BC hydro

2013 Resource Options Report Update

Appendix 6

Wood Based Biomass Potential Report

Wood Biomass Energy Potential of British Columbia

Prepared for

BC Hydro's Integrated Resource Planning Process

May 2013

EXECUTIVE SUMMARY

This report was completed in support of BC Hydro's Integrated Resource Planning Process. The data in this report is the result of an updated analysis and associated report that was provided to BC Hydro in December 2010. The analysis forecasts the availability of woody biomass fuels, with associated cost, that may be used for electricity generation over a twenty-eight year period. The analysis was completed using a comprehensive model that links existing and forecast regional fibre supplies (i.e., logs, roadside waste and sawmill residues) throughout the Province, with historic and forecast fibre demands by the existing forest industry.[1] Provincial fibre supplies that are surplus to the demands of the forest industry were presumed available as biomass fuel for energy production.

Tree mortality as a result of the mountain pine beetle epidemic, the flow of fibre between regions, the operating capacity of the forest industry (e.g., sawmills, plywood plants, pulp mills, pellet mills, bioenergy plants, etc.), the economic drivers that determine mill operating rates and the supply of residual fibre that results from the processing of timber were all quantified as part of this analysis. Forecasting regional fibre supply was facilitated with technical input from the Forest Analysis and Inventory Branch of the Ministry of Forests Lands and Natural Resource Operations.

Available biomass supply was reported for a 13-year period (2013 to 2024) and a 15-year period (2025 to 2040). The first period corresponds to the transition and decline in BC Interior harvest levels as a result of the Mountain Pine Beetle epidemic. The second period represents the subsequent time when a stable mid-term harvest is forecast. Biomass supply was forecast for 13 regions throughout BC and collated to define potential biomass volume for the Province as-a-whole.

Three sources of woodwaste biomass were examined in this analysis: sawmill woodwaste (defined herein as "Category B"), roadside woodwaste (i.e., "Category C") and standing timber ("Category D").[2] Roadside woodwaste was further sub-divided into two sources - waste as a result of normal harvesting operations (roadside residue) and waste as a result of the Mountain Pine Beetle epidemic (pulp logs). Municipal solid waste was not reviewed.

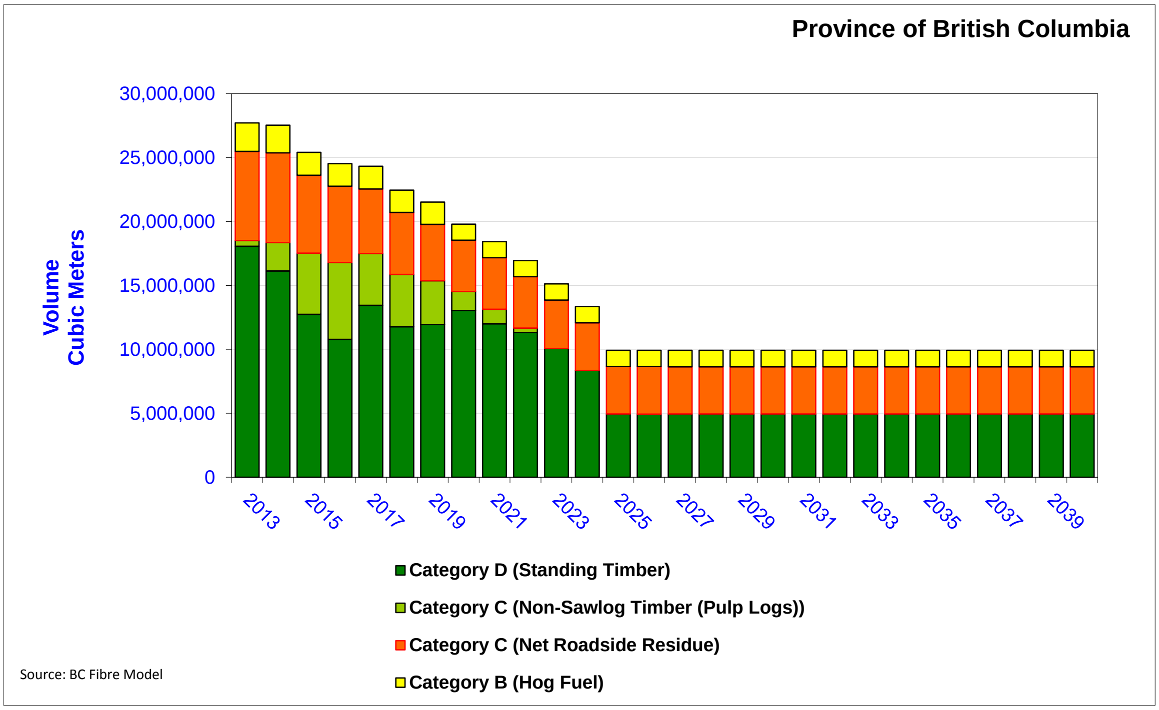
---

[1] The BC Fibre Model is used by most of the BC pulp mills and integrated forest products companies for strategic planning purposes.

[2] These biomass fuel categories correspond to the categories defined in BC Hydro's Phase I and Phase II Biomass Call for Power

The analysis demonstrates that the current volume of wood biomass potentially available for bioenergy production and surplus to the existing forest industry demand is about 27 million cubic metres. However, as a result of the change in supply following changes to the annual allowable cut and sawmilling activity, the volume of biomass potentially available for energy production should decline rapidly to about 10 million cubic metres by 2025. The volume of surplus biomass is forecast to remain at about 10 million cubic metres thereafter. Exhibit 1 forecasts the surplus wood biomass by type over a 28-year horizon.

Exhibit 1. Forecast of Available wood waste by Type



Based on this forecast, an estimated 11.9 TWh/year of energy equivalent is available for the 13-year period (2013 to 2024) and about 9.8 TWh/year thereafter (2025-2040). Exhibit 2 summarizes the energy and capacity potential, subdivided by fuel category, for BC. The availability of low cost sawmill woodwaste (Category B "hog fuel") provincially, is significant; however it is also widely scattered. Whether this biomass type alone can sustain a reasonably-sized bioenergy plant at a particular location in the province requires a regional analysis.

Cost of electricity generation from greenfield bioenergy plants is estimated to be (in Jan 2013 dollars) $84/MWh at 6%, $88/MWh at 7% and $93/MWh at 8% plus delivered fuel cost (using standard BC Hydro Resource Options Update financial assumptions, details of the derivation of this number are included in Appendix 1). The generation cost used for this report is $84/MWh at 6%. Delivered fuel cost includes: (1) commodity cost, which varies between regions and fuel categories; (2) delivery cost, which varies based on average regional transportation distance; and (3) cost for conversion to feedstock suitable for power generation. To estimate delivery cost, hypothetical plant locations were assumed for each Region (these locations are identified in Exhibit 3).

Exhibit 2 shows the cost of electricity by fuel type categories (i.e. weighted-average across all regions). In the current period, the cost of electricity generation using standing timber is $208/MWh as compared to $107/MWh when sawmill woodwaste (i.e., hog fuel) is used.

The determination of available unused biomass fuel within the province was calculated on a regional level, to ensure the fibre supply demands of the existing forest industry were recognized, localized and forecast in consideration for changes to the annual allowable cut. Exhibit 3 provides detail on the estimated potential volume (by fuel type) of sustainable bioenergy that currently exists within each planning Region (GWh/year). Also summarized in Exhibit 3 is the Provincial weighted-average delivered fuel cost ($/MWh) and total delivered cost of electricity.

Exhibit 3 demonstrates that the majority of the electricity potential lies in Category D, existing unused standing timber (8 TWh/year). Were this not included in the analysis, the forecast biomass electricity potential for the first 13-year period would drop from 12 TWh/year to 4 TWh/year.

Exhibit 2 Annual Available Biomass by Fuel Category, Period and Cost

Biomass Type	Potential Capacity (MW)		Annual Energy (GWh/year)		Estimated Cost ($/MWh)	
Forecast Period	2013 - 2024	2025 - 2040	2013 - 2024	2025 - 2040	2013 - 2024	2025 - 2040
Category D (Standing Timber)	906	692	7,930	6,070	$208	$216
Category C (Pulp Logs)	125	76	1,090	670	$134	$135
Category C (Roadside Residue)	249	265	2,180	2,320	$134	$134
Category B (Hog Fuel)	81	84	710	730	$107	$107
Total	**1,360**	**1,117**	**11,910**	**9,790**		

Exhibit 3. Available Biomass by Type, Region and Period

Biomass Type	Sawmill Waste		Roadside Residues and Pulplogs		Weighted-average for Sawmill waste, Roadside Residues and Pulplogs	Standing Timber		Sawmill Waste		Roadside Residues and Pulplogs		Weighted-average for Sawmill waste, Roadside Residues and Pulplogs	Standing Timber	
Region	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)
Coast - Mainland	188	$22	1,054	$48	$44	4,291	$143	209	$22	1,205	$48	$44	3,924	$143
East Kootenay	0	$18	225	$50	$50	12	$78	0	$18	225	$50	$50	0	$78
West Kootenay	241	$25	283	$58	$43	0	$85	246	$25	284	$58	$43	0	$85
Kamloops/Okanagan	0	$27	493	$53	$53	52	$85	0	$27	476	$53	$53	0	$85
Cariboo	0	$19	0	$45	n/a	319	$85	0	$19	0	$45	n/a	0	$85
Prince George	0	$21	416	$48	$48	921	$85	0	$21	106	$48	$48	0	$85
Mackenzie	0	$7	181	$48	$48	121	$88	0	$7	325	$48	$48	0	$88
South Peace	191	$29	255	$54	$43	30	$85	191	$29	255	$54	$43	11	$85
North-east	0	$4	0	$48	n/a	368	$99	0	$4	0	$48	n/a	368	$99
East Prince Rupert	43	$17	332	$48	$45	37	$81	43	$17	55	$48	$34	0	$81
West Prince Rupert	42	$18	34	$47	$31	1,611	$117	44	$18	53	$47	$34	1,589	$117
North-west	0	$18	0	$54	n/a	173	$90	0	$18	0	$54	n/a	173	$90
Total GWh per year and weighted-average cost	706	$24	3,273	$50	$46	7,935	$122	734	$19	2,984	$38	$44	6,065	$107

Industrial Forestry Service Ltd.

i

The analysis resulted in five primary conclusions.

1. Significant volumes of wood biomass that are surplus to the demand of forest industry exist. When all fibre categories are considered this volume equates to approximately 12 TWh of annual electricity potential during the first period and 9.8 TWh annually thereafter.
2. There are significant volumes of lower-cost fibre (sawmill woodwaste and roadside woodwaste) surplus to the current demand of existing industries. About 2.9 TWh/year worth province-wide. However, these fuels are scattered around the province and may not sustain many reasonably-sized plants at particular locations.
3. Much of the available standing timber exists as fibre in Coastal regions where it is currently uneconomic to harvest this fibre even for lumber production.
4. There is currently a 12-year surplus of fibre. After this time, available fibre is forecast to become scarce in many BC interior regions.
5. Cost of electricity from woody biomass can vary substantially, depending on the fibre types (fuel profile) that are utilized over the life of a plant.

List of Acronyms

AAC	Allowable Annual Cut
Biomass	An energy resource fuelled by the combustion of organic materials
BC	British Columbia
BCTMP	Bleached Chemi Thermo Mechanical Pulp
BCTS	British Columbia Timber Sales
Canfor	Canadian Forest Products Ltd.
Category B	Fuel type category used by BC Hydro in the Biomass Call for Power to describe sawmill residues
Category C	Fuel type category used by BC Hydro in the Biomass Call for Power to describe logging residues
Category D	Fuel type category used by BC Hydro in the Biomass Call for Power to describe standing timber
GIS	Geographic Information Systems
GJ	Giga Joule
GW	Giga Watt
ha	Hectare
Hog	Bark and Waste wood. Used to describe wood that has been processed through a "hogger" and ground into chunks.
BCH	British Columbia Hydro
IFS	Industrial Forestry Service Ltd.
IPP	Independent Power Producer
LP Canada	Louisiana Pacific Canada
m3	Cubic metre of wood.
MDF	Medium Density Fibreboard (panels used in house construction)
MFBM	Thousand Foot Board Measure (used to quantify lumber production)
MOF	Ministry of Forests, (Lands and Natural Resource Operations)
FLNRO	Ministry of Forests, Lands and Natural Resource Operations
MPB	Mountain Pine Beetle
MS	Microsoft
MSW	Municipal Solid Waste
MW	Mega Watt
MWh	Mega Watt hour
NBSK	Northern Bleached Softwood Kraft pulp
ODT	Oven Dry Tonne
OSB	Oriented Strand Board (in sheets similar to plywood)
Partition	Mechanism used by the FLNRO to split an AAC
SPF	Spruce, pine, Douglas fir
TFL	Tree Farm License
TSA	Timber Supply Area
TWh	Terawatt hour (equal to 1000 Gigawatts)

Energy Conversion Assumptions and
Key Assumptions for a Hypothetical Bioenergy Plant

1) 2.45 cubic metres of wood = 1 oven dry tonnes of wood at 0% moisture.

2) 1 MWh electricity requires 0.72 oven dry tonnes of wood biomass.

3) A Greenfield bioenergy plant costs $4.74 million per MW of capacity in Jan 2013$.

4) Annual cost to operate a biomass plant is 3.5% of capital. This includes operating, maintenance, taxes and miscellaneous expenses.

5) Plant amortization period was assumed to be 15 years.

6) Electric capacity factor is normally about 91%. Capacity values provided in this report do not reflect this capacity factor, they are gross values.

7) 6 percent was used as a discount rate and real cost of capital.

8) Annual operating hours were assumed to be 8,760 hours per year

9) Project lead time was assumed at 2 years (construction and major capital spending)

10) Selling price of electrical power to BC Hydro was assumed to be $84/MWh + delivered fuel cost. (See Appendix 1 for more details)

11) Annual allowable cuts, dead pine shelf life and harvest partitions were estimated in consultation with the Ministry of Forests ,Lands and Natural Resource Operations

12) Existing and future lumber industry demand, pulp mill demand, pellet mill demand, board plant demand was forecast using the proprietary “BC Fibre Model”.

13) Fuel demand from projects resulting from the BC Hydro Biomass Phase 1 Call for Power, the Integrated Power Offer, Community Based Biomass and the Conifex Power offer were incorporated in current and future demand.

14) Forecasts of the annual supply of available biomass were converted to a single sustainable volume by fuel (by fuel type category for each period studied) as follows:
    a. Category B – hog fuel was estimated as the average amount available over each 15-year period.
    b. Category C fuel was calculated as the average over every 3-year period and the lowest 3-year running average in each period was used.
    c. Category D Standing Timber was estimated as the average amount available over each period.

15) Urban and refuse-based biomass fuels were not incorporated in this analysis.

TABLE OF CONTENTS

List of Figures

List of Tables

List of Maps

Wood Biomass Energy Potential of British Columbia

1.0 Introduction

This report is an updated version of a previous paper completed for BC Hydro in support of its Integrated Resource Planning process. It provides background information on biomass resources that might be considered to meet future electricity capacity and energy needs. Potential biomass, in the context of this report, is defined as the amount of biomass that can be obtained directly or indirectly from the forest and that could be converted to electricity *after* consideration is given to the current and future supply and demand for wood fibre by the existing forest industry.[3]

The biomass supply forecasts were completed using data outputs from the proprietary "BC Fibre Model". This Model was designed to provide regional assessments of log, chip, minor residual fibre and biomass availability at a strategic level over a 28-year planning horizon. The theoretical construct and underlying database of the BC Fibre Model provides a representative snapshot of the BC forest industry. The Model and associated database have been extensively reviewed and acknowledged by all significant forest companies in BC, as well as B.C. Hydro and the Ministry of Forest and Lands and Natural Resource Operations. The Model is used on an ongoing basis by several of these companies to facilitate long-term strategic planning. Inherently, such a model requires considerable detailed knowledge of the forest industry across the Province; as well as assumptions on the social, biological, and economic factors that may affect the forest industry. A detailed description of these assumptions is outside the scope of this report.

[3] Municipal solid waste (MSW) and biogas generated from landfills are not quantified in this forecast.

2.0 Assignment Scope

The assignment scope was the determination of long-term biomass electricity potential within B.C. for the next 28-year period. The process involved updating an earlier version of this report that was produced in 2010 as part of BC Hydro's Integrated Resource Planning process. Much of the structure and the text in this report have remained unchanged since version 1, however all of the graphs and tables have been updated to incorporate, across all regions. These changes include:

- Changes in Crown land harvest forecasts based upon new government and industry analyses.
- Changes in private land harvest forecasts based upon actual harvests experienced over the past 5 years.
- Updates on sawmill closures (and ownership changes).
- All mid-term sawmill operating rates were adjusted to reflect the forecast availability of sawlogs in each region in the mid-term. Where deemed appropriate, sawmill closures were forecast to balance sawlog supply with demand.
- All regional fibre transfers and fibre imports from outside BC (logs, chips, sawdust, shavings and hog fuel) were updated based upon known purchase/sale agreements.
- The results of biomass fibre demands progressing from BC Hydro's Phase 1 and Phase 2 Biomass Calls for Power, Integrated Power Offer and Community Based Biomass Call, and the Conifex Power offer have been incorporated into the future fibre demands of the industry – thereby reducing overall biomass supply from the 2010 forecast.
- All estimates of regional delivered fibre costs were updated based upon the author's industry knowledge of current rates.

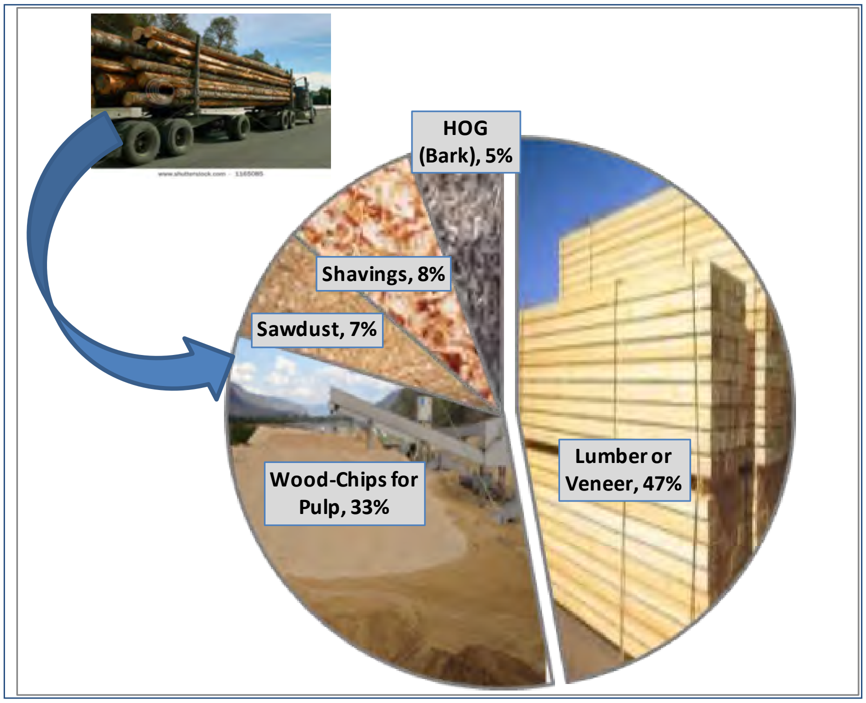
To predict biomass potential, the assignment required a review of Provincial biomass supplies (by region), demands on this supply by existing industry and lastly identification of surplus biomass potential. Long-term potential in terms of electrical production from the conversion of surplus biomass into electricity was quantified in terms of potential supply and cost. The uncertainty to this potential supply if sawmills re-direct waste biomass to internal uses is discussed, as well as the opportunity to acquire additional biomass supplies from lumber re-manufacturing facilities.

A second report was also prepared that examined the variables that independent power producers (IPP) might consider when developing business plans centered on the construction of a green-field biomass-to-electricity project. That report serves as the basis for calculating cost of biomass energy project before delivered fuel cost (see Appendix 1).

3.0 B.C. Forest Industry - Sector Overview

Trees in British Columbia are generally older and slower growing than those found in the USA. As a result, BC trees possess physical characteristics that are highly desired in the production of both pulp (for paper manufacturing) and lumber (for house construction). The age and characteristics of these trees results in shapes that are far from a perfect cylinder. Trees are often prone to defects such as cracks, stain, rot, decay, and geometric irregularities. Production of lumber from these imperfect shapes results in considerable waste. Only about 45 percent of the volume in every log that reaches a sawmill is converted into saleable lumber. The rest of the log is waste material that the sawmill must dispose of. Wood waste material exists in several forms. *Bark* is removed from the log prior to it entering a sawmill. The *slabs* that comprise the outer sides of a log are converted into *wood chips*. *Sawdust* is created by cutting a square or rectangular 'cant' into dimensional lumber. *Shavings* are created after the lumber has been dried and is planed to provide a smooth finish. Figure 1 shows the average proportional distribution of products and by-products from an average sawlog entering and exiting a primary breakdown mill (e.g., sawmill).

Figure 1. The Component Parts of an Average Sawlog



Disposal of solid wood industry by-products (comprising roughly 55% of every log) has led to the creation of several synergetic industries. The pulp and paper industry in BC developed decades ago as an outlet for the **Wood Chips** that are used in the production of market pulp. This industry pays a premium price for a secure chip supply. In many cases, pulp mills have developed long-term exclusive control over the wood chips produced by regional sawmills. These chip supply agreements have greatly benefited sawmills, providing a steady source of revenue that in poor lumber markets may approach 20 percent of a sawmill's gross revenue.

Historically, disposal of minor residual wood supplies (sawdust, shavings and bark) has been a constant challenge due to lack of demand for these by-products and the environmentally sensitive issues around storage or disposal. Until recently, incineration of these sawmills by-products in 'bee-hive' burners was the primary means of disposal. Alternative, innovative uses have since developed.

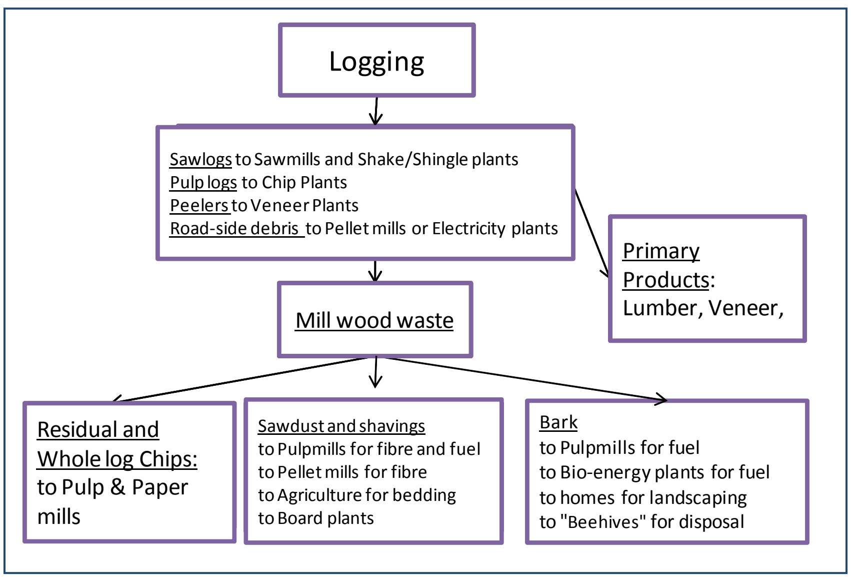
Until very recently, two BC pulp mills produce Sawdust Pulp, using a mixture of **sawdust and shavings,** and wood chips. In so doing they consumed about 30% of the provincial sawdust supply.

Pellet manufacturers have cropped up virtually everywhere in BC over the past 17 years to supply the burgeoning demand for "green" fuels generating electricity in Europe.

Although shavings and sawdust are the preferred fibre for pellets, a recent shortage in sawmill residues has caused pellet mills to begin using bark, and to begin their own economic trials in collecting and grinding roadside logging waste that remained after a sawlog harvesting operation.

Other smaller users of sawdust and shavings include particle board plants, agriculture (for bedding, soil manufacture and hothouses) and sawmill kiln-heat systems.[4] **Bark** produced by the sawmill and chip plant debarking process is typically used by three industries – Pulp and Paper Mills (to fuel their power boilers), Biomass Power Plants (to fuel stand-alone power or co-generation) and Sawmill Power Plants. Agriculture and Landscaping also use small amounts of bark. As a result of these initiatives, very few BC sawmills still utilize beehive burners today as a means of disposing sawmill residues. The basic flow of fiber in the forest industry follows the pattern shown in Figure 2.

Figure 2. Basic Fibre flow Diagram



3.1 The Mountain Pine Beetle and Lumber Economics

The mountain pine beetle (MPB) epidemic will continue to impact the BC Interior forest industry in several ways:

- Harvest levels have been increased significantly to promote the salvage of dead pine trees; the future consequence of both this increase and the remaining volume of un-salvaged dead pine will be an inevitable drop in available wood supplies. This drop will be below the levels harvested prior to the MPB epidemic.

[4] Part of the lumber manufacturing process requires that the moisture in lumber be removed so that it does not warp. Lumber is dried in sheds called "kilns". About ½ of the sawmills in the BC interior have small "Konis style" energy systems that use their own dry shavings to fire boilers for kiln heat.

- Manufacturing lumber from dead pine trees results in both a reduction in the volume and the value of lumber sold into the market place. The rate that this occurs is dependent on both physical and economic factors. Non-lumber grade trees could be used by the "residual" forest industry (i.e., pulp and paper, pellets, bioenergy). This could occur only if these industries are willing to pay the proportional cost (typically absorbed by the lumber industry) to administer, harvest and replant the areas where these trees prevail.
- The residual industry (with the exception of pulp mills) cannot (yet) afford the full cost of logging and delivering trees to their facilities. Hence, a green-field biomass to electricity facility not been built to utilize standing dead pine. Consequently, the amount of wood waste left in MPB-killed stands has increased significantly in the past 5 years.
- As the volume of poor-quality logs in MPB-killed stands increase over time, the unit cost to extract the remaining merchantable (lumber-grade) logs rises. The impact to lumber companies is a reduction in the amount of merchantable wood that they can economically access.
- Dead pine trees will not remain standing forever. After about 15 years, nearly 50 percent of them will have fallen over and they will begin to decay rapidly.

In 2008, the collapse of the US housing market resulted in a substantial drop in lumber selling-prices. In most instances, prices were below the cost of production. North American log processing mills reacted by curtailing production. Accomplished through a reduced number of operating shifts, increased down-time, or by permanent or indefinite mill closure. A significant consequence has been the reduction in the supply of mill waste by-products. The price of wood-chips rose considerably, and the price for sawdust, shavings and bark, (which in 2001 could be had for next to nothing) skyrocketed. Manufacturing plants that developed between 1998 and 2006 to utilize the large supply of sawmill residues were confronted with both a large increase in cost and reduction in supply of their raw materials. Other fibre supply sources needed to be explored. Roadside residues and whole-log grinding of dead pine stands were considered. To-date, the salvage of roadside residues in logging operations closest to manufacturing centers has proven to be economical – if supplemented with other cheaper sources of residual fibre. Grinding or chipping logs at any significant distance from a manufacturing plant is not currently economical for industries other than pulp and paper. To mitigate the higher cost of salvaging biomass from the forest, the existing residual industry has aggressively sought to develop long-term residual-wood supply agreements with BC sawmills. As a result, there is very little in the way of sawmill or veneer plant residues remaining in the BC Interior that have not already been allocated to a consumer.

3.2 Bioenergy Policy

The economic drivers of the forest industry that existed in BC ten years ago were insufficient to utilize the volume of dead pine trees that were forecast to develop in the BC Interior. The BC Liberal Government recognized this early on and incorporated a partial solution into their 2007 BC Energy Plan. The government's plan was to expand opportunities to generate electrical power by using alternative fuels such as mountain pine beetle wood. Initiatives resulted in the implementation of a Bioenergy Strategy, the creation of a BC Bioenergy Network, the application of an Innovative Clean Energy (ICE) Fund to support investment of new projects (eight of which have been bioenergy), and the initiation of the BC Hydro Phase 1 and Phase 2 Bioenergy Call for Power (8 projects awarded to-date). BC Hydro also worked with pulp and paper customers to identify biomass power projects that would result in customers securing funding under the federal government's Green Transformation Program. Six projects have been awarded to-date under this Integrated Power Offer, with a possible seventh and final project pending.

3.3 Bioenergy Fibre Supply Complications

In the development of a business plan for any bioenergy or fibre processing facility in B.C., **access to fibre** is a key consideration. BC land ownership is about 1% federal, 3% private and 96% provincial – so options are limited. An IPP can really only access Crown biomass fuel in one of two ways: (1) by acquiring a long-term forest license to harvest/collect biomass from Crown Land or, (2) by developing a relationship with a licensed tenure holder who already has access to wood.

Independent power producers that are already established in BC with some form of wood processing facility have two significant advantages over newcomers proposing a green-field facility – they likely have a long-term fibre supply, and their existing facility enables them to amortize the cost of generators or capital upgrades to the facility over a much shorter time period. The fact that existing major licensees (i.e., Tolko Forest Industries Ltd.) and pulp mills (i.e., Canfor Pulp and Paper, Mercer International, Domtar Corp.) have been the first to move forward on the utilization of forest biomass for electricity production is indicative of this advantage.

Greenfield bioenergy plants typically require 15-20 years to amortize the cost of new construction. They face the following complications:

- The Annual Allowable Cut (AAC) for each of the Province's timber supply areas and tree farms is determined by the Provincial Chief Forester. A re-determination is made about every five years. The rate at which timber is made available for harvesting is in response to social, economic, environmental and biological considerations. The Minister then apportions the AAC to applicants using various forms of agreement that grant rights to harvest Crown timber for varying terms. Most of the AAC in forest management units is already allocated to established forest companies under long-term tenure.

- Uplifts to the traditional AAC have been significant as a result of the beetle. However, the harvesting rights tied to these uplifts are non-replaceable and are typically for less than 15 years. The majority of these uplifts are scheduled to terminate in the next 5 to 7 years.
- Dead pine trees are unlikely to remain standing much longer than 20 years after they have been killed. Many stands have already been dead for over 12 years.
- A surge in sawmill residual value has made many sawmill owners reluctant to negotiate a long-term biomass supply agreement at a fixed value with IPP's.
- Considerable roadside logging waste exists in harvested dead-pine stands. Under Section 7 of the Wildfire Act, this waste material must be disposed of within 6 to 12 months after it is determined that a fire hazard exists. Therefore, this waste is not something that can be logistically stockpiled.
- The 2008-2010 drop in the price of lumber forced all sawmill operators to minimize their delivered wood costs. Recent harvesting has been concentrate in forests closest to existing sawmills. Very few 'forestry-based' communities in the BC Interior have significant volume of dead-pine trees close to potential points of consumption. As a result, the delivered log cost for all forest companies will increase in the near future and the corresponding transportation distance for roadside residues will increase.

As a result of these issues, establishment of large green-field bioenergy facilities focused on the utilization of dead-pine in the BC Interior have been unsuccessful to-date.

Compounding these problems is uncertainty surrounding the amount of biomass that is available now and into the future. Although the BC Ministry of Forests, Lands and Natural Resource Operations has considerable information on the area impacted by the mountain pine beetle, forecasts on actual long-term availability for bioenergy is unclear - because availability is limited by:

1. The regulated, forest management unit based AAC.
2. The demands of existing forest tenure license holders (predominately sawmills) on the AAC for certain grades of log.
3. The demands of existing users of sawmill residues and the business to business agreements that these users have in place with suppliers of sawmill residuals.
4. The forecasted change in the future annual allowable cut.

5. The forecasted change in log-quality coming from MPB-killed stands.
6. The estimated volume of logging waste that might be salvaged during harvesting.
7. The volume of logs that exist in forest management units where supply exceeds demand.
8. The distance an IPP is willing to go acquire biomass fuel (or the maximum delivered wood cost that an IPP can accept).

This project reviews biomass availability in the context of bioenergy while considering all of the uncertainties identified above.

4.0 Analysis Methodology

This analysis utilized the proprietary BC Fibre Model that forecasts timber quantity and biomass availability for 28 years, across over 100 geographic forest management units. In addition, the model considers and tracks all of the major wood processing facilities in British Columbia (sawmills, pulp mills, veneer plants, pellet plants shake and shingle mills etc.) and matches their forecast fibre demand in consideration of the available wood supply. The Model is used by industrial clients in the BC Pulp and Paper, solid wood and bio-energy sectors to provide strategic guidance in determining the potential impact of numerous 'what if' statements. As a result, their input into the industrial drivers used in the model (i.e., manufacturing plant capacities, mill operational efficiencies, sawlog recovery from MPB-killed stands) provides some of the best localized knowledge of the BC forest industry that exists in 2013.

The assumptions used in this analysis were evaluated and discussed with experts at BC Hydro, the Ministry of Forests, Lands and Natural Resource Operations and the Ministry of Energy Mines and Petroleum Resources. Future global and regional economics play an important role in forecasting long-term demand for solid wood products. Sources from which economic input is received that help drive the demand portion of the model include International WOOD MARKETS Group, RBC Capital Markets Equity Research, RISI, and the National Association of Home Builders. There are however numerous economic scenarios that may develop over the next three decades. What is presented herein is a single forecast based upon the best information available in March 2013.

This analysis examines the bioenergy capability of the Province of BC as-a-whole. It also examines capabilities within 13 geographic regions that comprise the Province. These geographic regions are not BC Hydro Planning Regions, but rather they constitute the timber supply regions from which the Forest Industry typically operates. Timber transfers across regions occur (and have been accounted for in the Model). Transfers across regions are typically small, due to terrain, infrastructure, timber type and the impacts of the mountain pine beetle. The fibre regions analyzed are shown in Map 1.

The availability of forest-based, woody biomass is framed within the context of the Annual Allowable Cut (AAC). Actual harvest levels within any single forest management unit (FMU) may exceed the prescribed AAC in any one year. However, for the purposes of this forecast and given its strategic nature, the AAC is the best available framework from which available biomass can be forecast.

In order to derive a forecast of available biomass by region, the Model was used to:

- Provide an AAC forecast for each forest management unit; Timber Supply Area (TSA), Tree Farm License (TFL) and a regionally aggregated forecast for woodlots, community forests and private harvest.
- Provided a coniferous sawlog availability forecast based on:
    - An average sawlog component in the annual harvest for all non-MPB forest management units; and
    - Application of shelf-life assumptions to all MPB impacted forest management units.
- Forecast demand from all coniferous log-using mills (lumber/veneer) and their resultant production of residual chips, sawdust and hog fuel.
- Forecast demand from all coniferous wood chip and biomass consuming mills.
- Compare, using tabular summaries and charts, the regional relationship by region between:
    - Sawlog supply and mill demand;
    - Residual chip supply and demand;
    - Sawdust and shavings supply and demand; and
    - Hog fuel supply and demand.
- Forecast annually available biomass with accumulation over the planning horizon.
- Forecast available biomass (to support new electrical generation) which includes all woody fibre not forecast to be consumed by the current forest industry today or in the future.

For the purposes of this report, “available biomass” includes four categories of fuel types that match the biomass fuel definitions from the BC Hydro Biomass Call for Power. The volumes associated with these fuel categories are not forecast to be consumed by the existing forest industry over the next 28-years.

- ***Category B:*** ***Sawmill woodwaste*** *(residual wood chips, sawdust, shavings and waste (hog fuel)),*
- ***Category C:*** was subdivided into two parts:

- ***Roadside residues*** *are comprised of tree tops and branches that are left at roadside as a result of timber harvesting (and is not part of the merchantable timber included in the AAC). These residues are typically burned on site by forest companies within 8 months after harvesting.*
- ***Pulp Logs*** are primarily dead trees or mountain pine beetle killed trees that are no longer suitable for the production of lumber. These logs *result from the harvest of sawlogs and are either burned at road side or delivered to pulp mills.*

- ***Category D:*** *Standing timber not harvested over the planning horizon due to lumber economics, lack of existing industry or lack of demand.*

As a result of the significant size of the B.C. pulp and paper sector and in the face of reduced sawmill activity because of the MPB, it was assumed that all residual wood chips would be consumed by that sector over the planning horizon and that none would be available to support new electrical generation capacity.

The forecast covers a planning horizon of 28 years from 2013 to 2040. In each year, a forecast of available biomass has been made, net of all other users, within the framework of the AAC. Available forest-based biomass over the 28-year planning horizon was then summarized into the following two periods:

- **2013–2024:** This is the period when significant volumes of MPB-killed pine trees are expected to be available for use as a result of increased harvest levels. During the latter part of this period it is forecast that harvest levels will fall after the impacts of the MPB-epidemic have subsided.

- **2025-2040**: In this period, it is assumed that all management units are at a mid-term sustainable level. The remaining forest industry is expected to operate in balance with the available fibre supply. As a result, available biomass within the framework of the legislated allowable cut will be relatively constant on an annual basis.

Within each period, a sustainable level of biomass availability has been estimated, based upon the forecast of annual biomass availability within each period. This approach will ensure that electrical generation capacity developed within the period will operate without fibre shortfalls in any single year. Where appropriate and feasible, surplus biomass forecast to accumulate in any one year will be carried forward into subsequent years in order to smooth the overall fibre flow.

The cost to deliver all available biomass to an assumed location (within each Region) where a biomass generation plant could be located was estimated. Cost included both the market cost of fibre (fuel cost) together with the expected average regional transportation cost (delivery cost, with allowance for conversion) assuming current technology and infrastructure).

Map 1. BC Fibre Supply Regions

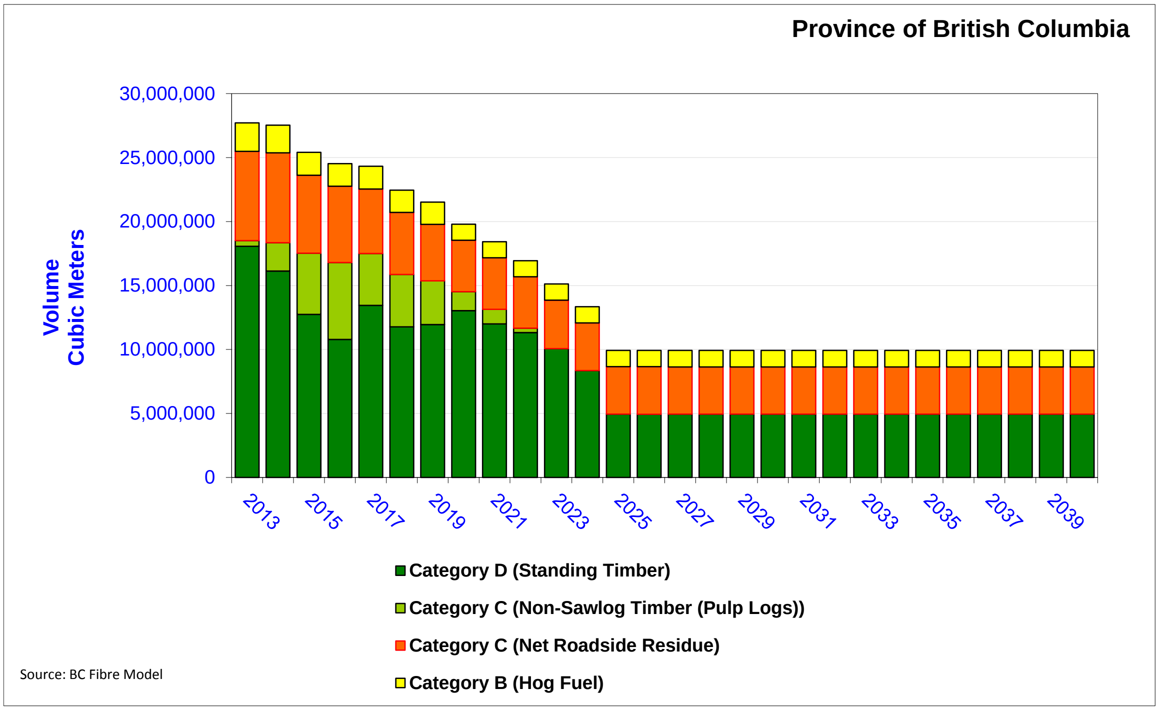
5.0 Provincial Bioenergy Summary

This report examines the Provincial bioenergy capacity of the Province of BC under the key assumption that all biomass within the framework of the annual allowable cut and not required by the existing forest industry is potentially available for electrical generation. The Province of BC has a current annual allowable cut of about 82 million cubic metres when considering all forest management units and contributions from private forest lands. This AAC exceeds the current demand for logs by the existing forest industry by a considerable margin – primarily as a result of: (1) uplifted AACs to address the MPB-epidemic, (2) recent lack of demand for lumber for house construction and (3) the high delivery cost of some of this fibre. As a result, there are significant amounts of biomass available to support new electrical generation capacity until about 2022. However after this period the AAC is forecasted to fall (due to loss of merchantable fibre from the MPB-epidemic) and industry will have rationalized to new levels of fibre supply.

Figure 3 shows the amount of biomass that is forecast to be available over a 28-year time horizon while operating within the framework of the Provincial Annual Allowable Cut. As can be seen by this Figure, a considerable amount of biomass fuel, now and in the future, exists in the form of standing timber. This volume declines in the very short-term as demand for lumber and veneer products continues to recover. Though not apparent from this figure, the majority of the standing timber shown in Figure 3 exists in coastal areas or northern parts of the Province. The availability of Category C (Pulp logs) is expected to disappear by 2023. This fuel comprises predominately MPB-killed pine trees. A forecast reduction in sawmilling activity (as a result of fewer quality sawlogs) will reduce the supply of wood chips and other sawmill residues. Over the next decade this should increase demand for dead pine trees by the pulp and paper industry and consequently reduce available biomass supply. Category C (Roadside woodwaste) are forecast to remain surplus to the existing forest industries needs for the next 28 years. As shown in Figure 3, Category B (sawmill woodwaste) occurs as sawmill residues that are not currently demanded by the existing forest industry. Most of this biomass supply currently exists on the BC Coast, Kootenays and in the Mackenzie area.

To estimate delivered fibre costs in the various fibre supply regions of BC, potential fibre delivery points were required for delivered fuel cost calculation purposes. Map 2 shows the potential fibre delivery points used in this analysis. This map is also colour coded to depict biomass potential based on each Supply Regions capacity to support a biomass energy plant for a 28-year period.

Figure 3. Province of BC Forecast Biomass Supply by Fuel Type



Due to the size, and diversity of terrain within BC, potential biomass fuel supply is dependent on regional supply/demand influences; hence Table 1 offers a Provincial summary of biomass electricity potential and cost for 13 regions. This table shows that, surplus to the needs of the existing forest industry, BC has sufficient biomass to generate an additional 11,913 GWh/yr of electricity for the next 13-year period. The weighted-average cost of this electricity is estimated at $181/MWh (weighted across all fibre categories and regions). In the long-term this capacity is forecast to decline in concert with a reduction in annual allowable cuts. For the second 15-year period, forecast capacity is expected to drop to 9,783 GWh/yr at a cost of $183/MWh.

The cost of biomass generated electricity depends largely on a bioenergy plants fuel profile and delivered fibre cost. Standing timber (Class D fuel) is generally the most expensive and results in a much higher cost of electricity than if a plant managed a fuel profile skewed towards Category B or C fuels. Table 2 shows the weighted-average cost of electricity in BC by fuel type. Table 3 provides additional detailed information on delivered fuel by supply region.

Map 2. Potential Fibre Delivery Points[5]

[5] Regional supply results were coloured to depict supply potential. "Good Potential" represents regions where there is sufficient surplus biomass to operate a 30MW (or greater) plant for 30 years. "Some Potential" has sufficient biomass to operate a plant < 30 MW but > 10 MW for 30 years. "Limited Potential" is any region having less than 10 MW surplus biomass and/or less than 30 years of supply.

Sensitivity analysis was completed that analyzed the change in generating capacity and cost if Category D and/or Category C (pulp log) fuels were removed from consideration. The results shown in Table 4 demonstrate a significant reduction in biomass fuel generating capacity (i.e., approx. 65%) and cost (i.e., approx. 30%) when certain categories of fuel are excluded from the Provincial fuel profile.

Table 5 provides a detailed summary of the estimated potential and cost for electricity generated by biomass from each of the supply regions identified in this analysis.

Table 1. Biomass Generating Capacity and Costs for BC

Region	2013 - 2024		2025 - 2040	
	Biomass Capacity (GWh/year)	Cost ($/MWh)	Biomass Capacity (GWh/year)	Cost ($/MWh)
Coast Mainland	5,533	$205	5,338	$201
Coast Vancouver Island		$205		$201
East Kootenay	236	$136	225	$134
West Kootenay	525	$127	530	$127
Kamloops / Okanagan	545	$140	476	$137
Cariboo	319	$169	0	$0
Prince George	1,337	$157	106	$132
Mackenzie	302	$148	325	$132
South Peace	476	$130	457	$128
North-east	368	$183	368	$183
East Prince Rupert	412	$132	98	$118
West Prince Rupert	1,686	$197	1,686	$196
North-west	173	$174	173	$174
Total BC	**11,913**	**$181**	**9,783**	**183**

Table 2. Electricity Cost by Fuel Type

Biomass Type	Potential Capacity (MW)		Annual Energy (GWh/year)		Estimated Cost ($/MWh)	
Forecast Period	2013 - 2024	2025 - 2040	2013 - 2024	2025 - 2040	2013 - 2024	2025 - 2040
Category D (Standing Timber)	906	692	7,930	6,070	$208	$216
Category C (Pulp Logs)	125	76	1,090	670	$134	$135
Category C (Roadside Residue)	249	265	2,180	2,320	$134	$134
Category B (Hog Fuel)	81	84	710	730	$107	$107
Total	**1,360**	**1,117**	**11,910**	**9,790**		

Table 3. Estimated Delivered Fibre Costs

Region	Hypothetical Fibre Delivery Location	Estimated Delivered Fibre Costs ($/MWh)		
		Sawmill waste	Roadside debris	Standing Timber
Coast (Vancouver Island)	Parksville	$17	$48	$143
Coast (mainland)	Aldergrove	$22	$48	$143
East Kootenay	Canal Flats	$18	$50	$78
West Kootenay	Castlegar	$25	$58	$85
Kamloops/Okanagan	Kamloops	$27	$53	$85
Cariboo	Hanceville	$19	$45	$85
Prince George	Ft St. James	$21	$48	$85
Mackenzie	Mackenzie	$7	$48	$88
South Peace	Chetwynd	$29	$54	$85
North-east	Fort Nelson	$4	$48	$99
East Prince Rupert	Houston	$17	$48	$81
West Prince Rupert	Kitimat	$18	$47	$117
North-west	Dease Lake	$18	$54	$90

Table 4. Sensitivity to Fuel Type

Scenario	2013 - 2024		2025-2040	
	Biomass Capacity (GWh/yr)	Cost ($/MWh)	Biomass Capacity (GWh/yr)	Cost ($/MWh)
Base Case	11,913	$181	9,783	$183
Remove Category D Fuels	4,151	$127	3,890	$127
Remove Category D & C (pulplog)	3,057	$125	3,225	$125

Table 5. Biomass Potential and Cost – by Region, Period and Fuel Type

	2013 - 2024							2025 - 2040						
Biomass Type	Sawmill Waste		Roadside Residues and Pulplogs		Weighted-average for Sawmill waste, Roadside Residues and Pulplogs	Standing Timber		Sawmill Waste		Roadside Residues and Pulplogs		Weighted-average for Sawmill waste, Roadside Residues and Pulplogs	Standing Timber	
Region	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)	Cost ($/MWh)	GWh/ Year	Cost ($/MWh)
Coast - Mainland	188	$22	1,054	$48	$44	4,291	$143	209	$22	1,205	$48	$44	3,924	$143
East Kootenay	0	$18	225	$50	$50	12	$78	0	$18	225	$50	$50	0	$78
West Kootenay	241	$25	283	$58	$43	0	$85	246	$25	284	$58	$43	0	$85
Kamloops/Okanagan	0	$27	493	$53	$53	52	$85	0	$27	476	$53	$53	0	$85
Cariboo	0	$19	0	$45	n/a	319	$85	0	$19	0	$45	n/a	0	$85
Prince George	0	$21	416	$48	$48	921	$85	0	$21	106	$48	$48	0	$85
Mackenzie	0	$7	181	$48	$48	121	$88	0	$7	325	$48	$48	0	$88
South Peace	191	$29	255	$54	$43	30	$85	191	$29	255	$54	$43	11	$85
North-east	0	$4	0	$48	n/a	368	$99	0	$4	0	$48	n/a	368	$99
East Prince Rupert	43	$17	332	$48	$45	37	$81	43	$17	55	$48	$34	0	$81
West Prince Rupert	42	$18	34	$47	$31	1,611	$117	44	$18	53	$47	$34	1,589	$117
North-west	0	$18	0	$54	n/a	173	$90	0	$18	0	$54	n/a	173	$90
Total GWh per year and weighted-average cost	706	$24	3,273	$50	$46	7,935	$122	734	$19	2,984	$38	$44	6,065	$107

6.0 Coast

Due to transmission and distribution considerations BC Hydro has historically separated the BC Coast into two regions; Vancouver Island and the Mainland. To maintain some consistency with this practice, the Coastal bioenergy opportunity is reported for both the Island and Mainland. However, the delivered cost of wood or biomass fuel and the availability of this fuel are similar, regardless of location. With respect to the delivered cost of wood or biomass fuel, the predominate feature of BC's Coast is presence of the Pacific Ocean. Most wood manufacturing facilities on the coast utilize the ocean as a transportation conduit. Logs, chips, sawdust, shavings and hog fuel move by barge and trade routinely from the Lower Mainland / Lower Coast to Vancouver Island and vice versa. The majority of coastal pulping capacity is located on Vancouver Island and over half of the fibre required by the four remaining Vancouver Island pulp and paper mills comes from sources other than Vancouver Island. Sawmilling capacity within the region is split roughly equally between the Lower Mainland and *Vancouver Island.* Thus the ocean exists not as a limiting factor, but as a means for the forest industry to access wood fibre over the entire region at comparable costs. Log dumps and barging are the key components to this transportation system. Once a tree is delivered to a coastal log dump, the cost to delivering the wood anywhere along the BC Coast is static. Transport companies adjust the size of their barges to accommodate a short or long haul (on the south coast) while keeping unit cost about the same.

The integration of island and mainland, with regard to wood supply, is also evident through governments' establishment of coastal timber supply areas and tree farm licenses - the boundaries often extending across the Strait of Georgia. Fibre processing mills in Campbell River, Nanaimo, Powel River and Vancouver procure their wood supplies from both the mainland and the island based on wood quality, logging cost and supply agreements. Transportation cost is seldom a limiting factor. As a result, this analysis regarding potential biomass supply for a possible IPP on Vancouver Island or on the Lower mainland is based on the entire Coastal biomass supply, with barging cost incorporated into delivered fuel cost estimates.

6.1 Background Information

Map 3 shows the location of the Coast in relation to the Province of BC. The forest industry on the Coast has been in a chronic state of decline for many years. Most of this is a result of a lack of economically-priced sawlogs and the quality of the logs. Most stands have a large amount of hemlock and balsam for which there is marginal demand. As a result, harvesting on the Coast has been considerably lower than the

AAC. This lack of demand may provide high-cost opportunity for biomass fuel procurement. The log supply on the Coast is currently dominated by four companies: Western Forest Products Ltd., Island Timberlands, Interfor and Timber West. The coastal log supply is currently furnishing about twenty-one sawmills, three plywood plants and several pulp mills. Cumulative AAC is about 22 million cubic metres. There are very few pine stands, hence the MPB-epidemic is not a concern and the forecast annual allowable cut is quite stable. Sawlog and pulp log demand from this AAC is currently forecast to remain fairly constant at about 14.2 million cubic metres. Thus a sizeable inventory of surplus standing timber exists.

Map 3. Coastal Region

6.2 Demand for Residual Fibre

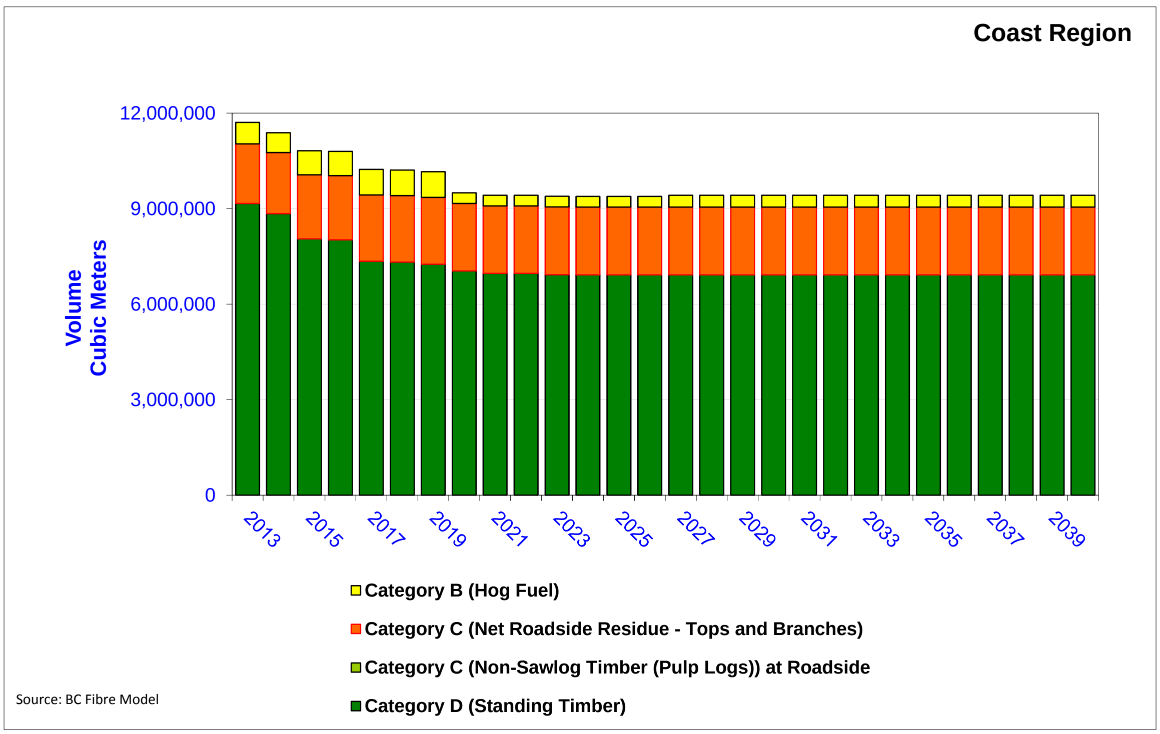
The demand for residual fibre on the coast has changed significantly in the last few years as a result of the closure of the Elk Falls pulp and paper mill. While residual wood chips remain in short supply (resulting in significant volumes of chips to be imported from the Interior), sawdust, shavings and hog fuel are currently surplus to industry needs.

Almost all minor residual fibre is consumed by either regional pulp and paper power boilers, or in the case of sawdust and shavings, by the significant animal bedding and agricultural markets. Debarking of logs being exported overseas (as an alternative to fumigation) has resulted in a recent spike in the availability of hog fuel at various export terminals.

6.3 Coastal Biomass Fuel Availability Forecast

Figure 4 shows the availability of biomass fibre by type over a 28-year forecast, given the assumptions described previously. The majority of available fibre for use as biomass is in the form of un-harvested AAC with some current surpluses of hog fuel (resulting from the closure of the Elk Falls Pulp mill). Available volumes have declined somewhat since 2010 as a result of the increased demand for biomass resulting from biomass power projects BC Hydro signed with Howe Sound Pulp, Nanaimo Forest Products and Catalyst under the Integrated Power Offer. Residual volumes have further declined as a result of the Mackenzie sawmill being destroyed by fire in 2011.

Figure 4. Net Available Biomass by Type – Coast



6.4 Biomass Energy Potential – Vancouver Island

Table 6 describes the biomass electrical generation potential for this region assuming the electrical generation facility is located centrally on Vancouver Island in the Parksville area. A maximum of 632 megawatts capacity biomass power plant could generate 5533 GWh annually at a forecast cost of $205/MWh over the next 13 years. In the second 15-year period this potential supply drops very slightly to 609 MW capacity producing 5338 GWh/year at a cost of $201/MWh. Excluding the significant volume of standing timber from bioenergy production reduces to opportunity to 1242 GWh per year at a cost of $127 per MWh.

Table 6. Vancouver Island Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	4291	3924
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	1054	1205
	Category B (Hog Fuel)	188	209
	Total	**5533**	**5338**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	632	609
	Average Annual Cost of Biomass ($/m3)	$68	$66
	Average Annual Cost of Biomass ($/megawatt-hr)	$121	$117
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$205**	**$201**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$127**	**$127**

6.5 Biomass Energy Potential – Coastal Mainland

Table 7 summarizes the biomass potential for an electrical generation facility assumed to be located in the Aldergrove area. The same maximum biomass power plant capacity of 632 megawatts could generate 5533 GWh/year electricity at a forecast cost of $205/MWh over the next 13 years. The potential supply decreases slightly to a maximum of 609 megawatts capacity over the next 15-year period, also at a cost of $201/MWh. The small improvement in cost is a result of slightly less available high-cost standing timber and slightly more available low-cost residual fibre when sawmills are forecast to improve operating rates.

Table 7. Coastal Mainland Biomass Fuel Supply and Price Forecast

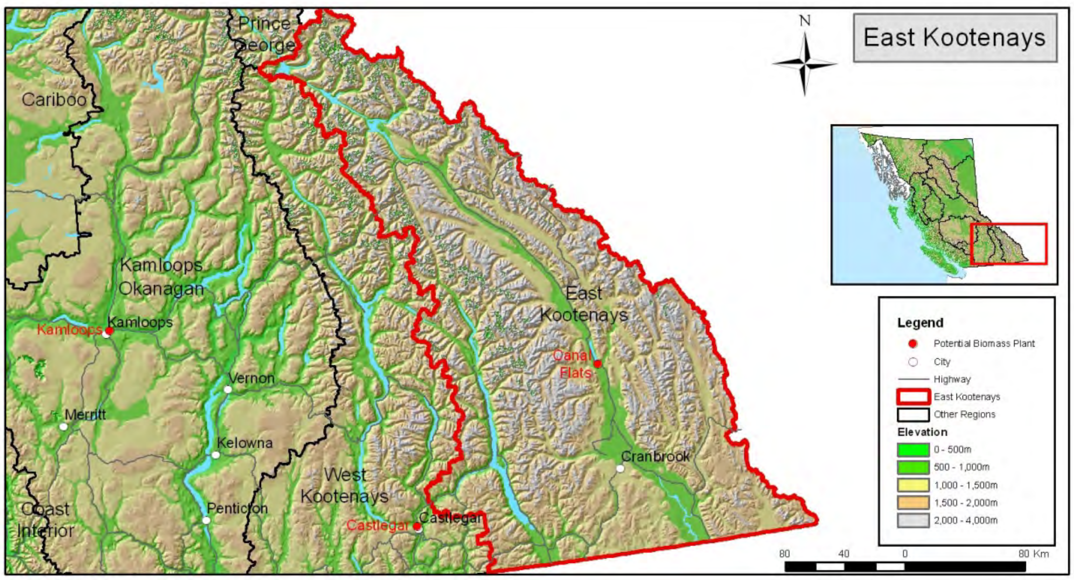
	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	4291	3924
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	1054	1205
	Category B (Hog Fuel)	188	209
	Total	**5533**	**5338**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	632	609
	Average Annual Cost of Biomass ($/m3)	$69	$66
	Average Annual Cost of Biomass ($/megawatt-hr)	$121	$117
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$205**	**$201**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$128**	**$128**

7.0 East Kootenay

7.1 Background Information

Map 4 shows the location of the East Kootenay Region in relation to the Province of BC. Rocky Mountains and wide valleys in the region are covered in forests that comprise about 40 percent lodgepole pine. Other principle species include Douglas fir, spruce, balsam fir and larch. The MPB epidemic has had a comparatively minor impact in the area to-date. By 2012, about 33 percent of pine trees are estimated to have been killed. Current AAC for the region is approximately 3.1 million cubic metres. The long-term post MPB-epidemic AAC is expected to drop 16 percent to about 2.6 million cubic metres.

Map 4. East Kootenay Region



7.2 Existing Industry

Eight sawmills, and a pulp mill comprises the forest industry in the East Kootenay Region. Since 2010, the two Tembec sawmills have been purchased by Canfor and Canfor's Radium sawmill was re-started and is developing a biomass energy system that should be operational later this year. Residual biomass is directed primarily to the Skookumchuck pulp mill owned by Tembec. Aside from pulp, the mill has been producing incremental electricity for a number of years. Surplus lower grade sawmill residuals are also often sold to Avista Corp. (a 46 MW biomass power plant in Kettle Falls USA). The transfer of biomass across the border is cost-effective since wood chips coming from the USA by truck can return on the back-haul with sawdust, shavings and hog fuel.

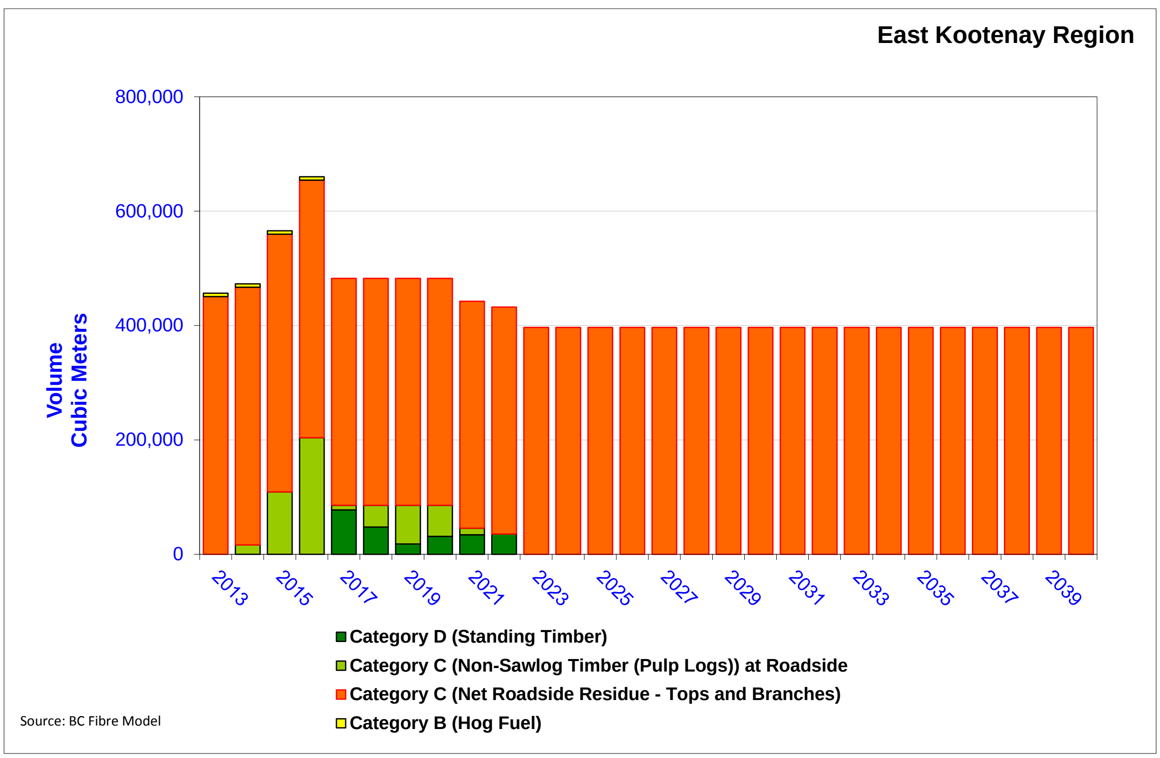
7.3 Demand for Residual Fibre

Within the East Kootenay Region, significant demand for residual sawmill fibre already exists to support power boilers, electrical generation facilities at the regional pulp mill and other mill energy systems. In the face of reduced sawmill activity that has been forecast for the Region, with a corresponding decline in available residual fibre, all of these consumers will either resort to using roadside residual fibre to meet their needs, harvest and consume pulp logs, or potentially switch to alternative sources of energy (such as natural gas in some power boilers).

7.4 East Kootenay Biomass Fuel Availability Forecast

Figure 5 shows forecast biomass fibre availability by type over the planning horizon. The majority of the opportunity lies with roadside residues. The standing timber and pulp logs that become available and then lost in the future are a consequence of the rationalization of sawlog demand to sawlog supply. As indicated in Section 7.1, if harvests are incrementally reduced by another 500,000 cubic metres, the closure of a sawmill is probable. Hence, surplus standing timber is available for only a short time, depending on when the forecast closure occurs.

Figure 5. Net Available Biomass by Type – East Kootenay



7.5 Biomass Energy Potential – East Kootenay

Table 8 summarizes the biomass potential for the Region, assuming an electrical generation facility is located central to the available fibre supply in the Canal Flats area. A maximum of 27 MW capacity biomass power plant could provide 236 GWh of annual energy at a forecast cost of $135/MWh over the next 13-year period. In the long term the potential falls slightly to 26 MW capacity providing 225 GWh of electricity over the second 15-year period at a cost of $134/MWh.

Table 8. East Kootenay Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	12	0
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	225	225
	Category B (Hog Fuel)	0	0
	Total	**236**	**225**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	27	26
	Average Annual Cost of Biomass ($/m3)	$29	$29
	Average Annual Cost of Biomass ($/megawatt-hr)	$52	$50
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$136**	**$134**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$134**	**$134**

8.0 West Kootenay

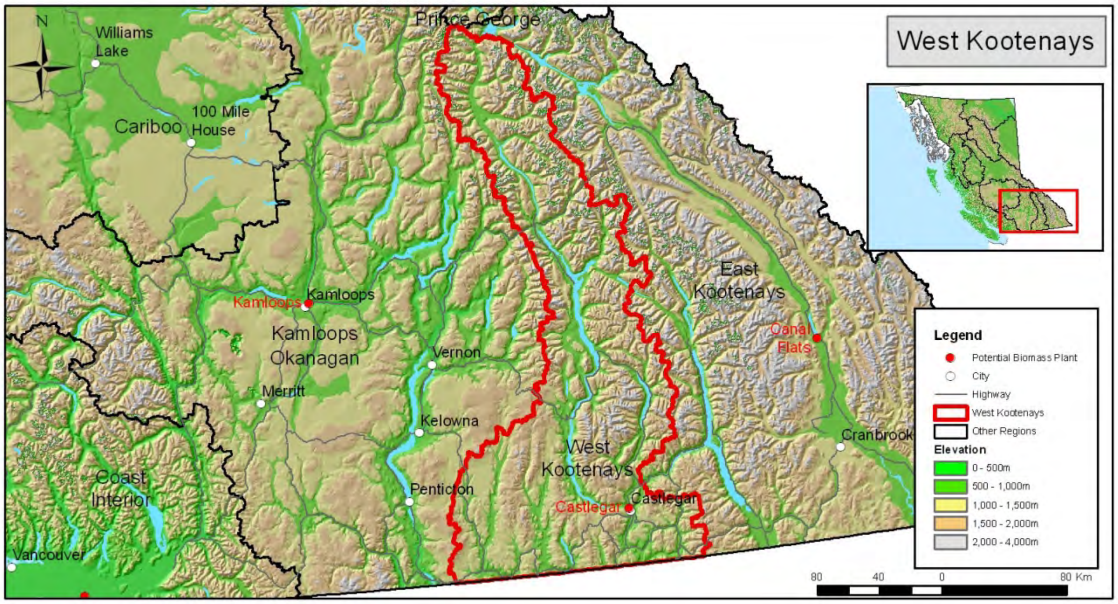
8.1 Background Information

Map 5 shows the location of the West Kootenay Region in relation to the Province. The region is extremely rugged with steep mountains and valleys running predominately north/south. Arrow Lake is a dominate feature that provides water transportation for logs harvested in the northern parts of the Region south to Castlegar. This in turn drives up delivered wood costs relative to other areas. The wetness of the climate results in both very good growing sites and a wide diversity of tree species.

Only about 25 percent of the trees in this Region are pine. As a result, the MPB-epidemic has only had a minor impact on the area. Of the roughly 29 million cubic metres of pine within the region, an estimated 4 million cubic metres of pine have been killed by the beetle. The epidemic appeared to have peaked in 2006. An estimated 10 million cubic metres of pine forecast to be killed by 2024 (half of what was assumed in 2010).

The current AAC for the Region is about 2.8 million cubic metres. There has not been in increase in the AAC as a result of the MPB-epidemic, nor is the long-term AAC likely to be significantly impacted by pine mortality.

Map 5. West Kootenay Region



8.2 Existing Industry

The existing Regional forest industry is dominated by many small independent sawmills and one large, modern and very efficient pulp mill (Celgar). Through a network of supply agreements with the regional sawmills, the pulp mill acquires its wood chip supply. Since this is insufficient to meet their fibre demand, the mill also has a very large whole log chipping program and imports a significant volume of chips from the USA. Celgar was awarded an EPA with BC Hydro under the Phase 1 Power Call. Since 2010, the Boundary sawmill at Midway commenced operations, and the Springer Creek sawmill announced its closure.

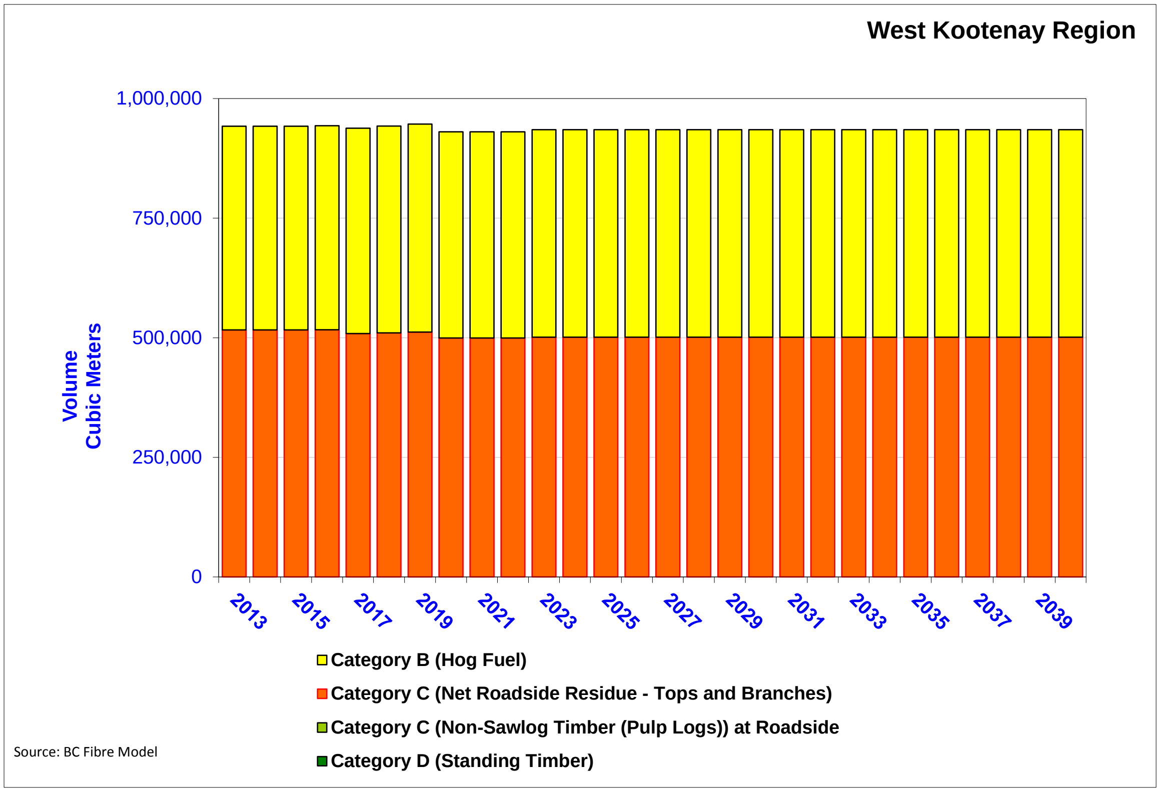
8.3 Demand for Residual Fibre

At the present time there is a surplus of both residual hog fuel and sawdust within the region, and this surplus is forecast to persist over the planning horizon given the small demand from regional consumers. The cost of forest-based residual fibre is high and access is difficult as a result of steep terrain and lake transportation.

8.4 Potential Fibre Sources for Energy

Figure 6 shows the availability of biomass fibre by type over the planning horizon, given the assumptions made. The surplus available biomass fibre over the entire planning horizon is a combination of roadside residues and surplus hog fuel.

Figure 6. Net Available Biomass by Type – West Kootenay



8.5 Biomass Energy Potential- West Kootenay

Table 9 summarizes biomass electrical generation potential for this region assuming an electrical generation facility is located in Castlegar. A maximum 60 MW power plant could produce between 525 and 530 GWh of annual energy at a forecast cost of $127/MWh over the planning horizon.

Table 9. West Kootenay Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	0	0
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	283	284
	Category B (Hog Fuel)	241	246
	Total	**525**	**530**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	60	60
	Average Annual Cost of Biomass ($/m3)	$24	$24
	Average Annual Cost of Biomass ($/megawatt-hr)	$43	$43
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$127**	**$127**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$127**	**$127**

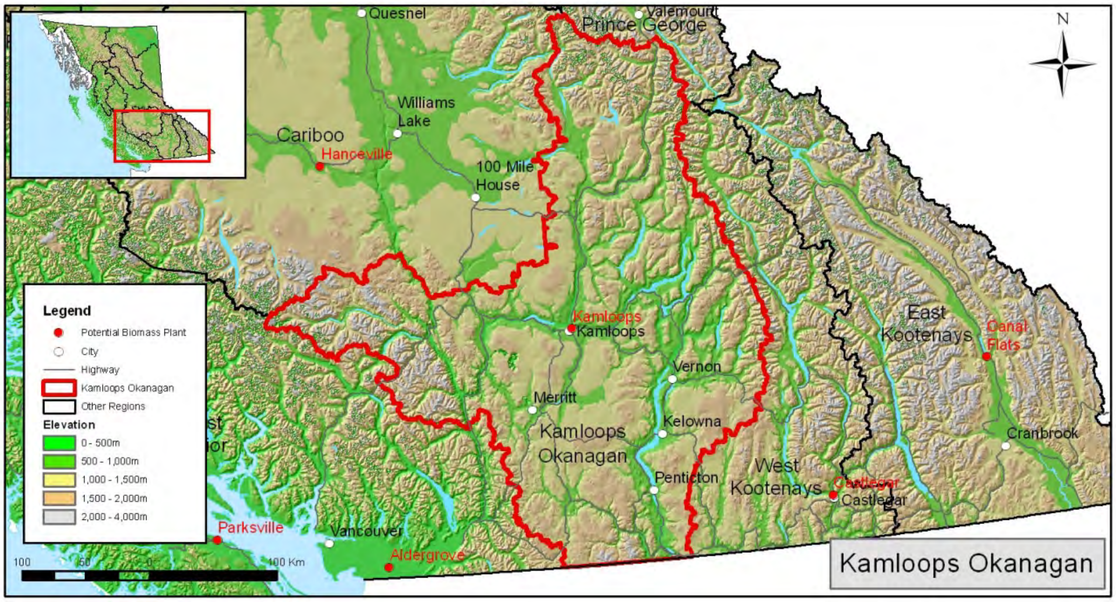
9.0 Kamloops / Okanagan

9.1 Background Information

Map 6 shows the location of the Kamloops/Okanagan Region in relation to the Province. The Region's size and diversity includes dry, hot, semi-arid grass lands in the south that transition to wet areas and rugged mountains in the north. The Thompson River, Okanagan and Shuswap Lakes are principle features in the Region. A large forest industry competes with the demands of a diverse tourism and recreation industry. The region has an estimated 210 million cubic metres of pine. By 2013, an estimated 68 million cubic metres of pine had been killed by the Mountain Pine Beetle. This is about 72% of the estimated 94 million that is expected to die from the epidemic that peaked in 2007.

The historic AAC for the Region was approximately 9 million cubic metres. It was increased to 13 million cubic metres to support salvage of logs from both fire and beetle mortality, and currently sits at about 10.2 million cubic metres. A future long-term sustainable AAC of about 8 million cubic metres is forecast by 2024.

Map 6. Kamloops/Okanagan Region



9.2 Existing Industry

Eight sawmills, five veneer plants, one independent power plant (Armstrong), three pellet mills and one large pulp mill comprise the existing forest industry in this region. The Ardew's sawmill and Tolko's Kelowna veneer plant shut in 2012, both citing a lack of sawlog/peeler log supplies. The Domtar pulp mill in Kamloops is the largest regional consumer of wood chips, hog fuel and (until recently) sawdust. In 2012 Domtar announced the closure of the part of the pulp mill that consumed sawdust for the production of "mini" pulp. This closure frees a considerable volume of sawmill residues to a new biomass consumer. It is assumed that Western Bioenergy, who was awarded an EPA with BC Hydro for a Merritt bioenergy plant under the Phase 2 Power Call, would eventually consume this surplus volume. Roadside residuals are currently in significant demand. In order to support biomass power production at Howe Sound Pulp and Paper approximately 200,000 ODTs of roadside material is transferred from the Kamloops/Okanagan region to the coast.

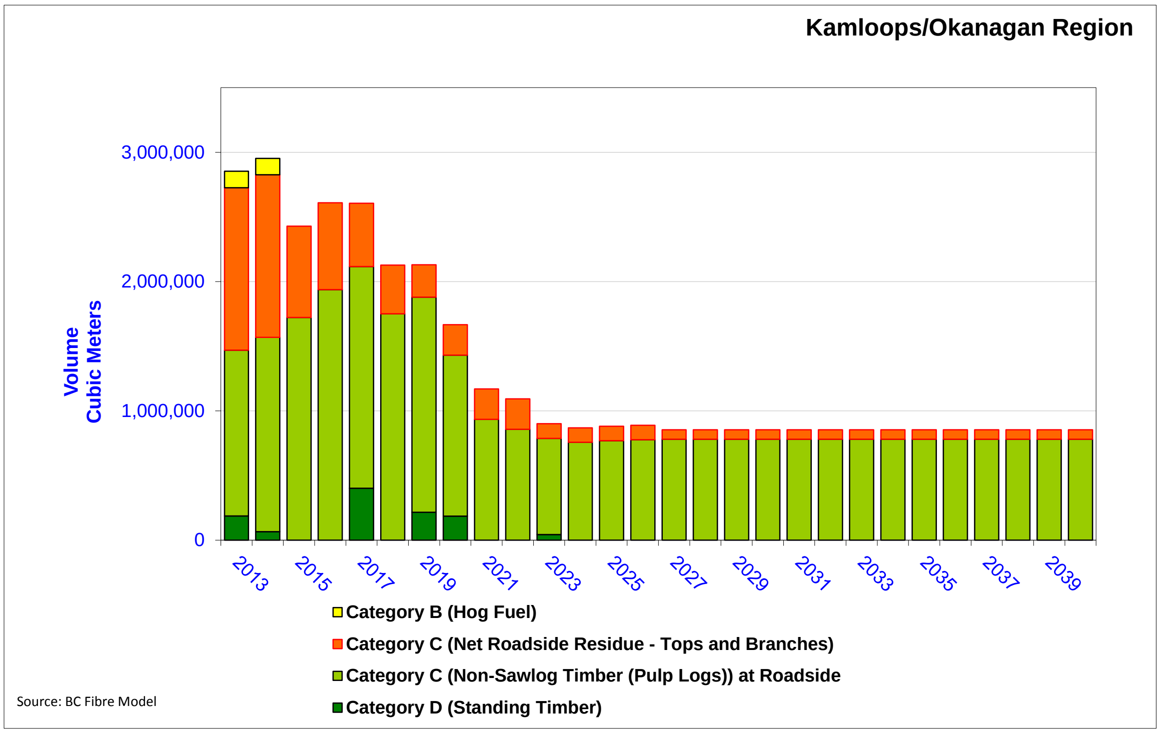
9.3 Demand for Residual Fibre

There are multiple users of minor residual sawmill fibre within the region, resulting in considerable historic demand and competition between companies. During the forecast period, a short term surplus of sawdust, shavings and hog fuel exist as a result of the closure to the Domtar sawdust digester. It is assumed that existing pellet producers or the proposed Western Bioenergy bioenergy power plant would secure this volume in the near term.

9.4 Potential Fibre Sources for Energy

Figure 7 shows the availability of biomass fibre by type over the planning horizon. For the term of the planning period the availability of standing pulp logs predominate. The risk inherent in this forecast is that pulp logs remain standing over the term of the planning horizon and do not fall over and decompose, or sustain losses to wildfire.

Figure 7. Net Available Biomass by Type – Kamloops/Okanagan Region



9.5 Biomass Energy Potential

Table 10 quantifies the surplus biomass potential for the region, assuming an electrical generation facility is centrally located to available fibre supply in Kamloops. A maximum 62 MW capacity biomass power plant generating 545 GWh of annual energy is possible at a forecast cost of $140/MWh for the first 13 years. After AACs are reduced, this potential falls to 54 MW producing 476 GWh/year for the second period at a cost of $137 per megawatt-hour.

Table 10. Kamloops/Okanagan Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	52	0
	Category C (Non-Sawlog Timber (Pulp Logs))	429	435
	Category C (Net Roadside Residue)	64	41
	Category B (Hog Fuel)	0	0
	Total	**545**	**476**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	62	54
	Average Annual Cost of Biomass ($/m3)	$32	$30
	Average Annual Cost of Biomass ($/megawatt-hr)	$56	$53
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$140**	**$137**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$137**	**$137**

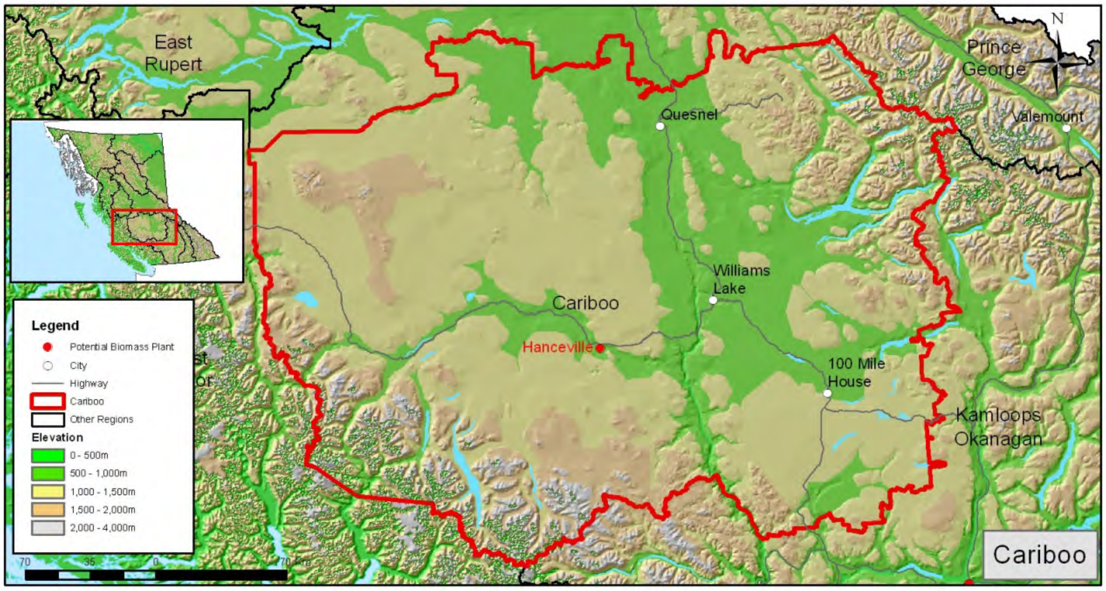
10.0 Cariboo

10.1 Background Information

Map 7 shows the location of the Cariboo Region in relation to the Province. Situated in the central interior, the relatively flat dry terrain is home to roughly 312 million cubic metres of Lodgepole pine. Pine trees comprise about 65 percent of the forests and 70 percent of these trees had been forecast to be killed by the beetle epidemic, The epidemic peaked in 2005 and in 2013 an estimated 219 million cubic metres of pine volume have been killed. Further mortality is not expected.

The traditional AAC for the Region was 8.5 million cubic metres. It is presently just over 13 million cubic metres and is forecast to fall to 7 million by 2022. At this reduced harvest level not all of the existing log processing facilities will be able to operate. In 2012 Tolko announced the permanent closure of its Creekside sawmill in Williams Lake.

Map 7. Cariboo Region



10.2 Existing Industry

The existing forest industry is very large. There are thirteen sawmills, two veneer plants, one OSB plant, two pulp mills, two pellet plants, a board plant and two power plants in the Region. West Fraser Timber Ltd. is the largest operating company followed by Tolko Industries Ltd.

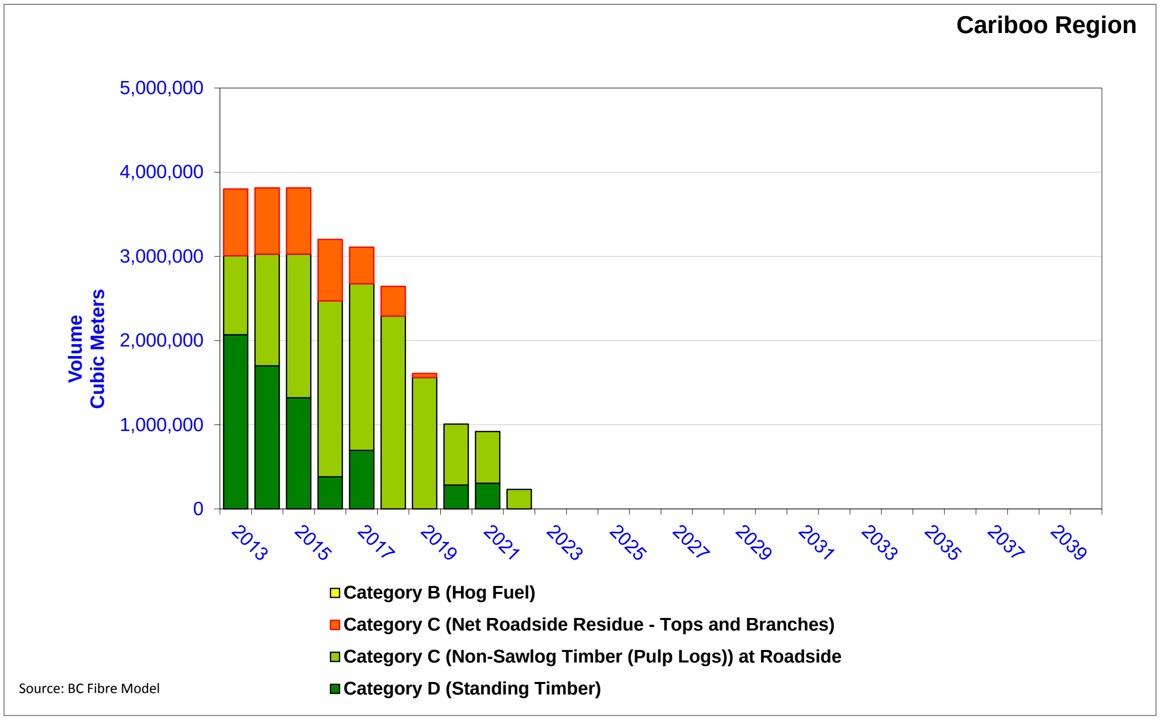
10.3 Demand for Residual Fibre

Given the diversity of the forest products industry that exists within the region, there is already significant demand for residual sawmill fibre to support power boilers, pellet plants, standalone electrical generation and other mill energy systems. In the face of reduced sawmill activity forecast for the region and consequently the decline in the availability of residual fibre, all of the residual fibre consumers will either resort to roadside residual fibre to meet their needs, harvest and consume pulp logs or potentially switch to alternative sources of energy (such as natural gas in some power boilers) or curtail operations.

10.4 Potential Fibre Sources for Energy

Figure 8 shows biomass fibre availability by type over the planning horizon. For the next 10 years there is a declining surplus of unused sawlogs, pulp logs and roadside debris. After this time, new opportunities are not apparent and even the existing industry may need to reduce operating rates, or consider closure due to shortfalls in fibre supplies.

Figure 8. Net Available Biomass by Type – Cariboo Region



10.5 Biomass Energy Potential

Table 11 summarizes the biomass potential for this region assuming an electrical generation facility is located central to the available fibre supply near Hanceville. A maximum 36 megawatts of capacity generating 319 GWh annually could do so at a forecast cost of $169/MWh over the next 10 years. As fibre supplies decline and existing mill closures occur due to constrained fibre supplies, new bioenergy opportunities are not forecast to become available.

Table 11. Cariboo Biomass Fuel Supply and Price Forecast

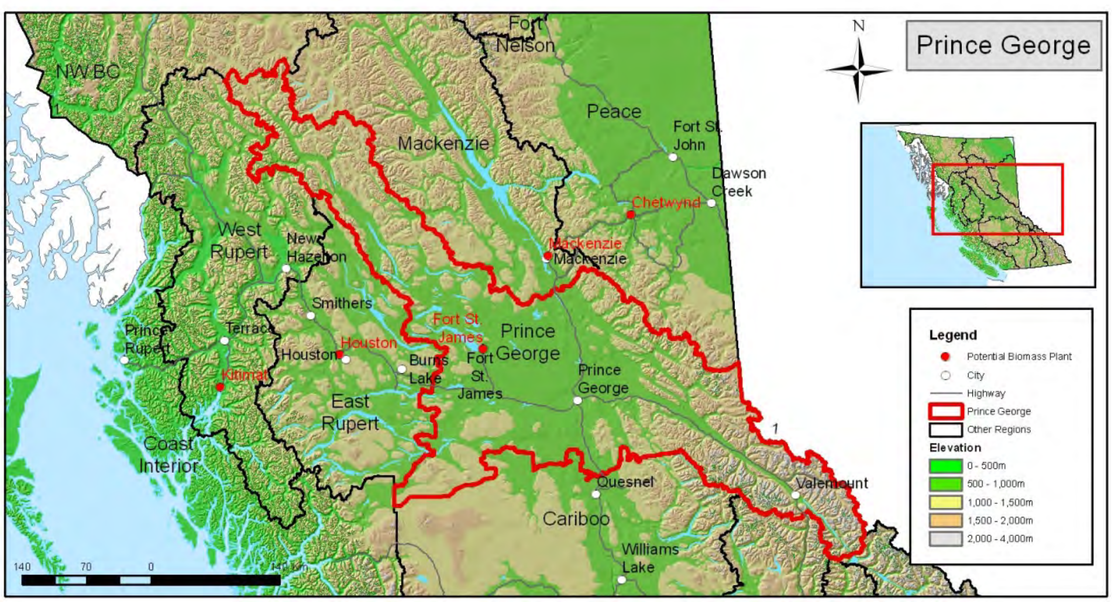
	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	319	0
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	0	0
	Category B (Hog Fuel)	0	0
	Total	**319**	**0**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	36	0
	Average Annual Cost of Biomass ($/m3)	$48	$0
	Average Annual Cost of Biomass ($/megawatt-hr)	$85	$0
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$169**	**n/a**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**n/a**	**n/a**

11.0 Prince George

11.1 Background information

Map 8 shows the location of the Prince George Region in relation to the Province. Though Lodgepole pine is heavily concentrated in certain areas, the size and diversity of the region includes extensive area where pine is a minor component of forest stands. Forests are composed predominately of pine, spruce and balsam fir at 47 percent, 31 percent and 19 percent respectively. The MPB-epidemic has had a significant effect on the roughly 293 million cubic metres of pine. Within the region the epidemic began in about 1999 and peak mortality occurred in 2005. By 2013 about 201 million cubic metres of pine are presumed killed and another 4 million are projected to die over the next 10 years. The historic AAC for the Region was about 11 million cubic metres. Due to the MPB-epidemic the AAC is currently about 14 million cubic metres. The long-term AAC is estimated to fall to 8.4 million cubic metres.

Map 8. Prince George Region



11.2 Existing Industry

Ten large sawmills, three pulp mills and three pellet mills currently operate within the Region. Another seven sawmills, a finger joint plant and a plywood plant have in the past four years been closed indefinitely. The Lakeland mill that was destroyed by fire in 2012 will be re-built. The forest industry is dominated by Canadian Forest Products Ltd (Canfor) which operates four sawmills and maintains controlling interest in the three pulp mills. Lumber producing competitors include the Sinclair Group, Carrier Lumber, Conifex, West Fraser and Dunkley. Sawmill residues from these solid-wood processing facilities are directed to the pulp mills for the production of pulp, paper and electricity, to Pacific Bioenergy, Premium Pellet and Pinnacle Pellet for the production of wood pellets and some residues moved north to Mackenzie or south to Quesnel. In the past few years, BC Hydro electricity purchase agreements were awarded to:

- Western Bioenergy for a greenfield plant in Fort St James,
- PG Log Sort for a greenfield plant in Prince George,
- Canfor Pulp (2 EPAs) for energy production at the Northwood pulp mill and the PG Pulp mill,
- West Fraser for energy production at their sawmill in Fraser Lake.

Since 2006, production of lumber has declined significiantly. This forced the residual forest industry to source some of their fibre directly from the forest, both in the form of roadside residues and pulp logs. Looking forward, Though lumber demand is returning and as a consquence the availability of sawmill residues is forecast to increase, it is probable that the pulpmills will need to source aoms of their fibre supplies through a whole log chipping program. Thereby reducing the long-term availability of staning trees after 2024.

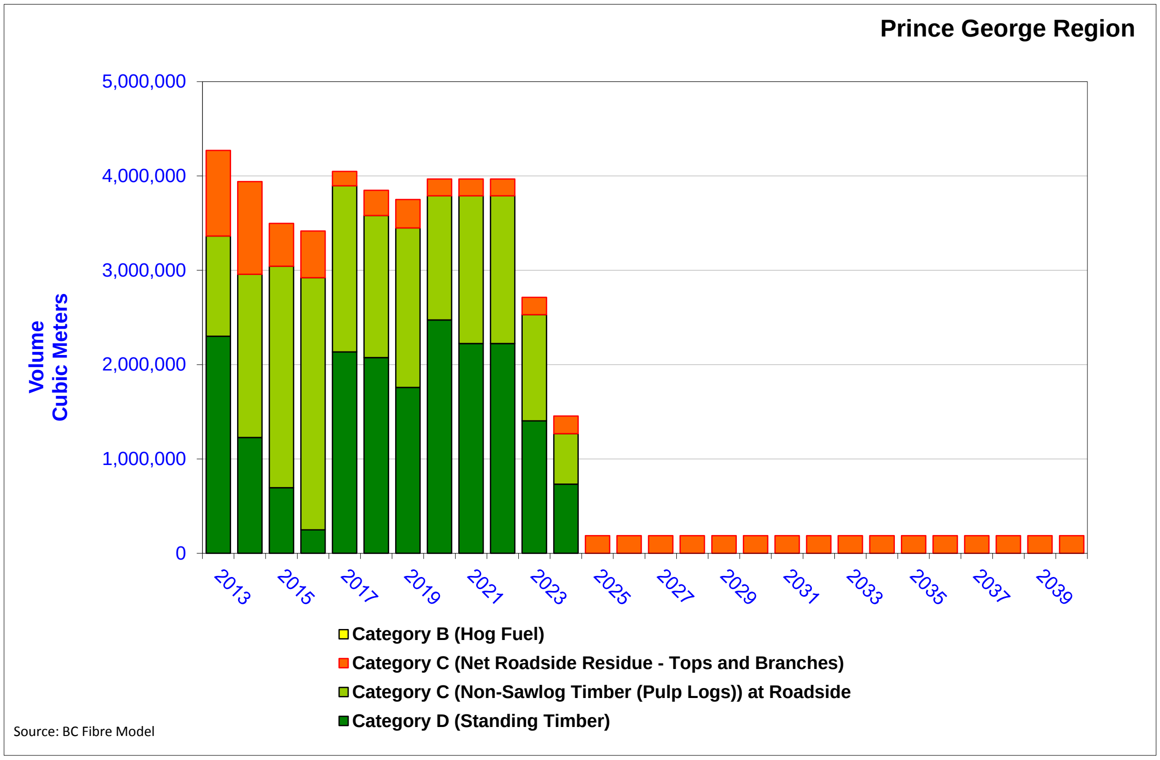
11.3 Demand for Residual Fibre

Given the size of the forest industry that exists within the region, there is already significant demand for residual sawmill fibre to support power boilers, pellet plants and other mill energy systems. In the face of reduced sawmill activity forecast for the region with the corresponding decline in availability of residual fibre, all of these consumers will either resort to roadside residual fibre to meet their needs, harvest and grind pulp logs or potentially switch to alternative sources of energy (such as natural gas in some power boilers).

11.4 Potential Fibre Sources for Energy

Figure 9 shows the forecast availability of biomass fibre by type over the planning horizon. For the next 12 years, standing timber and pulp logs are surplus to the existing industry's needs. After this time, roadside waste provides a small long-term source of potential biomass fuel.

Figure 9. Net Available biomass by Type – Prince George Region



11.5 Biomass Energy Potential

Table 12 summarizes the biomass potential for this region assuming an electrical generation facility is located central to the available fibre supply in Fort St. James. A maximum 153 MW capacity biomass power plant could generate 1337GWh of annual energy at a forecast cost of $157/MWh to 2024. As fibre supplies are reduced, this potential drops significantly to 12 MW producing 106 GWh/year for the second 15-year period at a forecast cost of $132/MWh.

Table 12. Prince George Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	921	0
	Category C (Non-Sawlog Timber (Pulp Logs))	314	0
	Category C (Net Roadside Residue)	102	106
	Category B (Hog Fuel)	0	0
	Total	**1337**	**106**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	153	12
	Average Annual Cost of Biomass ($/m3)	$42	$27
	Average Annual Cost of Biomass ($/megawatt-hr)	$73	$48
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$157**	**$132**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$132**	**$132**

12.0 Mackenzie

12.1 Forest and topography

Map 9 shows the location of the Mackenzie region in relation to the Province. The major topographic feature for the Region is the Williston Reservoir, which is bounded on either side by mountains with a preponderance of spruce and balsam on the slopes, and with pine on the flats and in the valley bottoms. The reservoir is critical in the transportation of fibre from the northern parts of the Region to the mills located in the southern end of the fibre supply area. Mountains and lake transport also add considerably to delivered fibre costs.

About 38 percent of the volume in the Region is Lodgepole pine, which comprises 117 million cubic metres. The MPB-epidemic in the Region peaked in 2009 and an estimated 78 million cubic metres have been killed to 2012. The epidemic is forecast to kill 87 million cubic metres.

The AAC for the Region is approximately 3 million cubic metres and has remained unchanged for the past 20 years. The post MPB-epidemic is forecast to have a relatively small long-term impact as a result of the surplus of older spruce and balsam in the region and due to harvesting significantly below the long-term sustainable level. BC Timber Sales commenced a large-scale dead pine salvage program in the southern part of the Region that will likely exceed the current AAC.

Map 9. Mackenzie Region

12.2 Existing Industry

The forest industry in the Mackenzie Region (4 sawmills and 2 pulp mills) collapsed during the period 2008 to 2010 due to a combination of financial difficulties and the availability of lower cost fibre in other regions of the Interior. At present, two sawmills and one pulp mill are operating. The second pulp mill was permanently shut. Canfor operates one sawmill, Conifex a second sawmill and Mackenzie Pulp (SinarMas) operates the pulp mill. Conifex was awarded and electricity purchase agreement with BC Hydro and is using infrastructure at the shuttered pulp mill to construct a 36 MW power plant.

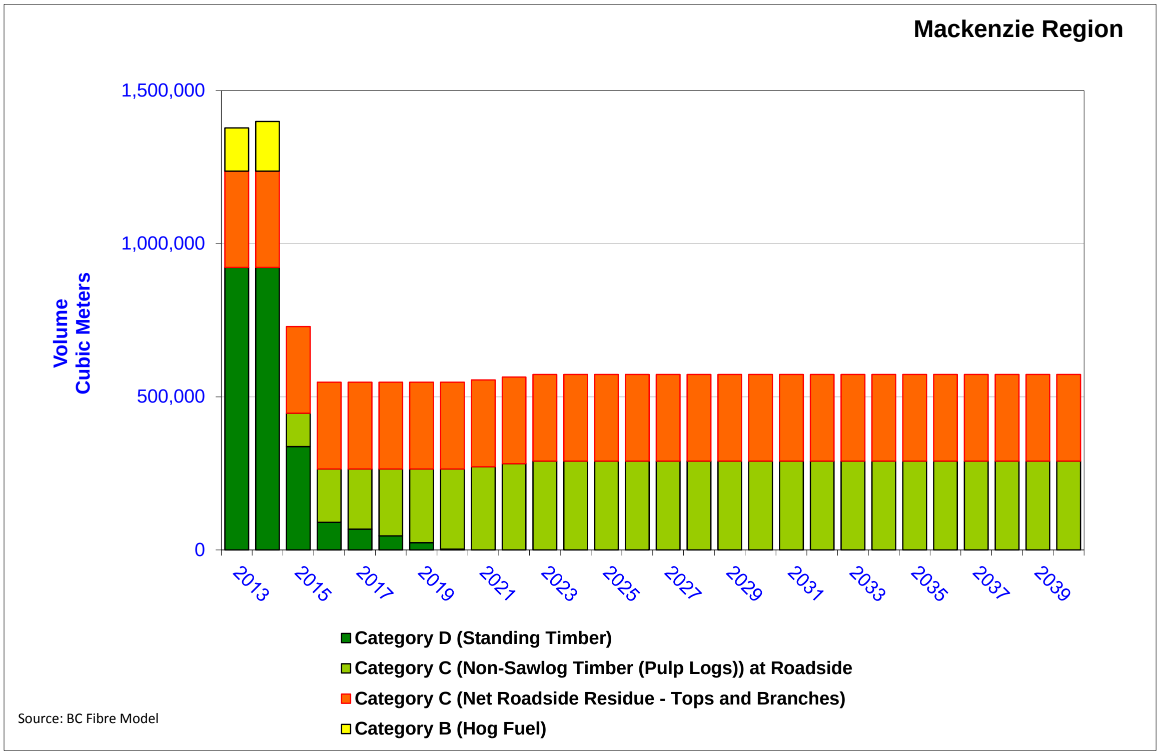
12.3 Demand for Residual Fibre

The Mackenzie Pulp mill is the last remaining pulp mill in BC to utilize sawdust and shavings for the production of pulp. It also utilizes the regional hog fuel produced at Canfor and Conifex. The completion of the Conifex power plant in 2014 will increase the regional demand for sawdust, shavings, hog fuel and roadside residues.

12.4 Potential Fibre Sources for Energy

Figure 10 shows the availability of biomass fibre over the planning horizon. The majority of the available fibre in the near term is standing timber that is not forecast to be harvested by the existing and re-emerging industry. As harvest levels decline in other Regions, the solid wood sector is forecast to grow within this Region, hence the availability of standing timber is significantly reduced over the planning horizon. This trend commenced in 2012 with several Prince George regional sawmills exporting volume out of the Mackenzie Region. The continued growth and export of this volume will result in substantial volumes of pulp logs and roadside waste being left at the side of logging blocks.

Figure 10. Net Available Biomass by Type – Mackenzie Region



12.5 Biomass Energy Potential

Table 13 quantifies the biomass potential for this region assuming an electrical generation facility is located in Mackenzie. Under the assumptions modeled, a 34 MW capacity power plant generating 302 GWh/year of electricity at a cost of $148/MWh is possible. This is in addition to the current demands of the industry and future demands of the Conifex power plant. Excluding standing timber from the supply and cost of fibre reduces the average cost of electricity to $132/MWh.

Table 13. Mackenzie Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	121	0
	Category C (Non-Sawlog Timber (Pulp Logs))	21	164
	Category C (Net Roadside Residue)	161	161
	Category B (Hog Fuel)	0	0
	Total	**302**	**325**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	34	37
	Average Annual Cost of Biomass ($/m3)	$36	$27
	Average Annual Cost of Biomass ($/megawatt-hr)	$64	$48
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$148**	**$132**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$132**	**$132**

13.0 Peace

13.1 Background Information

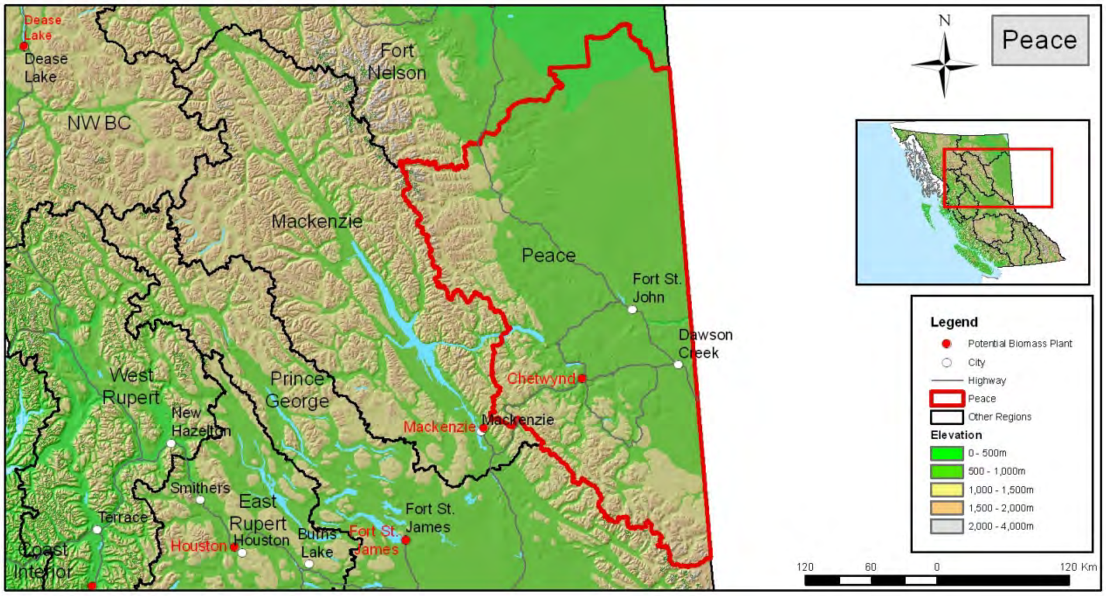
Map 10 shows the location of the Peace Region relative to the Province. The Region is unique from the rest of the Interior in that deciduous species play an important role for the forest industry. It is also unique in its difficulty in maintaining a skilled labour force as a result of competing demands from the oil and gas industry. Forests in the Region are predominately 35% spruce, 30% pine and 30 % deciduous. The MPB-epidemic expanded into the Peace in about 2006 and projections on the level of mortality may be understated. Currently, with an inventory volume of about 97 million cubic metres of Lodgepole pine, roughly 28 million are dead. The beetle epidemic peaked in 2010, and over the long term is forecast to kill 37 million cubic metres of pine.

The forecast of biomass availability in this analysis targeted the coniferous rather than deciduous species. Aspen trees in the region are utilized extensively in the production of OSB and pulp. Manufacturing residues at these plants are utilized internally for energy.

Coniferous residues from Chetwynd area sawmills are still incinerated in beehive burners or shipped to Mackenzie. Coniferous residues at Fort St John sawmills are used internally for heat or are shipped to Alberta.

The Coniferous AAC for the Region is about 3.2 million cubic metres. The MPB-epidemic is not expected to have a significant impact on the future coniferous AAC.

Map 10. Peace Region



13.2 Existing Industry

The existing industry is comprised of three coniferous sawmills, two OSB plants and two BCTMP pulp mills The Tembec BCTMP mill closed due to market-related issues in 2012. Canfor is the dominate licensee within the region operating two sawmills and one pulp mill. Tembec, Louisiana Pacific and West Fraser Timber also manage forestry assets within the Region.

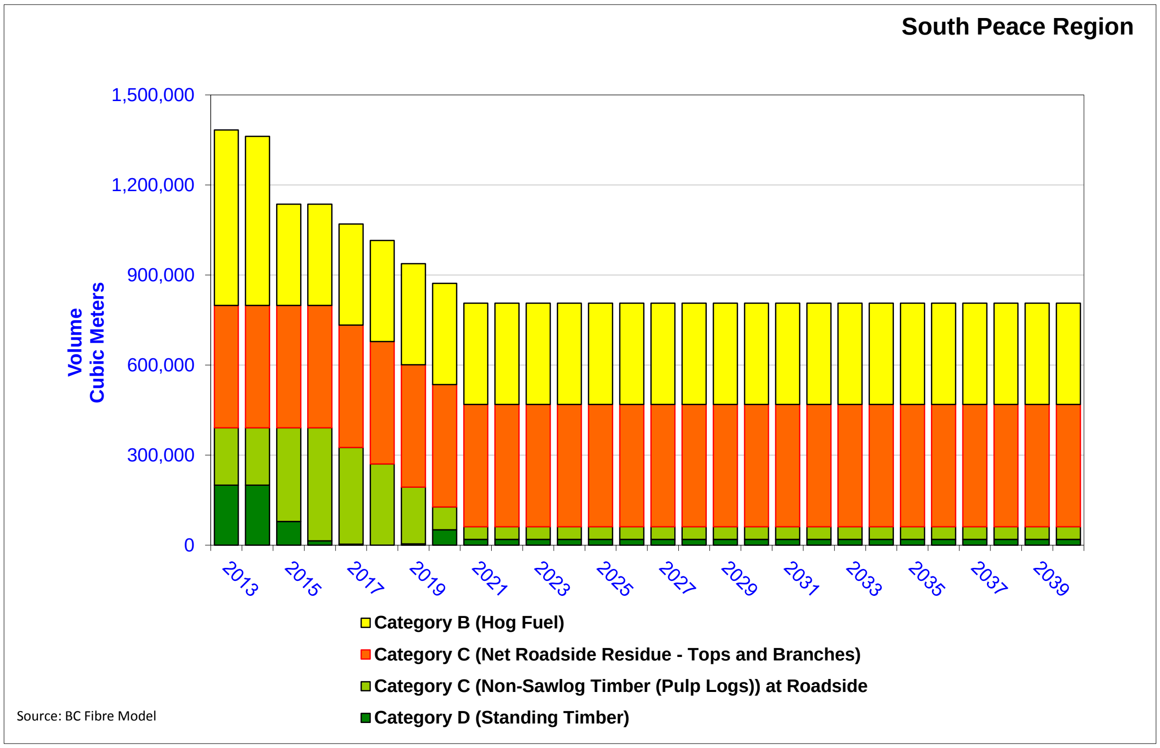
13.3 Demand for Residual Fibre

The three regional sawmills produce a significant surplus of both hog fuel and sawdust and shavings in the region. West Fraser was recently awarded an electricity purchase agreement with BC hydro to consume there sawmill residuals in Chetwynd through the integration of a biomass power plant at their sawmill. Canfor's Fort St. John sawmill uses some of their mill residues for internal heat and power, and ships excess fibre to Alberta. Canfor's Chetwynd mill residues are currently transported to Prince George and Mackenzie – the development of a pellet plant at the site has been proposed, with no construction planned to-date.

13.4 Potential Fibre Sources for Energy

Figure 11 shows the availability of biomass fibre by type over the planning horizon given the assumptions made. A combination of standing timber, pulp logs, roadside residue that is not forecast to be salvaged and considerable surplus hog fuel is forecast to be available over the entire planning horizon.

Figure 11. Net Available Biomass by Type – Peace Region



13.5 Biomass Energy Potential

Table 14 summarizes the biomass potential for this region assuming an electrical generation facility is located in Chetwynd. Given the stability of the available biomass supply within this region, a maximum 52 MW capacity biomass power plant could generate 457 GWh of annual electricity at a forecast cost of $127/MWh over the entire 28-year planning horizon.

Table 14. Peace Biomass Fuel Supply and Price Forecast

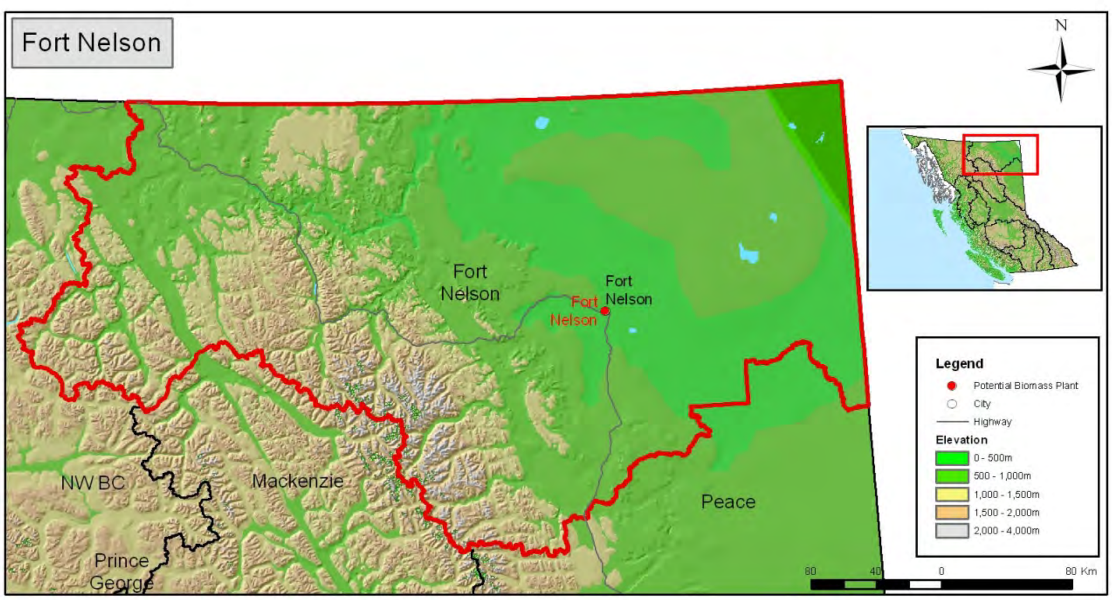
	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	30	11
	Category C (Non-Sawlog Timber (Pulp Logs))	24	24
	Category C (Net Roadside Residue)	231	231
	Category B (Hog Fuel)	191	191
	Total	**476**	**457**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	54	52
	Average Annual Cost of Biomass ($/m3)	$26	$25
	Average Annual Cost of Biomass ($/megawatt-hr)	$46	$44
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$130**	**$128**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$127**	**$127**

14.0 North-East BC (Fort Nelson)

14.1 Background Information

Map 11 shows the location of the north-east region of the Province. This region is coincident with the Fort Nelson Timber Supply Area and though predominately flat, is bisected by steep river valleys. The region is dense with marshes that create access difficulties and result in almost 90 percent of harvesting activities occurring in winter months. Large log inventories are therefore required to carry manufacturing operations through spring, summer and fall. Predominate tree species are spruce, aspen and pine. To-date, the MPB-epidemic has not significantly encroached into the Region. The hope is that cold winters in the northern-most parts of the Province will keep beetle populations to controllable levels. The current regional AAC is 1.6 million cubic metres. Although this AAC is forecast to remain at this level for the foreseeable future, significant opportunity exists to petition government to increase the AAC as a means to harvest pine stands. Historically, the AAC has targeted spruce and aspen – to the exclusion of pine. If the pine trees were utilized, a partitioned AAC of about 1 million cubic metres per year could be directed towards the long-term management of pine in the Region[6].

Map 11. North East Region



[6] This is not reflected in Figure 12 or Table 13.

14.2 Existing Industry

There is currently no active forest industry in the north-east Region. Canfor had two whole log manufacturing plants – a coniferous plywood plant and a deciduous OSB plant in Fort Nelson. Both are shut down indefinitely.

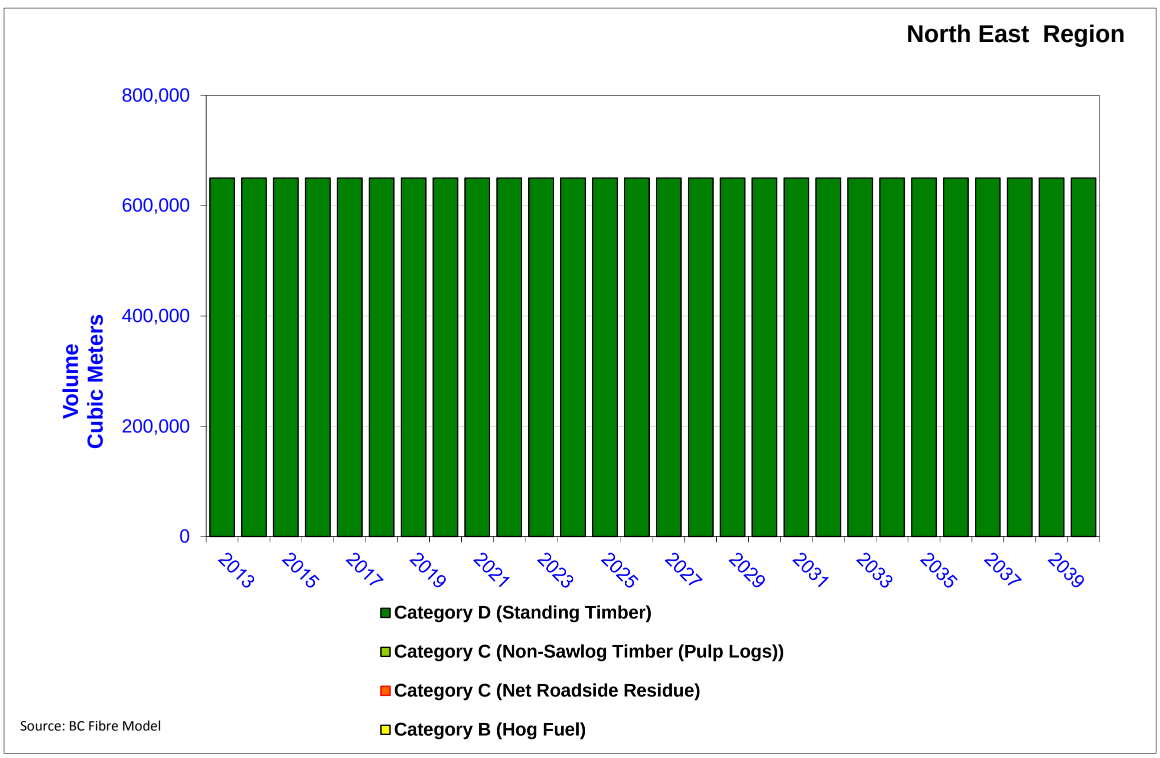
14.3 Demand for Residual Fibre

Since there is currently no industry operating in this region, there is no production or consumption of residual fibre. Although the demand for panels is growing significantly, North American production has been curtailed and will likely come on line prior to the Fort Nelson mills where the high cost of labour and logging makes the future uncertain. The forest industry here is not expected to recover until at least 2018.

14.4 Potential Fibre Sources for Energy

Figure 12 shows the availability of biomass fibre by type over the planning horizon. The lack of any operating forest industry in the region results in significant volumes of standing timber available to support biomass electrical generation over the entire planning period.

Figure 12. Net Available Biomass by Type – North East BC Region



14.5 Biomass Energy Potential

Table 15 summarizes the biomass electrical generation potential for this region assuming the electrical generation facility is located central to the available fibre supply in Fort Nelson. A maximum 42 MW capacity could generate 368 GWh/year of electricity at a forecast cost of $183/MWh over the entire planning horizon. All of this opportunity rests in the use of standing timber, which may not be the highest and best use of the forest resource.

Table 15. North-East BC Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	368	368
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0
	Category C (Net Roadside Residue)	0	0
	Category B (Hog Fuel)	0	0
	Total	**368**	**368**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	42	42
	Average Annual Cost of Biomass ($/m3)	$56	$56
	Average Annual Cost of Biomass ($/megawatt-hr)	$99	$99
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$183**	**$183**

15.0 East Rupert

15.1 Background information

Map 12 shows the location of the East Rupert Region relative to the Province. The eastern half of the Region is relatively flat and heavily treed with pine. In the west, the Coastal foothills transition to mixed forests of pine, spruce and balsam fir. The Region has about 141 million cubic metres of pine (comprising 54% of the forests), many of which were killed at the very start of the MPB-epidemic. The epidemic peaked in 2005 and by 2013 approximately 94 million cubic metres of pine have been killed. Another 6 million cubic metres of pine are forecast to die by 2020.

The AAC for the Region is approximately 5.3 million cubic metres. This has been increased significantly from 2000 when the area supported about 4.5 million cubic metres of AAC. This harvest is expected to complete its progressive decline to about 2.9 million cubic metres by 2027, as a result of the loss of merchantable pine trees.

Map 12. East Rupert Region

15.2 Existing Industry

The Region currently has operating four large sawmills, a particle board plant and two pellet plants. A fifth sawmill, (Hamptons Babine sawmill) was destroyed by fire in 2012 and plans are to rebuilt this plant. Carrier's Cheslatta sawmill was shut in 2010. With five operating sawmills, at least one sawmill may need to shut in the future due to lack of economic sawlog supplies. The larger companies controlling the fibre in the Region include West Fraser, Canfor, and Hampton Affiliates.

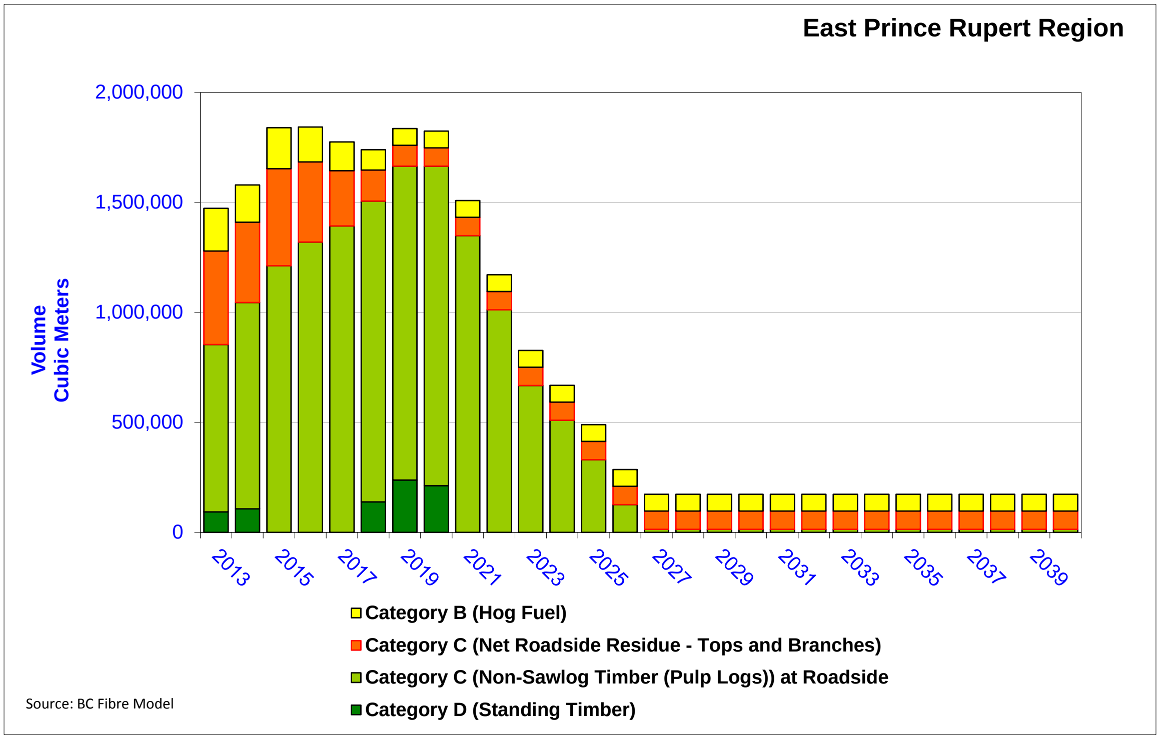
15.3 Demand for Residual Fibre

As a result of the diversity of the industry within the Region, there is already significant demand for residual sawmill fibre to support power boilers, pellet plants and other mill energy systems. However, with the 2010 closure of Eurocan Pulp, a surplus of hog fuel has developed and is forecast to remain for the next 10 years.

15.4 Potential Fibre Sources for Energy

Figure 13 shows the availability of biomass fibre by type over the planning horizon. Significant volumes of standing timber, non-sawlog fibre and roadside residual fibre are available during the next 12 years as a result of AAC's being higher than forecast industry demand. As the AAC is reduced and the industry aligns to the available log supply, this availability is significantly reduced over the planning horizon.

Figure 13. Net Available Biomass by Type – East Prince Rupert Region



15.5 Biomass Energy Potential

Table 16 summarizes the surplus biomass potential for this region assuming an electrical generation facility is located central to the available fibre supply in Houston. A 47 MW capacity biomass power plant could generate 412 GWh/year of electricity at a forecast cost of $132/MWh over the next 13 years. As fibre supply is reduced, this potential declines to 11 MW capacity (98 GWh/year) over the second 15-year period at a forecast cost of $118/MWh.

Table 16. East Rupert Biomass Fuel Supply and Price Forecast

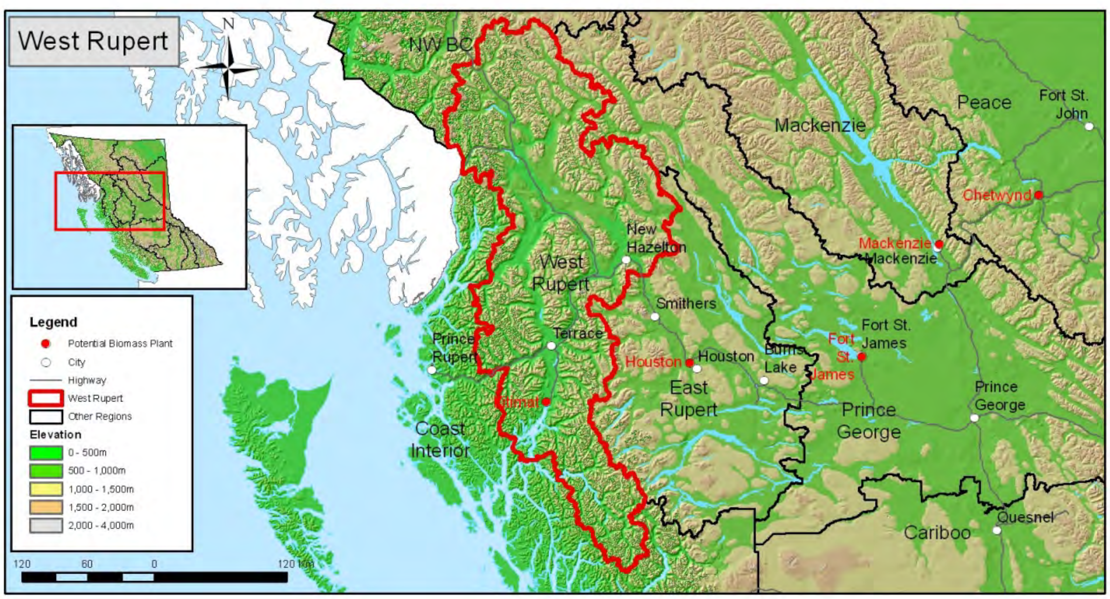
	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	37	0
	Category C (Non-Sawlog Timber (Pulp Logs))	285	8
	Category C (Net Roadside Residue)	47	47
	Category B (Hog Fuel)	43	43
	Total	**412**	**98**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	47	11
	Average Annual Cost of Biomass ($/m3)	$27	$19
	Average Annual Cost of Biomass ($/megawatt-hr)	$48	$34
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$132**	**$118**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$129**	**$118**

16.0 West Prince Rupert

16.1 Background Information

Map 13 shows the location of the West Rupert Region relative to the Province. This Region is characterized by heavy rain falls and mild climate, resulting in some of the most productive growing sites in BC. Hemlock, balsam and cedar are the principle tree species in the Region. The old-growth characteristics of existing stands have resulted in trees that are generally large, decay-ridden and are generally less desirable for lumber than spruce, pine or fir. Only six percent of the region is covered in pine trees and very little of this has been impacted by the MPB-epidemic. Although the epidemic has encroached on the area, it will not have a measurable impact on the long-term AAC. The current and forecast AAC for the region is about 3.2 million cubic metres.

Map 13. West Rupert Region



16.2 Existing Industry

The current industry is comprised of one operating sawmill. The sawmill in Terrace commenced operations under new ownership in 2012. There is currently no buyer or outlet for the sawmill's residual fibre and it is either stockpiled or land-filled.

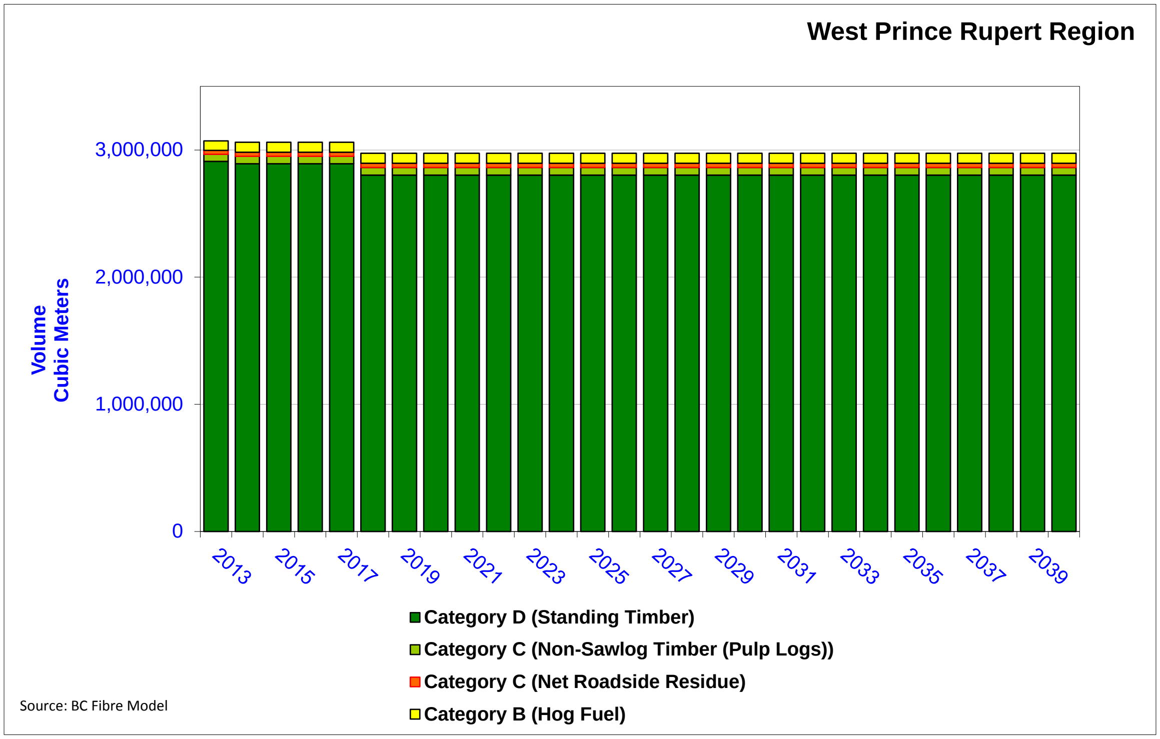
16.3 Demand for Residual Fibre

Following the 2010 closure of the Eurocan pulp mill, there is currently no demand for residual fibre in this region.

16.4 Potential Fibre Sources for Energy

Figure 14 shows the availability of biomass fibre by type over the planning horizon, given the assumptions made. As can be seen, lack of a substantial operating forest industry in the region results in significant surplus volumes of standing timber being available to support biomass electrical generation.

Figure 14. Net Available Biomass by Type – West Rupert Region



16.5 Biomass Energy Potential

Table 17 summarizes the biomass potential for the region assuming an electrical generation facility is located in Kitimat. A 192 MW capacity biomass power plant could generate 1686 GWh of electricity annually at a forecast cost of $196/MWh over the entire planning horizon. Most of this opportunity rests in the utilization of standing timber. Removing the fibre supply reduces the energy opportunity to approximately 76 GWh per year at a cost of $118 per MWh.

Table 17. West Prince Rupert Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years	
		2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	1611	1589
	Category C (Non-Sawlog Timber (Pulp Logs))	22	34
	Category C (Net Roadside Residue)	12	19
	Category B (Hog Fuel)	42	44
	Total	**1686**	**1686**
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	193	192
	Average Annual Cost of Biomass ($/m3)	$64	$63
	Average Annual Cost of Biomass ($/megawatt-hr)	$113	$112
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$197**	**$196**
	Biomass Electricity Cost - exclude Standing Timber ($/MWh)	**$115**	**$118**

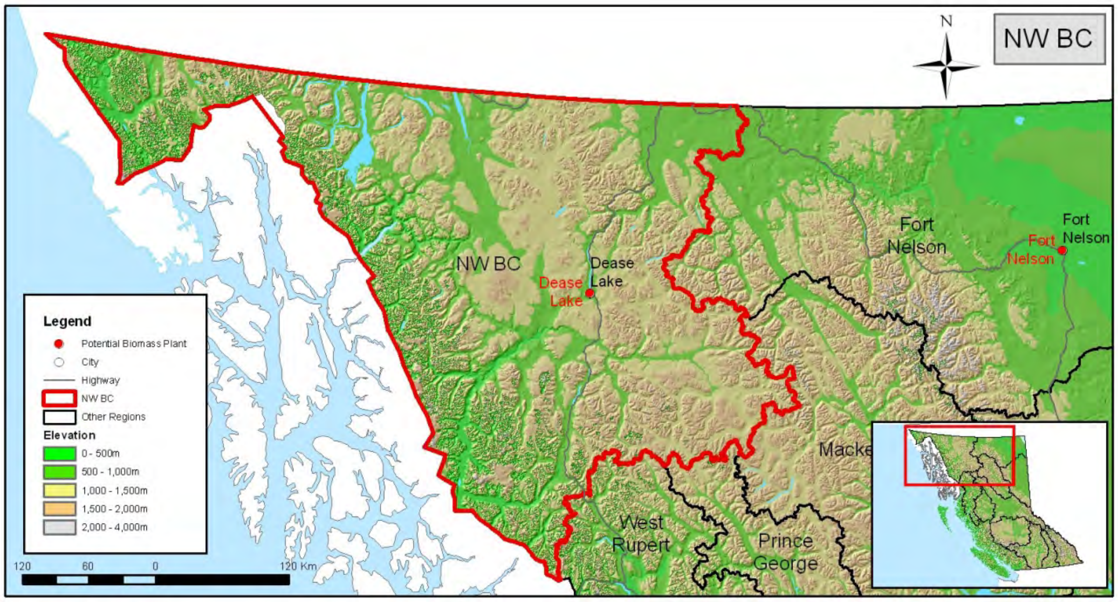
17.0 North-West BC

17.1 Forest and topography

Map 14 shows the location of the North-West Region of BC relative to the rest of the Province. This Region is coincident with the Cassier Timber Supply Area and covers over 15 million hectares. In the west, the region consists of rugged ice-capped mountains, dissected by several major river valleys. To the east, mountains and plateaus are separated by wide valleys and lowlands. Only about 25% of the Region is forested – and this is generally located on steep slopes unsuited for forestry operations or is located on very poor growing sites. About 200,000 hectares is considered to support what is largely a very community-based logging industry. The mountain pine beetle has not yet had a measurable impact on the pine forests beyond a few spot infestations in the southern tip of the region.

The AAC for the Region is 300,000 cubic metres. It is not expected to increase or decrease due to a forecast lack of demand.

Map 14. North West Region



17.2 Existing Industry

Almost all of the harvested timber from the Region is exported out of the region for processing elsewhere. There are several small portable mills the periodically supply rough lumber to meet intermittent local demand.

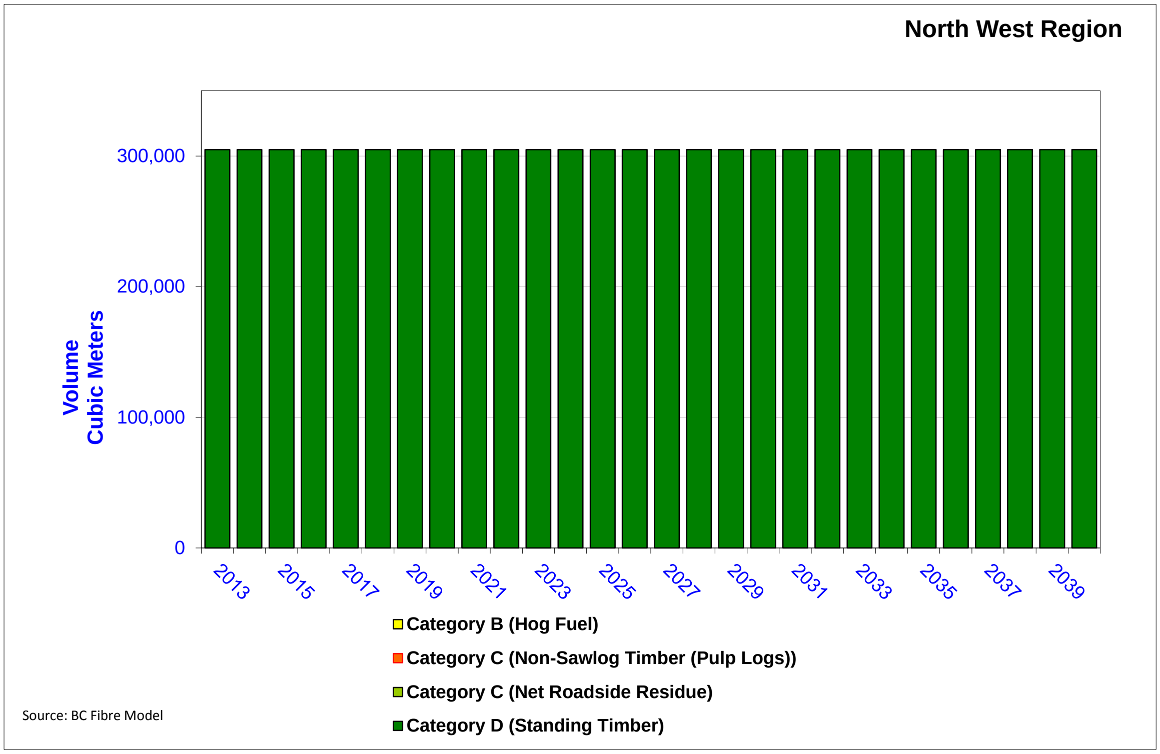
17.3 Demand for Residual Fibre

There is no production or consumption of residual fibre in this region

17.4 Potential Fibre Sources for Energy

Figure 15 shows the availability of surplus biomass fibre by type over the planning horizon, given the assumptions made. Lack of any commercial operating forest industry results in only standing timber being available to support biomass electrical generation.

Figure 15. Net Available Biomass by Type – North West BC Region



17.5 Biomass Energy Potential

Table 18 summarizes the biomass potential for this region assuming tan electrical generation facility is located central to the available fibre supply in Dease Lake. A maximum of 20 MW capacity biomass power plant could generate 173 GWh of annual energy at a forecast cost of $174/MWh over the entire planning horizon, with the assumed use of only standing timber.

Table 18. North-west BC Biomass Fuel Supply and Price Forecast

	Biomass Fuel Category	Forecast Years		Forecast Years	
		2013 - 2024	2025 - 2040	2013 - 2024	2025 - 2040
Sustainable Supply of Biomass Fuel for Electrical Generation (GWh per year)	Category D (Standing Timber)	173	173	305,000	305,000
	Category C (Non-Sawlog Timber (Pulp Logs))	0	0	0	0
	Category C (Net Roadside Residue)	0	0	0	0
	Category B (Hog Fuel)	0	0	0	0
	Total	**173**	**173**	305,000	305,000
Biomass Electricity Generation Cost Calculations	Maximum Generation Capacity (megawatts)	20	20	**20**	**20**
	Average Annual Cost of Biomass ($/m3)	$51	$51	$51	$51
	Average Annual Cost of Biomass ($/megawatt-hr)	$90	$90	$90	$90
	Average Capital and Operating Cost ($/megawatt-hr)	$84	$84	$84	$84
	Biomass Electricity Cost ($/megawatt-hour)	**$174**	**$174**	**$174**	**$174**

18.0 Electrical Generation Capacity Sensitivity Assessment

This analysis was completed under an assumption that all biomass within the framework of the AAC and surplus to the needs of the traditional forest industry is eligible for consideration for electrical generation. This assumption inherently includes large volumes of high-priced biomass fuel. Two sensitivity analyses were performed for each region to calculate the volume of available biomass fuel and its associated cost if all higher-cost standing timber and non-sawlog fibre (i.e. pulp logs surplus to the pulp and paper sector) were assumed not to be available for use in bio-electrical generation.

Table 19 provides a Regional and Provincial summary of the resultant biomass potential and cost, if: a) Category D was excluded from consideration for electricity generation; and b) Category D and Category C (Pulp Logs) were excluded from consideration for electricity generation.

Table 19. Sensitivity Analysis

Region	Scenario 2, Exclude Category D Fuel (Standing timber)				Scenario 3, Exclude Category D and Category C (standing timber and pulp logs)			
	2013 - 2024		2025-2040		2013 - 2024		2025-2040	
	Biomass Capacity (GWh/yr)	Cost ($/MWh)	Biomass Capacity (GWh/yr)	Cost ($/MWh)	Biomass Capacity (GWh/yr)	Cost ($/MWh)	Biomass Capacity (GWh/yr)	Cost ($/MWh)
Coast Mainland	1,242	128	1,414	128	1,242	128	1,414	128
Coast Vancouver Island		127		127		127		127
East Kootenay	225	134	225	134	225	134	225	134
West Kootenay	525	127	530	127	525	127	530	127
Kamloops / Okanagan	493	137	476	137	64	137	41	137
Cariboo	0	84	0	0	0	84	0	0
Prince George	416	132	106	132	102	132	106	132
Mackenzie	181	132	325	132	161	132	161	132
South Peace	446	127	446	127	422	127	422	127
North-east	0	84	0	84	0	84	0	84
East Prince Rupert	375	129	98	118	90	117	90	117
West Prince Rupert	76	115	97	118	54	108	63	110
North-west	173	84	173	84	173	84	173	84
Total BC	**4,151**	**$127**	**3,890**	**$127**	**3,057**	**$125**	**3,225**	**$125**

As is apparent in Table 19, the provincial capability to produce electricity from surplus fibre is significantly reduced (77% in the first 15-year period) when standing timber is removed from consideration. Provincial capability decreases by 82 percent when both harvesting and salvage of standing timber (i.e., scenario 3) is removed from consideration for biomass electrical generation.

18.1 Competing Internal Demands

It is impractically to assume that the annual harvest and consumption of all available timber and recovery of all available roadside biomass is feasible. As a result, caution was exercised when considering the utilization of these potential energy sources. Conservatism was applied to the calculation of available biomass fuel, recognizing that biomass fuel volumes will fluctuate over time, and an IPP must consider future short-falls in developing a fuel plan profile.

Not factored into this analysis is the uncertainty that sawmills in the BC Interior will consume more of their own residuals internally. They might do this to produce steam energy to dry lumber or veneer. Many log processing plants continue to use natural gas and propane for heat. About one-third of BC Interior mills currently use some portion of their residual stream in Konis-style, low pressure energy systems. Typically these mills use dry shavings from the planing process; however some mills can use green sawdust and hog fuel. While use of residual fibre for this purpose is small, it may limit realization of some of the forecast volumes herein.

18.2 Lumber Re-manufacturing Plants

Lumber remanufacturing in the BC Interior is a relatively insignificant source of fibre given that the vast majority of Interior mills produce 100% dimension lumber for housing markets. In the US dimension-milling process, sawmills produce almost exclusively finished packages of lumber for rail shipment to the buyers in the mid and eastern US. Very little (less than 5%) of BC Interior mills sell lumber to remanufacturing operators who subsequently add value to the wood through additional milling to produce boards or molding. On the BC Coast, remanufacturing is more common because of the properties of cedar and hemlock species. In a typical coastal cedar sawmill up to half of the lumber shipped goes to remanufacturing plants for secondary milling into US siding and molding markets. A smaller, but significant, percentage of the coastal hemlock sawmills sell hemlock lumber to remanufacturers who produce door and molding stock for US and foreign markets. Currently the residual fibre output from the 40+ remanufacturing plants that remain on the BC Coast is used in greenhouses for power or growing medium, agriculture, animal bedding or end up in the pulp/paper mill hog fuel stream.

Appendix 1

Theoretical Biomass IPP Business Case

BC Hydro

Theoretical Biomass Independent Power Producer Business Case for Planning Purpose

MAY, 2013

Table of Contents

BC Hydro

Theoretical Biomass Independent Power Producer Business Case for planning purpose

1 Disclaimer

This business case is presented for discussion purposes only and should be considered speculative in nature. The development of this IPP business case is a means of considering how an Independent Power Producer (IPP) may 'think' when researching potential investments in a biomass-fired power plant producing electricity for the power grid.

The values assumed herein are theoretical in nature, but are based on reasonable operating assumptions and costs as seen within B.C. or as reported by industry participants.

This report was prepared for BC Hydro to demonstrate the influence of key variables considered in the calculation of unit energy costs for its long term Integrated Resource Planning (IRP) purpose. This report also provides recommendations on costs to assume for the purpose of the IRP.

The authors are not responsible for the use of the data and assumptions presented herein beyond that of the stated intent.

It is recommended to anyone planning to prepare a proposal for any Call for Power that they secure appropriate energy and fibre supply expertise rather than relying on the data and assumptions included herein.

BC Hydro

Theoretical Biomass IPP Business Case

2 Introduction

In order to support the ***Integrated Resource Planning*** process within BC Hydro, the following Theoretical Biomass Independent Power Producer (IPP) business case was prepared to provide perspective on the influence of biomass fuel types to electricity costs to BC Hydro. This report provides recommendations on the costs (unit energy costs) to assume for the purpose of the IRP.

The intent of this document is not to provide a business plan sufficient to support individual biomass electrical generation investment decisions, but rather, to demonstrate key variables that must be considered to evaluate the potential for a biomass electrical generation facility.

2.1 Overview of the Business Model Assumed

The unit energy costs for typical biomass power plants are influenced by conversion factors and key variables that are described in the following table. The values assumed herein are for discussion purposes only.

The authors do not suggest that these variables are specific to any one region or proposed plant, but rather that they are within a range of plausible values and as such are presented by way of example.

3 IPP Business Case Model

This Biomass IPP Business Case Model is a simplified version of those typically used to develop formal business plans in support of investment decisions. It reflects the basic data used in the derivation of unit energy cost and is presented as an information source.

Exhibit 1 depicts the Model assumed and the variables that form the basis of the descriptions below.

Exhibit 4. Sample IPP Biomass Business Model

Wood Consumption per megawatt hour	0.72	Oven Dry Tonnes per megawatt hour	
Installed Capacity	35	megawatts	
Saleable Average Annual Energy (MWh) (91% Capacity Factor)	279,006	megawatt hours (net of losses and operational down time)	
Annual Wood consumption	220,752	Oven Dry Tonnes per year	
	540,842	Cubic metres per year	
Investment Cost			
Fixed Investment Cost per MegaWatt	$ 4,740,000		
Total Fixed Investment Cost	$ 165,900,000		
Amortization			
Years of Service	15		
Maximum Hours of production	131,400		
Amortized Cost of Plant (over saleable hours)	**$40**	**per megawatt hour**	
Fuel (wood fibre) Cost	$24	per cubic metre	
Volume to Weight Conversion	2.45	cubic metres per Oven Dry Tonne	
Total Fuel Cost	$58	per Oven Dry Tonne	
Wood Cost per megawatt hour	**$41**	**per megawatt hour**	
Variable Operating Cost			
Annual operating and maintenance cost	$5,806,500	3.5%	of capital cost
Operating cost per megawatt hour	**$21**	**per megawatt hour**	
Profit			
As a % of capital employed	4%		
Return on Capital per megawatt produced	**$23.78**	**per megawatt hour**	
Annual Return on Capital for this plant	$6,636,000		
Unit Energy Cost Excluding Fuel	**$84**	**per megawatt hour**	
Total Unit Energy Cost	**$125**	**per megawatt hour**	

4 Variable Descriptions and Assumptions

Each line of the Biomass IPP business model is discussed with a description of the variable and an overview of considerations required when considering the variable and associated Model outcomes.

4.1 Wood Consumption per Megawatt Hour

It is assumed that in a traditional wood-fired electrical generation facility that 0.72 oven-dry tonnes of wood fibre are required to generate one-megawatt hour of electricity.

It is further assumed that 2.45 cubic metres (solid wood equivalent) of wood fibre are required to make an oven-dry tonne (ODT) of biomass fuel.

In most cases within the current biomass consumption industry in British Columbia (pulp mills, Atlantic Power; Williams Lake, and others), wood fibre when delivered to a power plant is measured and paid for using “green” weight. The reason forest industry users do not use “dry” weight as the basis for payment is that the cost of collecting and testing wood samples from each supply source is not considered cost-effective given the current value (price paid) for hog fuel and roadside residual biomass fuel sources. Biomass consumers typically measure supplier-delivered wood-fibre randomly, in order to establish green-weight to dry-weight conversion factors that are then used to negotiate delivered biomass costs.

To demonstrate the relationship between logs and biomass, a dry weight conversion is assumed herein, consistent with conversions used for the transaction of higher-value wood chips.

Sawmill owners purchase and/or acquire (harvested) wood on a per cubic metre basis. When it is hauled to the mill, it exists in a green or natural form and each cubic metre is made up of wood and water in varying proportions. The amount of water in each cubic metre depends on the species, the time of year and in the case of BC Interior pine, the length of time the tree has been dead.

“Green” wood typically has about 45-50% water. Dead pine can have as little as 13% water. “Oven-dry” wood is bone dry wood that contains no water (0%).

As a result, a cubic metre of green wood in any form (e.g., log, chip, sawdust or hog fuel) will have a different weight when it is transported than a cubic metre of wood that has been dead for some time. However, regardless of the weight (including water) of each cubic metre of wood, it is always a cubic metre on a volumetric basis.

By way of example, consider a pile of logs that have been purchased or harvested and paid for on a per cubic metre basis, and that currently exists as biomass inventory in a sawmill yard. A sawmill owner may wish to sell some of these logs to a biomass generating power plant, but the purchaser wants the wood delivered by truck in chip form.

One cubic metre of pine log, chipped (or ground up), is still have one cubic metre of wood, it is just in a new form and it is now in a truck.

Once the chips are in a truck, assuming not measured every cubic metre of log going into the chipper was measured, must somehow be quantified. The simplest way to quantify chips is by weight. However, if some of the logs were green and some had been dead for many years, the amount of water in each cubic metre of log is inconsistent. This is why the derivation of the relationship between wood weight (ODT's) and volume (cubic metres) is important to a biomass consumer.

What is known is that oven-dry pine (bone-dry pine) weighs 925 pounds per cubic metre. This is a very consistent relationship within nature. It is defined as the bulk density of pine. Each softwood or hardwood species has its own unique bulk density. Dense woods such as oak for example, have a higher bulk density (a cubic metre of oak weighs more than pine if both are compared on an oven-dry basis).

One tonne of wood of any species, however, weighs 2204 pounds. A tonne is a tonne.

Since each species has its own unique bulk density (pounds per cubic metre), it takes a different number of cubic metres of each species to make up an oven-dry tonne of that species.

An oven-dry tonne of pine, requires 2.38 cubic metres (2204/925 = 2.38).

When chipped-up logs are in a truck, the actual weight of the wood will depend on the amount of water that saturated each log that was chipped. Some logs will have lots of water, others will have little. To convert all the green wood (of varying weights as a result of their water content and of uncertain volume) to a number which forms the same basis for transaction or sale purposes, the green weight of the wood must be converted to the oven-dry weight of the wood, based upon a sample. The transaction resulting in the sale of wood then takes place on a “oven-dry” basis, since the relationship between weight and volume for oven-dry wood is constant.

To determine the samples conversion, a truck is weigh-scaled both full of chips and then empty to verify the tonnes of green chips in the truck. A sample of chips, representative of all the chips in the truck, is then weighed separately. This sample of chips is then put in a hot oven for 24 hours to dry and then re-weighed. At this point, the chip sample is assumed to be oven-dry and contains only wood – no water. The ratio of the “oven dry” weight to the original “green” weight of the sample is considered the oven dry percentage, or in layman’s terms, it represents the weight of wood only in the green chips. This ratio is then multiplied by the net weight of green chips in the truck and the oven-dry tonnes of chips results.

Math for a simple example:

- Truck weight (tare) = 45 tonnes
- Truck full of green pine wood chips = 95 tonnes
- Net weight of green pine wood chips = 50 tonnes
- Sample of green pine chips = 1 pound
- Oven dry sample = 0.5 pounds (i.e. 0.5 pounds of water)
- Oven Dry % = 50%
- Oven-dry pounds of chips = 50 tonnes × 50% = 25 tonnes of oven-dry chips
- 25 tonnes × 2204 pounds per tonne = 55,100 pounds of dry chips
- Since pine weighs 925 pounds per cubic metre, then:
  55,100 ÷ 925 = 59.56 cubic metres of chips in truck.
- The green weight (what is hauled and delivered) = 50 tonnes. What is purchased is the calculated dry weight of 25 tonnes.

Regardless if discussing green or dry wood weight, the 59.56 cubic metres of chips in the truck is constant *in this example*.

Some transactions of residual fibre (such as hog fuel or sawdust) are sold on a “green” basis, but in these cases the buyer and the seller must agree on the moisture content of the fibre being sold, since it is always sold based upon weight. In places where trees are very uniform in moisture content, the conversion to ODT’s is usually agreed upon in advance and only checked sporadically. When live and dead pine logs are mixed together to form the biomass supply stream, the only reliable way to ensure a consistent measurement of the volume of wood sold is to calculate the oven-dry weight of the wood sold via sampling.

The relationship is also applied when utilizing roadside residues. The volume of fibre is typically not measured for its cubic metre input prior to grinding. However, because of the relationship between weight and volume, a biomass sample can be measured to, determine the oven-dry percent and back-calculated to derive the cubic metre volume equivalent that was used to make the truck full of roadside residues.

In the forgoing example, a single tree species conversion was assumed for simplicity. In many parts of BC, the fibre supply for a bioenergy plant would likely include a mixture of pine, spruce, balsam, hardwoods or fir. The actual conversion will be based upon the species being consumed. In this instance, the bulk densities of each species and the proportion of each species expected in the fibre supply would be calculated and substituted for our assumed 2.45 cubic metres per oven-dry tonne average for the province.

4.2 Installed Capacity

This variable reflects the gross electrical capacity assumed to be generated within the proposed plant.

For purposes of the calculations presented herein, a 35 megawatt plant capable of producing a maximum of 306,600 megawatt hours of electricity (if operating 365 days per year and 24 hours per day) was assumed.

The 35 megawatt capacity was selected because it represents a plant large enough to take advantage of most economies of scale and secondly that it represents a plant with a fibre requirement that could be sourced within many regions of the province. As plant sizes increase, plant operating efficiencies may decrease, however the saving may be offset with an increased cost to deliver fuel over a wider range of forest area.

4.3 Salable Average Energy (Capacity factor)

In order to forecast the amount of electricity that is actually produced (and can be sold) from the power plant, the gross number is typically reduced for planning and financial purposes to account for operational efficiencies that prevent the plant from running continuously. Capacity factor is therefore the ratio of delivered annual energy to maximum annual energy if the plant was run flat out at maximum output. Capacity factors may vary from as low as 83 percent to as high as 96 percent. In this hypothetical business case a 91 percent capacity factor was assumed.

4.4 Annual Wood Consumption

The total volume of wood fibre required to support a plant is derived from the assumed plant size and electricity production (in megawatt hours).

For the purposes of the 35 megawatt plant assumed in this example, the plant would require 220,752 oven-dry tonnes of wood fibre (or 540,842 cubic metres (solid wood equivalent)) annually to operate the plant over the course of one year. This is based upon 35MW capacity operating 8760 hours per year and requiring 0.72 ODT per MWh.

4.5 Investment Cost

The cost to purchase land, equipment and to build a suitably-sized biomass generation facility and connect this facility to the electrical grid is included in this cost estimate.

While costs are not directly related to the size of the plant being considered, for the purposes of the report presented herein, it was assumed that the capital cost of biomass generating plant would be approximately $4,740,000 per megawatt produced.

For the 35 megawatt plant assumed herein, therefore, a capital cost of $165,900,000 was assumed.

4.6 Amortization Period

Amortization of the capital cost of the plant (and in doing so allowing the investor to recuperate the investment as the plant operates) is done by assuming the planning horizon over which the initial investment is assumed to be paid off. Typically, this also suggests that the plant and equipment will operate over that time frame.

For purposes of this report, an amortization period of 15 years was assumed. A 15 year amortization period was selected with regard to the longer-term uncertainty of biomass fibre supply.

If a shorter amortization period is assumed, the required price of electricity would have to increase in order to recuperate the investment faster. The opposite is true if you assume a longer amortization period.

Amortization period may also impact on annual operating costs (see below) since the longer the plant is assumed to operate, the greater is the chance that maintenance costs may increase.

4.7 Fuel (Wood Fibre) Cost

The fuel wood supply assumed to support a proposed biomass electrical generation facility is quite possibly one of the most important, but difficult to forecast variables in the business plan.

Using BC Hydro definitions, the following fibre types could potentially be accessed to support a proposed plant:

- **Category B:** Sawmill Residuals including wood chips, sawdust, shavings, and hog fuel.
- **Category C:** Roadside waste (tops, branches and other non-sawlog material harvested (pulp log?), but not hauled to a consuming mill) derived following logging.

- **Category D**: Standing Timber

When considering the fibre supply from a proposed plant, a number of factors will impact availability and cost, as follows:

Category B:

Access to sawmill residual fibre including wood chips, sawdust, shavings, and hog fuel, is invariably done through business-to-business relationships between an IPP and a sawmill owner.

Today, a significant proportion of sawmill residual fibre in each region of the Province is already committed to existing pulp, paper, board and pellet plant operations or used internally by the producing mill for their own energy production.

There are a variety of purchase and sale contract types covering residual fibre. Some residual fibre is tied up in virtual perpetuity, some is tied in long-term renewable contracts and some is sold in the “spot market.

Each of these fibre types are transacted based upon average regional prices that are impacted by a number of factors such as supply and demand, end use pricing (residual chips are often priced based upon the price of Northern Bleached softwood Kraft pulp). Once a purchase price is set, organizing transportation logistics and cost to deliver the fibre from the supplier mill to the consuming mill is typically the responsibility of the buyer. These logistic costs are basically limited to transportation distance, road speeds hauling cycle times and the price for diesel fuel. In the rare occasion that trucks can be utilized to back-haul a different fibre type, costs are reduced.

Category C:

Roadside residues includes tree tops (crowns), branches and other non-sawlog material that has been harvested, but not transported to a consuming mill. Roadside residual fibre is typically accumulated along roads where sawlogs and pulp logs are loaded onto logging trucks.

Access to this fibre can only be done as part of a cooperative agreement with tenure holders who initially harvested these sites.

The process of accessing this fibre includes:

- Mobilization to the site of appropriate equipment including grapple excavator and grinder,
- Mobilization of trucks capable of being loaded and more importantly, unloaded at the receiving mill,
- Picking up and grinding the residual roadside fibre into a size and form suitable for use within the plant,
- Hauling the biomass material to the receiving plant.

Today, roadside residues are accessed to supplement fibre supplies for mills that traditionally used sawmill residuals as their primary fibre source. This has occurred at a time when reduced sawmill activity has created Category B sawmill fibre supply shortfalls.

Category D:

Since the majority of BC forests exist on Crown land, standing timber can be accessed in one of two ways:

1. Purchase of logs from an existing tenure holder who holds a right to harvest, or
2. Acquisition of tenure from the Crown that allows an IPP to harvest a given volume of timber on their own.

In either case, standing timber is likely the highest cost fibre type available to the IPP because the cost of the timber includes the additional costs of:

- Finding suitable forest.
- Developing the appropriate cutting permits and licences to harvest.
- Paying the Crown a stumpage fee – the cost of which varies based upon the quality of the wood.
- Surveying, marking and measuring the trees.
- Locating and developing roads and bridges to the site.

- Harvesting the trees – the cost of which varies based upon the size and density of the trees
- Processing and loading the logs onto logging trucks.
- Delivering the logs – the cost of which varies based on travel distance and road speeds.
- Rehabilitating the harvested area by planting new trees – the cost of which may vary based upon the quality of the growing site and the amount of brush competition that can inhibit the re-establishment of a commercial tree species
- Surveying the harvested area to ensure that a suitably stocked plantation establishes itself over the ensuing 10-20 year period.

The volume of each Category of biomass fuel that goes towards developing a fuel profile will vary for each business plan and may vary on an annual basis. Exhibit 2 illustrates a possible distribution of fuel types assumed to be consumed in the example presented herein. The resultant fuel profile has an average fibre cost of approximately $35 per oven-dry tonne.

The depicted fibre costs are typical of BC Interior operations and the fuel distribution assumed results in the average delivered fuel cost of $25 per megawatt hour (see Exhibit 1).

Exhibit 5. Fibre Cost Estimator

Fibre Supply By Source		Fuel Type					Total / Average
		Dry Shavings	Sawdust	Roadside Residue	Hog Fuel	Standing Timber	
Percent Demand		5%	10%	30%	30%	25%	100%
Regional Fibre Cost	($/ODT)	$35	$20	$25	$2	$75	$30.60
Average Delivery Cost	($/ODT)	$10	$10	$50	$10	$30	$27.00
Total Delivered Fibre Cost	($/ODT)	$45	$30	$75	$12	$105	**$57.60**
Total Delivered Fibre Cost	($/m3)	$18	$12	$31	$5	$43	**$23.51**

4.8 Variable Operating Cost

This variable is intended to include all costs related to:

- Manpower,

- Operating costs including fuels (other than wood fibre delivered and conversion costs),
- Maintenance costs (other than capital replacement)
- Related "day-to-day" costs.

For simplification, it is expressed as a percentage of the original capital invested and represents the "variable" cost" of operating the plant (excluding fibre). For the example contained herein, variable operating cost is assumed to be 3.5%.

This may be increased if there are hidden costs such as royalties to First Nations, municipal taxes, capital equipment maintenance etc. Cost would also increase as the amortization period for a plant increases.

4.9 Profit

Profit is meant to reflect the return to the investor for the capital used to create the plant. It is expressed as a percentage.

Profit is assumed to be earned on an annual basis.

For purposes of this report, 4% profit was assumed. It is important to note that this percentage may be increased significantly as risk increases. BC Hydro may impose commercial terms such as punishing liquidating damages or separate "firm" and "non-firm" energy prices on the IPP. The required sales price and profit would need to rise to offset these risks.

Of additional note is that 4% profit on the original cost of capital equates to a 6% real return on the declining amortized value of the investment over 15 years. This "real" rate is consistently applied to all resource options (e.g. small hydro, wind, etc.) to allow for fair comparison.

4.10 Return on Capital (per Megawatt Produced)

The return-on-capital employed is calculated as the profit input as a percentage of the capital invested over the annually salable electricity generated.

4.11 Unit Energy Cost

Unit Energy Cost is divided into two components – the cost of project and the cost of delivered fuel. In this hypothetical business case the resultant cost of project is $84 per megawatt hour. This value was utilized in support of the report describing the Biomass Energy Potential in BC in 2013 "Wood Biomass Energy Potential of British Columbia". The cost can vary considerably with modification to the assumptions described herein.

Fuel cost varies throughout the Province based on available profile, regional fibre demand, transportation distances and delivery methods.

The Unit Energy Cost is the summation of the cost of project and delivered fuel cost. In this business case, Unit Energy Cost is estimated at $125 per megawatt hour: