumed rate (see Klass, D.L. Biomass for renewable energy, fuels and chemicals. USA: Academic press, 1998)
d Includes biomass and some plastics
e Assumed rate (see Klass, D.L. 1998)
f Calculated as Items (bX(1-c)XdX(1-e))
g Conservative value - especially if high plastic content
h Calculated as Item f X Item g

[1] van den Broek, R. Faaij, A., van Wijk, A. Biomass combustion power generation technologies. Report commissioned by CEC-DG-XII, 102 pp. (No. 95029), Department of Science, Technology and Society, Utrecht University, Netherlands, 1995. http://www.chem.uu.nl/nws/www/publica/95029.htm.

[2] Layzell, D.B, Stephen, J., Wood, S.M. Exploring the potential for biomass power in Ontario: A response to the OPA supply mix advice report. February, 2006. Available at http://www.biocap.ca/files/Ont_bioenergy_OPA_Feb23_final.pdf.

[3] Kumar, A., Cameron, A.B., Flynn, P. C. 2004. Pipeline transport of biomass. Applied biochemistry and biotechnology 113: 27-39.

[4] Statistics Canada CANSIM table 128-0009

[5] BC Municipal solid waste tracking report 2001/2002- http://www.solidwastemag.com/PostedDocuments/PDFs/2005/AugSep/BCwastetracking2000.pdf#search=%22BC%20municipal%20tracking%20report%22

B. Sustainable Agricultural Sources

Crop residues: In BC about 585,100 ha of crop land were sown in 2001 (Table 2) and this land area yielded about 2,310 Kt of grains (wheat, oats, barley, rye, canola and mixed grains), tame hay and fodder corn. When the water content of the biomass was taken into consideration, the agricultural yield of BC was estimated at 1,424 Kt (dry) per yr.

In grain crops, the grain yield accounts for only about 50% of the above-ground dry biomass in the entire crop (i.e. the harvest index), whereas in hay and fodder crops, virtually all of the above ground portion of the crop is taken as yield. Consequently, total residue was estimated to be 288 Kt(dry) per year (Table 2).

Table 2. BC crop production in 2001, and estimate of residue that could be used for bioenergy.

Crop	Area(1)	Production (2)	Water Content (3)	Dry Matter Production (4)	Harvest Index (5)	Total Residue (6)	Removable Residue (7)	Bioenergy Potential (8)
	ha	kt	%	kt(dry)	%	kt(dry)	kt(dry)	PJ/yr
Wheat	30,300	83.6	16%	70.2	50%	70.2	35.1	0.562
Oats	32,400	41.5	16%	34.9	50%	34.9	17.4	0.279
Barley	36,400	100.7	16%	84.6	50%	84.6	42.3	0.677
Rye	2,800	4.3	16%	3.6	50%	3.6	1.8	0.029
Mixed Grains	2,800	3.4	16%	2.9	50%	2.9	1.4	0.023
Canola	24,300	34.0	16%	28.6	50%	28.6	14.3	0.228
Tame hay	445,200	1,543.0	32%	1,049.2	95%	55.2	27.6	0.442
Fodder corn	10,900	499.0	70%	149.7	95%	7.9	3.9	0.063
Total	**585,100**	**2,310**		**1,423.6**		**287.8**	**143.9**	**2.302**

(1) http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table13Can.htm
(2) Ibid
(3) Assumed values
(4) Calculated as Production X (1-water content)
(5) Assumed values
(6) Calculated as (DM production/harvest index)-DM production
(7) Assumes 50% of total residue can be removed as a bioenergy feedstock
(8) Assumes 16 GJ/t(dry) in removable residue

Since some biomass must be left on the field to maintain soil carbon stocks, and there are current markets (e.g. animal bedding) for another portion of the residue, it was assumed that 50% of the total residue or 144 Kt(dry) would be available for use as a biomass energy resource. Assuming an energy content for this biomass of 16 GJ/t(dry), the bioenergy potential of crop residues in BC was estimated to be **2.3 PJ/yr** (Table 2).

Livestock manure: Averaged over the period 1995-2006, annual livestock numbers were about 2.7[6] million, including cattle, pigs, turkeys, sheep/lamb and other poultry. Given typical manure production rates per animal per year, total manure production was estimated at 1,380 Kt(dry)/yr, with 93% of this amount being attributed to the 760,000 cattle in the province.

Assuming that it was possible to recover 85% of the poultry and pig manure, but only 25% of the cattle manure and 10% of the sheep/lamb manure, it was estimated that 388 Kt(dry)/yr of manure would be available for use as a bioenergy resource. Energy content values (LHV) for manure reported in the literature[7] ranged from 13.5 GJ/t(dry) for poultry to 17.8 GJ/t for sheep/lamb. Using these values, manure from BC animal production was estimated to be able to contribute **6.06 PJ/yr** to the province's bioenergy potential.

Table 3. Average annual production of livestock manure from 1995-2006, and estimate of potential contribution to bioenergy.

Livestock type	Head (1)	Manure Production Rate (2)	Total Manure (3)	Recoverable (4)	Total Available (5)	Energy Content (6)	Bioenergy Potential (7)
	#/yr	t(dry)/head/yr	t(dry)/yr	%	t(dry)/yr	GJ/t	PJ/yr
Cattle	759,688	1.69	1,283,872	25.0%	320,968	15.7	5.039
Pigs	170,965	0.21	35,903	85.0%	30,517	17	0.519
Turkey	819,569	0.04	32,783	85.0%	27,865	13.5	0.376
Sheep and lamb	66,804	0.28	18,705	10.0%	1,871	17.8	0.033
Other poultry	847,617	0.01	8,476	85.0%	7,205	13.5	0.097
Total	2,664,643		1,379,739		388,426		**6.06**

(1) from Cattle: CANSIM table 003-0032; Pig: CANSIM table 003-0004; Sheep and lamb: CANSIM table 003-0031; Turkey and other poultry: http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table19Can.htm
(2) From Klass (1998)
(3) Calculated as # head X manure production rate
(4) From Helwig, T., Jannasch, R., Samson, R., DeMaio, A., Caumartin, D. 2002. Agricultural biomass residue inventories and conversion systems for energy production in Eastern Canada. NRCan Contract #23348-016095/001/SQ
(5) Calculated as Total Manure X % recoverable
(6) From Klass (1998)
(7) Calculated as Total Available X Energy Content

[6] Statistics Canada CANSIM tables 003-0032, 003-0004, 003-0031, http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table19Can.htm.
[7] Klass, D.L. 1998. Biomass for renewable energy, fuels, and chemicals. Academic Press. San Diego, USA, 651p.

Biomass crops on summerfallow land: In BC, about 36,765 ha of agricultural crop land is not planted to crops in any given year, but left as summerfallow. Assuming that 50% of this land could be used for the growth of biomass crops (e.g. switchgrass or *Miscanthus*) and the crops had a conservative yield of 8 t(dry)/ha/yr, this land area would generate about 147 Kt(dry)/y of biomass for energy. Assuming 16 GJ/t(dry), the potential would be **2.35 PJ/yr** of thermal energy from biomass on summerfallow land.

Biomass crops on new or converted agricultural land: The total farm land area in BC is about 2.6 Mha[8]. If 10% of this land were to be converted to biomass crop production or an equivalent amount of new agricultural land were to be brought into production, the resulting land area (258,712 ha) producing 10 t(dry)/ha/yr would yield 2.6 Mt(dry)/yr biomass for energy use. Assuming an energy content of 16 GJ/t(dry), the energy content of this biomass would be **41.4 PJ/yr**.

C. Sustainable Forest Sources

Forest residues: Of the 95 million ha of BC, about two thirds or 60 Mha[9], is forested land. Of this, 35 Mha are either under protection, uneconomic for harvest or inaccessible. Of the remaining 25 million ha, less than one percent – about 200,000 ha[10] - is available for timber production in any given year.

On average over the period 1993-2002, BC's forests produced 74 Mm^3/yr[11] of roundwood (Table 4), an amount equivalent to 40% of Canada's average roundwoood production of about 184 Mm^3/yr. (Production from 2003-2006 has not been included in this calculation since roundwood harvest for these years included an allocation for mountain pine beetle wood, and that is considered separately in this analysis).

Assuming a wet wood density of 0.96 t/m^3 and 44% water content, the 74 Mm^3/yr would have a mass of 39.8 Mt(dry)/yr. Assuming that 30% of the entire forest harvest was residue, and that 70% of this could be removed as a bioenergy feedstock (taking into account the need to conserve soil nutrients, carbon stocks and biodiversity habitat), approximately 11.9 Mt(dry) biomass per yr would be available as a bioenergy feedstock (Table 4). Given 16 GJ/t(dry), the bioenergy potential of the residual forest biomass in BC would be about **191 PJ/yr**.

Table 4. Calculation of the potential contribution of BC's forest residues to the province's bioenergy potential.

Item #		Units	Value
a	Industrial Roundwood volume	Mm3/yr	74.0
b	Industrial Roundwood dry matter	Mt(dry)/yr	39.8
c	Residue as % of total biomass in harvest	%	30%
d	Total Residue	Mt(dry)/yr	17.1
e	Proportion of residues that could be removed sustainably	%	70%
f	Sustainably removable residue	Mt(dry)/yr	11.9
g	Energy Content	GJ/t(dry)	16
h	Bioenergy Potential	PJ/yr	191.0

a From Natural Resources Canada: http://www2.nrcan.gc.ca/cfs-scf/selfor/members/section1/I-2print.asp?lang=en&prv=9
b Calculated as 0.96 t/m3 X (1-0.44(water content)) X Item a
c From Smart Generation: Powering Ontario with Renewable Energy. 2004, David Suzuki Foundation http://www.davidsuzuki.org/files/Climate/Ontario/Smart_Generation_full_report.pdf)
d Calculated as (Item b X Item c)/(1-Item c);
e Assumed value;
f Calculated as (Item d X Item e);
g Assumes 44% water content - See General methods
h Calculated as Item g X Item f

Enhanced silvicultural practices: Silvicultural practices include stand establishment, site preparation, pre-commercial thinning, early tree removal, intermediate cuttings, stand and site rehabilitation, residue recovery and inferior tree removal, and replanting after harvest with high quality seed stock.[12] These activities are known to increase the longer-term productivity of forests by as much as two-fold or more compared with current practices.[13]

[8] Source: Statistics Canada http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table5Can.htm#59
[9] British Columbia's Forests and Society: An Overview, http://www.for.gov.bc.ca/hfp/sof/sof.htm
[10] Vold, T. Ministry of forests. Experience developing a results based forest practices code for British Columbia, Canada. Presented at the XII World Forestry Congress in Quebec City, 2003. Available at www.for.gov.bc.ca/hfp/publications/00194/WFC_RBC_Paper.pdf
[11] Natural resources Canada http://www2.nrcan.gc.ca/cfs-scf/selfor/members/section1/I-2print.asp?lang=en&prv=9
[12] Manley A, Richardson J. Silviculture and economic benefits of producing wood energy from conventional forestry systems and measures to mitigate negative impacts. Biomass and Bioenergy 1995;9:89-105.
[13] Layzell, D.B. and J.D. Stephen. 2006. Linking Biomass Energy to Biosphere Greenhouse Gas Management, pp. 217-232, *in* [Bhatti, J.S., R. Lal, M.J. Apps and M.A. Price, eds.] Climate Change and Managed Ecosystems. CRC Press, Boca Raton, 446 pp.

Improved silvicultural practices could be used to increase the production of traditional forest products (lumber, pulp and paper) or to establish fast growing plantations could be used as feedstocks for bioenergy. If enhanced silvicultural practices were to lead to a 20% increase in current forest productivity, 10% of this could be directed to the production of additional forest products and 10% for the production of fast growing bioenergy plantations (Table 5).

An increase in annual roundwood production for wood products in BC would increase the availability of residues for use as bioenergy feedstocks. With a 10% increase in forest productivity, 1.2 Mt(dry) / yr sustainably removable residue would be generated with a bioenergy potential of about **19.1 PJ/yr**.

With an additional 10% increase in forest productivity where all the biomass was directed to bioenergy use, 4.0 Mt(dry) biomass/yr could be provided as an energy resource, an amount of biomass with a bionergy potential of **63.7 PJ/yr**.

Table 5. The potential for enhanced silvicultural practices to provide bioenergy feedstocks in BC.

Item #	Units	Value
To enhance production of traditional forest products		
a Percent Enhancement	%	10%
b Industral Roundwood dry matter	Mt(dry)/yr	4.0
c Residue as % of total biomass in harvest	%	30%
d Total Residue	Mt(dry)/yr	1.7
e Proportion of residues that could be removed sustainably	%	70%
f Sustainably removable residue	Mt(dry)/yr	1.2
g Energy Content	GJ/t(dry)	16
h Bioenergy Potential	PJ/yr	19.1
To produce fast growing trees for energy production		
I Percent Enhancement	%	10%
j Industral Roundwood dry matter	Mt(dry)/yr	4.0
k Energy Content	GJ/t(dry)	16
l Bioenergy Potential	PJ/yr	63.7

a Assumed impact of Silviculture on sustainable forest harvest
b-h, Similar to Table 4
i Assumed impact of Silviculture on sustainable forest harvest
j Calculated as Item i X Table 4, Item b
k Assumes 44% water content, see General Methods

D. Mountain Pine Beetle (MPB) Wood: a temporary bioenergy resource

Mild winters in recent years have resulted in an explosion in the population of Mountain Pine Beetles that have left a major devastation in their wake. The province has increased the annual allowable cut to encourage use of the forest resource before it catches on fire or decays. During this period (estimated at 10 to 20 years), there will be additional forest residues that could be directed for energy production. However, there will also be excess, non-recoverable forest resources that could be directed towards energy extraction. Both these options will be considered here.

Table 6. The potential for bioenergy feedstocks from residues linked to an increased allowable cut of MPB trees.

Item #	Units	Value
a Recoverable MPB wood - volume	Mm3	417
b Recoverable MPB wood - dry weight	Mt(dry)	224.2
c Residue as % of total biomass in harvest	%	30%
d Total Residue	Mt(dry)	67.3
e Prop. of residues that could be removed sustainably	%	70%
f Sustainably removable residue	Mt(dry)	47.1
g Years for Harvest	yrs	20
h Removable, non-recoverable biomass	Mt(dry)/yr	2.4
I Energy Content	GJ/t(dry)	16
j Bioenergy Potential	PJ/yr	37.7

a Source: Eng M, Fall A, Hughes J, Shore T, Riel B, Walton A, Hall P. April 21, 2006. Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the projection of non-recovered losses for the reference management scenario- Based on the 2005 Provincial Aerial Overview of Forest Health and revisions to „the model‰ (BCMPB.v3). http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v3.ReferenceScenario.Update.pdf
b Assumes density of 0.96 t/m3 when the wood had water content of 44%
c Assumes 70% of forest harvest is roundwood, 30% residue
d Calculated as Item b X Item c
e Assumed value as per Table 4
f Calculated at Item d X Item e
g Assumed value - the biomass may need to be harvested more quickly and stockpiled
h Calculated as Item f / Item g
i Conservative value, especially with the low water content of biomass
j Calculated as Item h X Item i

Residues from increased harvest of MPB-killed trees. Table 6 provides an assessment of how the increased harvest of MPB-killed trees for traditional wood products might impact the availability of residues as a bioenergy feedstock. Provincial estimates have suggested that 417 Mm^3 of dead pine could be harvested for traditional wood products over the next 20 years. This harvest would leave a forest residue of 47.1 Mt(dry) biomass, or sufficient for 2.4 Mt(dry) to be converted into energy every year for this period (Table 6). This would provide an additional **37.7 PJ/yr** of biomass energy potential.

It is worth noting that these numbers assume that the forest sector is able to take advantage of the increased annual allowable cut associated with MPB-killed trees. If this is not likely to be the case, as has been suggested recently then the untapped AAC would become non-recoverable biomass and even greater volumes would be available for energy conversion.

Non-recoverable MPB-killed biomass as a bioenergy resource. Provincial estimates have suggested that at least 358 Mm^3 of dead MPB wood will be non-recoverable for traditional forest products and therefore be available as an energy resource over the next 20 years[14].

Table 7 summarizes the implications of using this volume of wood as an energy resource. The excess (non-recoverable) wood volume would equate to 173.2 Mt(dry) biomass, or 8.7 Mt(dry)/yr for each of 20 years.

This annual harvest of biomass could provide about **139 PJ/yr** of biomass energy, an amount equivalent to 15% of the provinces current fossil fuel use.

Table 7. The potential for bioenergy feedstocks from excess (non-recoverable) MPB wood in British Columbia.

Item #		Units	Value
a	Excess MPB wood - volume	Mm3	358
b	Excess MPB wood - dry weight	Mt(dry)	192.5
c	Proportion that can be sustainably removed	%	90%
d	Total removable, excess biomass	Mt(dry)	173.2
e	Years for Harvest	yrs	20
f	Annual removable, excess biomass	Mt(dry)/yr	8.7
g	Energy Content	GJ/t(dry)	16
h	Bioenergy Potential	PJ/yr	138.6

a Source: Eng M, Fall A, Hughes J, Shore T, Riel B, Walton A, Hall P. April 21, 2006. Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the projection of non-recovered losses for the reference management scenario- Based on the 2005 Provincial Aerial Overview of Forest Health and revisions to „the model‰ (BCMPB.v3). http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v3.ReferenceScenario.Update.pdf
b Assumes a density of 0.96 t/m3 when the wood had water content of 44%
c Assumes whole, dead tree harvest, leaving 10% for nutrient and soil carbon
d Calculated as Item b X Item c
e Assumed value - the biomass may need to be harvested more quickly and stockpiled
f Calculated at Item d / Item e
g Conservative value, especially with the low water content of biomass
h Calculated as Item f X Item g

Summary and Conclusions

The analysis carried out here clearly shows that the Province of British Columbia has very large biomass resources which, if tapped, could provide over 50% of the current fossil energy demand in the province (920 PJ/yr). The 32.3 Mt(dry) biomass/yr estimated in this report is about 80%-90% of the annual roundwood harvest in the province over the period1993-2003.

In energy terms, this amount of biomass would be sufficient to maintain about 8000 MW of power generation at 80% capacity and 39% efficiency (typical of large combustion power generation facilities). (However, power generation may not be the optimal way to use this large biological resource.)

The trees killed in the Mountain Pine Beetle (MPB) infestation in the province could provide 11 Mt(dry) biomass/yr for 20 years, or about 19% of the province's fossil energy demand for this period (Table 8). The majority of this would be from whole tree harvest of 'non-recoverable' pine, but there would also

Table 8. The bioenergy potential of British Columbia. The current fossil energy demand in the province is 920 PJ/yr.

Biomass Feedstock	Resource Size (dry t/yr)	Bioenergy potential (PJ/yr)	% of Potential	% of total fossil energy
Municipal Solid Waste				
MSW	**948,450**	**15.2**	**2.9%**	**1.6%**
Sustainable Agriculture				
Crop residues	143,901	2.3	0.4%	0.3%
Livestock manure	388,426	6.1	1.2%	0.7%
Biomass Crops on summerfallow land	147,060	2.4	0.5%	0.3%
Biomass Crops on new /converted land	2,587,118	41.4	8.0%	4.5%
TOTAL SUSTAINABLE AGRICULTURE	**3,266,505**	**52.1**	**10.1%**	**5.7%**
Sustainable Forestry				
Forest residues	11,940,429	191.0	36.9%	20.8%
Enhanced silviculture for traditional forest products	1,194,043	19.1	3.7%	2.1%
Enhanced silviculture for bioenergy plantations	3,980,143	63.7	12.3%	6.9%
TOTAL SUSTAINABLE FORESTRY	**17,114,615**	**273.8**	**52.9%**	**29.8%**
Mountain Pine Beetle: A Temporary (20 yr) Resource				
Residue from increased AAC to harvest dead pine	2,353,882	37.7	7.3%	4.1%
Whole tree harvest of non-recoverable pine	8,660,736	138.6	26.8%	15.1%
TOTAL MPB FOR BIOENERGY	**11,014,618**	**176.2**	**34.1%**	**19.2%**
Total potential	**32,344,188**	**517.4**	**100%**	**56.2%**

[14] Source: Eng M, Fall A, Hughes J, Shore T, Riel B, Walton A, Hall P. April 21, 2006. Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the projection of non-recovered losses for the reference management scenario- Based on the 2005 Provincial Aerial Overview of Forest Health and revisions to „the model‰ (BCMPB.v3). http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v3.ReferenceScenario.Update.pdf

be a contribution from the residue associated with the increased Annual Allowable Cut (AAC) of MPB wood linked to more traditional forest products.

As for the long-term, sustainable production of biomass for energy, the study showed that municipal waste streams and sustainable agriculture and forestry could provide about 37% of the province's current fossil energy needs. Sustainable forestry – including enhanced use of existing residues, and more intensive forest management practices, were estimated to be able to provide about 17 Mt (dry) biomass per year, or about 30% of the province's current fossil energy demand.

In comparison with forestry, the agricultural sector in the province is relatively small, but it was estimated to be able to provide 5.7% of the province's fossil energy demand (3.3 Mt(dry)/yr, Table 8) , especially if land could be allocated for the cultivation of fast growing biomass crops.

As for the municipal solid waste stream, the analysis estimates that it could provide 948,000 t(dry)/yr or about 1.6% of the province's current fossil energy demand.

This analysis is conservative, especially in terms of the additional forest management strategies that could be implemented to increase biomass production for use as an energy resource. However, the report does provide details of how the calculations were done, so readers could easily adjust the numbers if they would like to incorporate different assumptions.