A Bioenergy Strategy for British Columbia

Prepared for
BC Ministry of Forests and Range
BC Ministry of Energy, Mines and Petroleum Resources
BC Hydro

2006
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Wood Pellet: John Swaan, Wood Pellet Association of Canada
MPB: Mountain Pine Beetle Initiative, CFS, Natural Resources Canada
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Roadside Residue: Jack MacDonald, Forest Engineering Research Institute of Canada (FERIC)
Tolko/Nexterra Heffley Creek Gasifier: Nexterra Energy
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A Bioenergy Strategy for British Columbia


4. The Timeline for Emerging Bioenergy and Biorefining Technologies by A. Potter, Forest Research Opportunity BC.
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The timely development of viable bioenergy strategy options for the consideration of British Columbia decision makers would not have been possible without the active participation, ongoing support and thoughtful guidance provided by the members of the Bioenergy Steering Committee. Forintek gratefully acknowledges the contributions to our work by Janice Larson (MoEMPR), Henry Benskin, Bob Friesen, Ray Schultz (MoFOR), Ken Baker (FII) and Jeff Barker (BC Hydro).

A vibrant BC wood bioenergy industry currently exists within the forest and the energy industries. It includes some of the financiers of, and equipment suppliers to both primary industries. The knowledge used to critically assess the business case for wood energy and to estimate biomass harvesting and transportation costs was developed through one-on-one interviews and ongoing follow-up with many BC wood bioenergy industry, industry association and government experts. Forintek and FERIC acknowledge and thank the champions from our forest industry and government membership. Management and staff from our industry members operating in Mountain Pine Beetle impacted communities and from the BC Ministry of Forests and Range and the Canadian Forest Service Mountain Pine Beetle Initiative generously shared their experience and perspectives on business case development and strategy options with Jean Cook, Brian McCloy and Jack MacDonald. Forintek acknowledges and thanks the champions from the forest industry, BC Hydro, the Independent Power Producers, MoEMPR, the Ministry of Economic Development (MoECON), the Ministry of the Environment (MoENV), the Council of Forest Industries of BC (COFI) and the Wood Pellet Association of Canada who provided their perspectives in one-on-one interviews. Forintek would especially like to acknowledge and thank the bioenergy sector experts who attended the June 7th meeting of experts facilitated by David Cawood.

The European Union and the United States have set targets and are currently implementing bioenergy strategies in their jurisdictions. A cornerstone of the recommended strategy for BC is to actively stimulate innovation by BC enterprises focusing on the timely adoption of technology emerging here and elsewhere. The judicious use of new technology adapted for cost effective use in BC is critical to ensure the ongoing competitiveness of a growing BC bioenergy sector. Canadian industry technology providers and institute, government and academic researchers are actively engaged and contributing now to the global development and commercialization of new technology. Forintek and Forest Research Opportunity BC acknowledge and thank the many individuals of the research community who shared their knowledge on the nature and timing of globally emerging technologies with Alan Potter. Forintek would especially like to acknowledge the timely assistance provided by the participants of the July 5th forum of academic researchers facilitated by Alan Potter.

No multidisciplinary team can deliver a project of this scope and consultative nature in a short time without a reliable and extremely efficient person acting as the communications centre and assistant to all. The project team would like to convey our great appreciation and many thanks to Ava Mak and all those who supported Ava at Forintek. We could not have done it without you.
Bioenergy - A Plan for British Columbia

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Executive Summary

A Bioenergy Strategy for British Columbia has been jointly developed by Forintek and the Bioenergy Steering Committee. Results from the Forintek project demonstrate that bioenergy is a timely strategic opportunity for BC today. This report is a call for action and presents a strong vision for the immediate development and future use of bioenergy, from all sources, in British Columbia.

Recommendation: The Province champion and implement the Bioenergy Strategy. BC Hydro issues a call for tender (CFT) for wood residue power.

Bioenergy Strategy

- Engage the bioenergy sector in BC.
- Create an information hub to serve the sector and be responsive to stakeholders.
- Support sustained sector growth.
- Leverage resources.
- Expand the scope to include all sources of biomass.

Vision: To lead the bioeconomy in Western Canada with a strong and sustainable bioenergy sector.

British Columbia is, by far, Canada’s dominant user of biomass for energy (bioenergy) and has 50% of Canada’s biomass electricity generating capacity. In 2005, the industry self-generated the equivalent of $150 million in electricity. But in 2005 the forest industry also purchased approximately 65% of the electricity bought by industry in BC. Individual forest industry plants are the largest single customers of BC Hydro and Terasen Gas.

British Columbia is Canada’s dominant producer of forest “bio-products”. Total sales of products made by the BC Forest Industry are projected to exceed $18 billion in 2006. BC manufacturers export biomass, in the form of pellets andhog fuel, as bioenergy feedstock. BC production of wood pellets has increased significantly in recent years and in 2007 will likely be a $200 million business with projected annual production of 900,000 tonnes.

British Columbia is a net importer of electricity and demand will increase by up to 45% over the next 20 years. Domestic wood residues have the potential to offset all of BC’s current power imports and meet some of the future load growth.

Dry, mountain pine beetle (MPB) killed wood makes superb bioenergy feedstock.

Western Canada may be one of the most secure locations on the planet for an environmentally responsible energy company to invest.

A strategy is provided to attract investment by energy companies, create opportunities for BC technology providers to supply global markets and entice industries and communities to produce and use bioenergy. BC will provide the “live laboratory” to engage the global research community and focus it on Western Canadian economic development priorities. The adoption of this Bioenergy Strategy should lead to the following benefits for British Columbia:
Progress towards BC electrical energy self-sufficiency.
A sustainable and consistent supply of alternate energy.
Reduced energy costs and new sources of income for BC’s forest and agriculture industries.
The creation of approximately 1,500 well-paying jobs in the BC central interior replacing projected job losses in the sawmilling sector.
Improvement in air quality resulting from the closure of beehive-type incinerators.
Greenhouse gas reduction when wood residue is substituted for fossil fuels.
Reduction in the threat of forest fires and a more timely return to productive forests.
Innovative, value-added solutions for agricultural residue management and opportunities for dedicated bioenergy crop development.
World leadership in the development and commercial adoption of wood energy technology.

Strategy Options are based on

- The business case for bioenergy in British Columbia today.
- An increased volume of economically accessible biomass.
- Technology available today and a timeline for emerging technologies that can be adopted by BC bioenergy generating facilities.

The Opportunity for British Columbia

There are numerous opportunities for increased bioenergy production in BC. The table below provides a snapshot in time for 2006.

**Volume and Potential Uses for Additional BC Biomass Delivered at $50/BDt in 2006**

<table>
<thead>
<tr>
<th>Biomass*</th>
<th>Heat</th>
<th>Electricity</th>
<th>Pellets</th>
<th>Annual GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 million BDt</td>
<td>160,000 TJ</td>
<td>13,000 GWh</td>
<td>8 million tonnes</td>
<td>5 Mt (NG electricity offset) 9 Mt (coal electricity offset)</td>
</tr>
<tr>
<td><strong>Comparisons</strong></td>
<td>84,000*** TJ of natural gas was purchased by Terasen Gas industrial customers in BC in 2003 160,000 TJ is enough to heat 900,000 homes</td>
<td>2005 electricity imports =7400 GWh 300,000 BDt’s of biomass is sufficient feedstock for a 60 MW (gross) power plant Site C is 900MW BC forest industry already generates 600 MW</td>
<td>BC 2007 sales are projected to be 900,000 tonnes</td>
<td>Significant reductions from the current 67.5 Mt (million tonnes) of GHG emissions annually in BC.</td>
</tr>
<tr>
<td><strong>Conversion Factors Used</strong></td>
<td>1 BDt = .020TJ 1 BDt = 20GJ</td>
<td>1000 BDt = 1.6GWh</td>
<td></td>
<td>Assume wood has only 80% of the efficiency of natural gas</td>
</tr>
</tbody>
</table>

* 8 million BDt = 7 million BDt of roadside residues PLUS 1 million BDt of residues currently burned in beehive burners Using this wood for energy would not displace or interfere with the normal wood supply to the forest industry.
** These are approximate conversion factors and comparisons. Conversion factors rely on biomass content and moisture, the equipment used to convert the biomass to energy, and a host of other factors.
***To be confirmed by Terasen Gas
The year 2006 is only a snapshot in time. Economically accessible wood biomass supplies will likely decline as less of the MPB killed resource is harvested by the forest industry.

The forest industry, through the Forest Products Association of Canada (FPAC) has declared its intent to become energy self-sufficient. An Energy Plan target for alternative energy growth consistent with BC forest industry targets for energy self sufficiency could create synergistic opportunities and better business cases for both the energy and forestry sectors.

Opportunity: The province and BC Hydro are well positioned to facilitate and stimulate new bioenergy projects today.

Strengths: Wood biomass supplies from roadside residues present no “food or fuel” issues. The BC forest industry is a global leader in using innovation to reduce costs and improve business cases.

It will take the collaborative efforts of the forest industry, government policy makers, independent power producers, pellet producers and BC Hydro to realize the vision.

Recommended Business Case Development

Based on the review of options included in the Business Case for Wood Energy as well as interviews held with a variety of industry and government officials, it would appear that there are two potentially economically viable options for utilizing the wood energy resources in BC.

The first option is to expand the burgeoning wood pellet industry in BC but at the same time create a domestic market in BC so that this important source of renewable energy is used as much as possible to supply the energy needs of BC.

The second and most important option in the eyes of both government and forest industry officials is energy self-sufficiency for the BC forest industry. Not only is the forest industry an important user of wood energy, it is also critical to the success of the delivery of wood fuels to itself and other users such as the wood pellet industry. The following recommendations are therefore focused on accomplishing these two objectives.

BC Hydro Power Acquisition Financing – Reinstate BC Hydro’s capital financing program for new wood residue power development with existing industrial customers.

CFT Process- Have BC Hydro consider a dedicated wood residue Call for Tender.

Fuel Price Risk- Encourage BC Hydro to consider taking on some of the fuel price risk for wood residue fuel above a certain baseline in the same way they were prepared to take the gas price risk for CCNG projects.

Amendment of the Tier Two Power Price – BC Hydro apply for an upward amendment of the Tier Two industrial power rate based on the results of the 2006 independent power contract awards. [Under the BCUC-approved Stepped Rate program, BC Hydro is obligated to change the Tier Rate on April 1, 2008.]

Federal incentives – The federal government could

- Implement the Large Final Emitter System and GHG Offset Trading system as soon as possible
- Implement the RPPI program immediately.
- Extend R&D tax credits to first commercial demonstration projects and permit the flow through of losses to shareholders of technology companies.
- Expand the Market Incentive Program for Distributors of Electricity to include more provincial and private utilities.
- Allow the Canadian Industry Program for Energy Conservation (CIPEC) to consider funding biomass fuel switching and cogeneration projects in addition to its energy efficiency mandate.
- Increase the level of funding for all CIPEC energy programs. Extend the Renewable Energy Deployment Initiative (REDI) beyond its planned end in March 2007, and specifically increase the level of funding for projects from $80,000 to $1 million per facility.

Biomass Inventory – The provincial MoFOR should attempt to quantify the volume and cost of wood energy sources including mill residues, pulp chip surpluses, harvesting residues and finally that portion of the MPB affected timber that will not be utilized by the forest industry but might be available for energy purposes. Similarly the Ministry of Agriculture should attempt to determine the volume and cost of utilizing agricultural residues for energy purposes.

Shelf Life of MPB Timber for Energy Purposes – Studies could begin immediately to determine the longevity of MPB timber for energy purposes.

Salvage Tenure for Harvesting Residues – The MoFOR could consider the issuance of long term salvage licenses for those energy companies that require such security.

Upgrading Forest Roads – The MoFOR could use a portion of their MPB funding to upgrade forest roads so they are suitable for the transport of forest fuels.

Public attitudes toward wood residue projects – The government could undertake a public education program on the benefits of replacing fossil fuels with BC wood residues.

Property and sales tax incentives – The Province could consider sales tax exemptions for wood residue cogeneration projects as BC has done for run-of-river projects.

Research and Demonstration Tax Credits – Both the federal and provincial governments could consider the extension of R&D tax credits to first commercial demonstration projects and the flow through of tax credits to shareholders in publicly traded companies.

Lack of Capital for Forest Industry Heat and Power Development – The BC government could encourage the forest industry, independent power producers and BC Hydro to work collaboratively on developing, financing and operating new wood energy facilities.

Reduce the Cost of Delivery of Harvesting Residues – The BC government, FERIC, IPPs, wood pellet producers and the forest industry could work collaboratively on reducing the cost of delivering harvesting residues for energy purposes. In this regard, field trials should be conducted under the direction of FERIC to determine the most cost-effective method of delivery.

Review Steam Engineer Staffing Requirements – The BC government could review the staffing requirement for steam engineers operating high pressure steam vessels to make them consistent with jurisdictions such as Holland.

Create a mechanism to pull together BC’s research and innovation resources to focus on bioenergy.
**Recommended Strategy Development**

1) Launch the BC Bioeconomy and actively support the forest industry to achieve energy self sufficiency.

2) Dedicate resources to MoFOR to lead the development of BC biomass supply information platforms with MoEMPR. Proceed on a project by project basis with industry in BC to add capacity.

3) Keep the business case document “live”. Use the recommendations and continuously improve the business case for bioenergy in BC.

4) Engage and inform the MPB emergency response teams. Engage and inform stakeholders through targeted communications and access to information and support.

5) Engage stakeholder champions to counter false perceptions about negative air quality of wood pellets and industrial bioenergy plants. Monitor progress and create success stories.

6) Demonstrate and announce to the world that BC is the leading Bioeconomy in Canada.

7) Join forces with Alberta, Saskatchewan and Manitoba to become Canada’s Western Energy Superpower, create additional demand for biomass and attract “green” businesses to Western Canada.

8) Develop a Western Canadian business-case-informed strategy for marketing, new product and process development and new sources and uses of biomass and technology jointly with the Prairies. Encourage the federal government to immediately develop a greenhouse gas action plan that will provide incentives for renewable energy producers and thereby reduce greenhouse gas emissions.

The strategy could be encapsulated in the following suggested terms:

**BC SuperPower**

“Leading the world in Home Grown Sustainable Bioenergy for self sufficiency and export”

“BC – part of a Western Energy Superpower”
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1 Objective

To develop and validate (with experts and key officials from the BC Ministry of Energy, Mines and Petroleum Resources (MoEMPR), the BC Ministry of Forests and Range (MoFOR) and BC Hydro, the Forest Products Sector and the Energy Sector) bioenergy strategy options for presentation to British Columbia Government decision makers.

2 Introduction

British Columbia has abundant natural forests that our stewards have responsibly managed and maintained into the 21st Century. Independent assessments of our forest practices, available on MoFOR and NRCan websites conclusively demonstrate that BC forest practices are among the best in the world. We are global leaders in the sustained social, environmental and economic use of our forest resources. Citizens value the quality-of-life our forests provide and expect continued government commitment to responsible stewardship and sustainable uses of our forests for centuries to come.

British Columbia’s natural gas, coal and electricity are coveted by a world thirsty for energy. World markets are now indicating a growing demand for renewable energy sources. While citizens living near, driving by and flying over vast tracts of Mountain Pine Beetle (MPB) damaged forests see little hope for a brighter future, the MPB damaged forests represent a vast store of renewable energy.

Policy action 20 in the 2002 BC Energy Plan recognizes biomass energy (bioenergy) as a “BC Clean” energy source. The Energy Plan is currently being updated. In February 2006 Forintek suggested that under normal circumstances, wood bioenergy would be a good place to start for the alternative energy section of the upcoming Energy Plan update. Dry MPB damaged wood makes high quality biomass for energy. The opportunistic and growing stockpile of Mountain Pine Beetle (MPB) killed trees make wood bioenergy a priority.

In March 2006 MoEMPR joined forces with MoFOR and BC Hydro to assess bioenergy strategy options for BC. A Bioenergy Steering Committee was formed to focus and guide the sponsors’ efforts with Forintek. The Steering Committee’s overall priority was to provide viable options for government to stimulate and demonstrate real progress towards the sustained growth and use of bioenergy in BC, with a near term emphasis on wood energy as a part of the solution in addressing the MPB epidemic.

The MPB Action Plan and results from the Canadian Forest Service MPB Initiative (Stennes and McBeath, 2005) clearly demonstrate that the MPB damage has created an overwhelming supply of additional wood biomass in the BC interior. Results from the Forintek wood bioenergy project (MacDonald 2006, McCloy 2006) conclusively demonstrate that even the small percentage of that wood that is economically accessible while the forest industry is still harvesting for other products could produce approximately 1,500 MW of power (13,000 GWh per year). This amount is almost double BC Hydro’s 2005 electricity imports. After the forest industry leaves an area, the wood is not economically accessible today. However, biomass could be economically accessible in future provided the capacity and transmission infrastructure was available in the right locations. How much capacity to add, where, and uncertainties regarding the security of a reliable long term supply of biomass feedstock are compelling reasons for a strategy to attract the capital to build bioenergy projects.

While the order of magnitude of the opportunity is enormous the Steering Committee and Forintek are mindful of the experiences of other jurisdictions where rapid and unplanned economic growth has led to
detrimental social, environmental and, ultimately economic consequences. A strategy is provided to use the MPB damaged wood to launch the BC Bioeconomy and effect a smooth transition to a sustainable bioeconomy in British Columbia when the MPB wood biomass opportunity is gone.

MoEMPR’s immediate objectives are to develop viable bioenergy strategy options for consideration in the preparation of the updated Energy Plan. Wood bioenergy is an opportunity for MoFOR for consideration in the Mountain Pine Beetle (MPB) Action Plan. The driver for forming the partnership in March, 2006 was a common need to create opportunities for the sponsors to synergistically promote wood bioenergy as an environmentally sustainable economic development mechanism for First Nations and forest dependent rural communities.

In recognition of the opportunity identified by the Forintek project MoEMPR added a fourth branch to the Electricity and Alternative Energy Division, responsible for Bioenergy Strategy development and implementation in September 2006. The Branch will continue to champion BC’s bioenergy in close collaboration with MoFOR and BC Hydro.

This report provides viable options to use our vast biomass resources responsibly in the context of BC’s emerging plan to promote the sustainable use of biomass, from all sources, for energy. The report documents the results of our joint efforts to date (Sept 2006) in developing such a Bioenergy Strategy for the province. It is recommended that the strategy be adopted and implemented by the province, the BC Hydro issue an RFP for biomass power and the business case and strategy be further developed.

3 BC Bioenergy Strategy Team

3.1 Bioenergy Steering Committee

- Henry Benskin, Deputy Chief Forester, BC Ministry of Forests and Range.
- Bob Friesen, Assistant Deputy Minister, Tenures and Revenue Branch, BC Ministry of Forests and Range.
- Ray Schultz, Assistant Deputy Minister, Mountain Pine Beetle Response, BC Ministry of Forests and Range.
- Jeff Barker, Manager, Business Strategic Planning, BC Hydro.
- Ken Baker, CEO, Forest Innovation Investment.

3.2 Forintek Project Team

- Overall project management and secretariat to steering committee: Dr. Jean Cook, Research Manager, Forintek Canada Corp.
- The business case for BC wood energy: Brian McCloy, RPF, President BW McCloy & Associates.
- Resource harvesting and transportation costs: Jack MacDonald, RPF, FERIC Team Leader.
- Facilitator: Dr. David Cawood, David Cawood Consultancy Inc.
- Linkages to other Canadian jurisdictions and agencies, Dr. Jim Dangerfield, Vice President, Western Division, Forintek Canada Corp.
- Linkages to the global research community: Dr. Alan Potter, Executive Director, Forest Research Opportunity BC
4 Bioenergy Strategy Results to September 2006

4.1 Background

The Bioenergy Strategy and results to date demonstrate BC leadership and significant progress towards a much larger transformation of the Canadian Forest Sector envisioned by the combined membership of the National Institutes: Forintek, FERIC and Paprican.

In 2005 BC’s wood pellet industry enjoyed a 1/6th share of a growing European Union (EU) market for bioenergy feedstock. From the perspective of the EU, the woody debris remaining after other products have been extracted from merchantable trees in BC is an enviable source of biomass. EU actions demonstrate that they have found BC wood pellets to be affordable, reliable and a high quality source of biomass. Wood biomass, including pellets, can be converted into energy in the form of heat, power, and synthetic gas to replace natural gas. Potentially it can also be used to make liquid transportation fuels as well as specialty chemicals and a growing list of other “bio” materials and products. Driven primarily by the need for energy security, but also by a desire to reduce greenhouse gas (GHG) emissions, the EU has put in place effective incentives, policies and regulated penalties to stimulate innovation and private sector additions to bioenergy generating capacity. One result has been a rewarding diversification of wood product markets for the EU forest industry.

EU investment in their pulp industry and global investments elsewhere have negatively impacted the global competitiveness of North America’s pulp and paper industry. EU incentives have enhanced EU pulp mill access to the capital necessary to upgrade their facilities, install new technology and become net power exporters. Moreover, unlike Canadian mills, EU mills are now able to sell their greenhouse gas credits into the new European GHG trading market and generate extra revenue.

BC is blessed with abundant natural resources. However, BC’s population and Canada’s economy do not compare to the EU. We have a large and diverse land base with geographically dispersed communities. The key BC challenge is to build the integrated energy and forest industry infrastructure needed to economically access and use our biomass resources for energy. Our policies and infrastructure are still based on an historical model: fossil fuels and hydro for energy; lumber and pulp the dominant wood products from our forests. Historical models are unlikely to sustain BC for the future. BC therefore needs to look at a business model which also includes sustainable biomass-based energy and bio-products.

In contributing to the development of a Bioenergy Strategy for the Province, Forintek focused its efforts on business models for sustainable wood based energy in British Columbia and biomaterials and products from Western Canada for the future.

The scope of our sponsors’ effort is broader. It is recognized that BC may need to adjust policies in response to global drivers outside Canada’s control. BC’s very great challenge is to effect an orderly change to new models. The challenge is not unique to BC. Linkages of BC efforts to the plans, actions and experiences of other agencies and jurisdictions are actively underway by the Steering Committee and the Forintek project team.

The economic development challenge for BC is not limited to MPB impacted communities. The increasing competitiveness and volatility of global lumber, panel, pulp and paper commodity markets are impacting the Canadian forest industry and all the communities in which they operate. Increased demand, and price, for wood biomass is one way to add the margin necessary for some mills to continue operating...
in some communities. Because of Canada’s high delivered log costs relative to our global competitors it is desirable to adapt historical models to encourage the synergistic establishment of biomass and other product lines to complement our traditional wood and fibre products.

In March of this year, Forintek and our sponsors actively engaged the forest and energy industries to critically assess the business case for more wood energy in BC. As illustrated by the pellet industry, utilization of more wood biomass in cooperation with the licensees is one way to increase the utilization of each merchantable stem harvested and increase the economic value of Canada’s forest estate.

### 4.2 Forintek Wood Bioenergy Project Strategy Objectives

- Champion biomass energy and make it a priority for the Alternative Energy section of the Energy Plan update.
- Inform the MPB Action Plan.

### 4.3 Opportunities and Benefits

- In 2005, the industry self-generated the equivalent of $150 million in electricity. But in 2005 the forest industry also purchased approximately 65% of the electricity bought by industry in BC. Individual forest industry plants are the largest single customers of BC Hydro and Terasen Gas (MoEMPR, BC Hydro).

- The BC forest industry currently has the capacity to generate over 600 MW (over 5,000 GWh per year) of electricity (FPAC, 2005) from biomass. For comparison, the Site C dam would generate 900 MW.

- British Columbia is a net importer of electricity and demand will increase up to 45% over the next 20 years. Domestic wood residues have the potential to offset all of BC’s current power imports and meet some of the future load growth (BC Hydro).

- The increasing BC demand for energy could be mitigated, or even reversed, if the forest industry used more of its biomass to become energy self-sufficient.

- In 2003 it is estimated that the forest industry bought approximately 45% of the natural gas purchased by industry in BC, but these figures have yet to be confirmed by Terasen Gas.

- The pulp and paper sector could broaden its product mix by undertaking the development of a new/alternate line of business: i.e. energy production and bio-products.

- The economic “shelf life” of MPB killed pine for energy is longer than what is now considered the “shelf life” for commodity wood products. The energy content of dry wood is higher than when it is wet. Fresh wood is desirable for pulping chips, sawing into lumber or peeling and flaking into structural panel products. Under some stand conditions the economic shelf life for conventional wood products may be less than 10 years. Other conditions could lead to an economic shelf life for energy products well in excess of 30 years. However in the latter case the upper limit is practically and independently determined by the Chief Forester in setting annual allowable cuts. Continued forest stewardship for our future must enable the new young forest that has generated to grow.

- Added bioenergy generation capacity in BC would create more demand for dry MPB damaged wood, reduce fire risks to BC communities, mitigate increasing stewardship costs and shorten the return to productive forests.
• There are still beehive burners operating throughout the province at lumber processing facilities. They burn wood residue with no energy capture and have negative impacts on local air quality [McCloy, B. and DW Bradley (2005)].

• Under the previous federal government the large industrial users, which include some pulp mills, had a GHG reduction target reduction of 50 megatonnes per year as part of a Canadian compliance plan. The use of more biomass to displace natural gas or coal will lower BC GHG emissions.

4.4 Champions

The members of the steering committee can be viewed as the first BC bioenergy champions. BC needed to engage more people in strategy development so more champions can emerge as the project work progressed. By March 2006 the rising economic and environmental costs of energy from fossil fuels was a public concern. Our sponsors required viable bioenergy strategy options delivered as soon as possible. Forintek suggested the use of an expert facilitator as well as a project manager to deliver strategy options directly to the sponsors as the options were developing. Our sponsors formed a steering committee who kept the Forintek team focused on the options and supporting knowledge most valued from a BC perspective. Strategy options were finalized with the sponsors at a meeting on September 8, 2006.

Results from the Forintek wood bioenergy project (McCloy, 2006, MacDonald, 2006) clearly demonstrate that even without the MPB problem BC has vast wood biomass resources and leads Canada in bioenergy generating capacity. Continued economically accessible wood biomass and capacity are tied to the continuing global competitiveness and ongoing operation of the forest industry. The forest industry commonly uses bioenergy to provide most of its heat and some of the power needed in BC operations. Forest companies have working relationships, and biomass supply agreements, with independent power producers. In Williams Lake, for example, a number of companies collaboratively supply bioenergy feedstock to an independent power producer, who sells the electricity to BC Hydro. When capital is available, the forest industry adds bioenergy capacity to substitute biomass for natural gas. Prices are sufficient for a viable business case. The forest industry, through the Forest Products Association of Canada (FPAC) has declared its intent to become energy self-sufficient. The BC forest industry is well positioned to benefit from their efforts and success and move beyond to become a net energy exporter.

The overall approach to further develop our strategy was to build the business case for bioenergy on an energy project by energy project basis in collaboration with industry experts.

An Energy Plan target for alternate energy growth consistent with B.C forest industry targets could create synergistic opportunities and better business cases for both the energy and forest industries.

4.5 Forintek Wood Bioenergy Project

4.5.1 Approach

The members of Forintek have identified a need for the forest sector to encourage the synergistic supply of (1) a consistent quality and quantity of wood to a variety of primary and “margin added” manufacturing facilities and (2) over time, wood biomass to bioenergy and bio-products facilities. Governments, innovatively responding to new opportunities to add flexibility to the system, could facilitate an orderly change to new models. The MPB epidemic in BC may be strategically converted into a timely “opportunity” to test the approach.

In February 2006, Forintek suggested that more synergies between the major licensees and the energy industry could be employed to immediately increase BC wood bioenergy generating capacity. Forintek set
out to find ways the system could be adapted so that distribution of more wood feedstock by licensees to those in the business of using biomass for energy could be beneficial to all parties. All parties benefit if the licensees, and therefore ultimately the Province, realize more economic benefit from currently low value wood by providing a wood biomass supply to an energy producer able, and willing, to pay for it.

This is the approach the Forintek project team used, with the active assistance of innovative champions from government and the energy and forest industries, to carry out our project. The same approach could be used to explore supply chain synergies and new distribution channels among licensees on the BC coast, or BC farmers, for bioenergy or other product diversification efforts.

A necessary precondition for economic diversification is the existence of customers who are willing to pay for the new products. It is convenient that the EU chose to regulate renewable energy goals thereby creating customers willing to pay for biomass in the form of pellets at the same time that the MPB produced dry wood, a highly valued biomass for energy. As a result, there is a strong business case for BC to expand export markets and create more domestic demand for our “home grown energy” focussed on the utilization of MPB damaged timber.

The project started March 14 when David Cawood and Brian McCloy joined Jean Cook to form the initial Forintek project team. David facilitated meetings and proactively supported the timely synthesis of steering committee ideas, and our collective results, in a strategic framework. In preparation for the first meeting of the steering committee and project team Brian McCloy produced draft bioenergy strategy options based on his assessment of the business case for wood energy in BC. The critical element is accurate information of the delivered costs of the energy feedstock. Forintek arranged for Brian to start working with FERIC. On April 1 Jack MacDonald joined the Forintek project team. Jack provided preliminary estimates of harvesting, processing and transportation costs to inform the business case.

4.5.2 The Business Case

The first of three facilitated meetings between the Steering Committee and the project team was held on April 18. Brian McCloy provided conclusive evidence that BC now leads the nation in wood biomass energy production and consumption.

- There is a solid business case for displacing natural gas with wood biomass for fuel to produce heat in pulp and paper and wood products manufacturing. BC mills are using their own wood wastes from manufacturing as fuel to reduce costs at their own operations.
- There is a solid business case for producing pellets from whitewood feedstock (sawdust and planer shavings from sawmills) delivered at a cost of less than $20 per bone dry tonne (BDt) for sale in the EU market. Higher delivered biomass costs require markets much closer to home. But the market prices closer to home are significantly lower reflecting lower transportation costs.
- The business case is not viable for an independent power producer to build a new electricity plant and supply it directly with feedstock harvested from MPB killed stands. Delivered biomass costs in BC are too high and the price paid by BC Hydro for biomass power has historically been relatively low (e.g. $54/MWh for the 2002/03 power calls).
- The business case for the pulp and paper industry to generate excess electricity at their operations in collaboration with independent power producers is likely to be economically more viable than a stand alone power plant.
- The forest industry lacks capital to add electricity-generating capacity beyond their existing operations.
The project team identified a potential opportunity for government and the wood bioenergy industry to improve the business case for pellets and electricity by using supply chain synergies. The Steering Committee asked Forintek to pursue the opportunity and provide strategy options and recommendations.

### 4.5.3 Delivered Costs of Biomass.

Today the most economical sources of wood biomass are from sawmills or plywood mills. Manufacturing residues such as hog fuel, fines, sawdust, planer shavings and veneer trimmings are used for heat and power at the mill, or sold as wood feedstock to another facility near the mill.

Biomass is also available from harvested stands, but is more costly to the energy company. Forintek wood bioenergy project results from a case study in the Quesnel TSA (MacDonald, 2006) demonstrate that there is a significant amount of accessible wood produced by the licensees and left at roadside (roadside residues) as they are harvesting wood for other products in the most severely MPB damaged areas. Using this wood for energy would not displace or interfere with the normal wood supply to the forest industry.

FERIC conducted a study to estimate the costs of harvesting, processing, and transporting beetle-killed pine to supply feedstock for a potential power plant. Three harvesting systems were examined, as determined by the ratio of fuel wood volume to saw log volume in the stand. Costs were developed for the generic harvesting systems, and then applied to the Quesnel/Nazko corridor in central Interior of British Columbia as a case study. Estimated spread in delivered cost estimates, within $5 BDt, to an energy plant within 100km for two process methods are listed in Table 1. For each source FERIC used the lowest cost harvesting system. Complete descriptions of the harvesting systems and methods used are provided in MacDonald (2006).

**Table 1: Delivered costs of wood biomass feedstock in 2006**

<table>
<thead>
<tr>
<th>Source</th>
<th>Costs* borne by the forest licensee</th>
<th>Costs borne by energy company</th>
<th>Cost to an energy facility within 100km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside Residues</td>
<td>$35/BDt + stumpage</td>
<td>Processing Transportation</td>
<td>$50/BDt</td>
</tr>
<tr>
<td>On site whole tree chipping</td>
<td>No forest licensee</td>
<td>Planning &amp; Administration Road Development Falling and Skidding Savaging biomass Processing Transportation Reforestation</td>
<td>$90/BDt</td>
</tr>
</tbody>
</table>

*felling and skidding to roadside*

Table 1 illustrates and quantifies the value of taking the time and effort to create supply chain synergies for bioenergy projects. Line 1 is the least cost scenario for an energy company. In the case of roadside residues, a ‘win-win’ situation exists. The forest licensee avoids the cost of residue disposal. The energy company realizes savings in road building, harvesting, stumpage avoided and silviculture costs. Additional benefits include less site damage, smoke reduction and freer movement of wildlife and cattle. Collaboration can benefit the licensee and significantly reduce the delivered wood costs for the energy company.
The Line 2 represents the least cost scenario for a salvage operation when the forest licensee is no longer harvesting logs. This scenario will hopefully be more than a decade into the future when forest licensees are no longer able to profitably harvest MPB damaged timber. Long term (15 year+) biomass supply agreements are desired by the energy company. For the case of the whole stand chipping, precedents for salvage systems exist but will be reviewed and may be adapted in future to better meet the needs of both an energy company and MoFOR.

For the case of roadside residues, synergistic long term biomass supply arrangements need to be developed. Ideas for innovative arrangements that could meet the needs of the energy company, the forest licensee and MoFOR were suggested during the project. McCloy (2006) provides recommendations. Discussions are continuing among parties. A key requirement for the energy company is to have evidence of a secure and long term biomass feedstock agreement to obtain financing for bioenergy projects. Such long term supply agreements are not a standard business practice from the perspective of the forest licensees. Innovative solutions are needed.

### 4.5.4 A Sustainable Biomass Supply

At least thirty year timelines for the projected amount of biomass that could be sustainably supplied, from all sources, are needed to plan and implement any bioenergy strategy. As the near term major biomass resource steward, MoFOR has the competencies and infrastructure in place to take the lead role in developing biomass supply information with MoEMPR. Biomass inventory would be a new role and additional resources would need to be dedicated to effectively deliver this innovative mandate.

In order to assess the business case for a specific energy project in a particular location the energy company and licensees need to inventory the potential biomass in the area today and make projections of the available biomass, and delivered costs, over the next 15-30 years, depending on the energy project. The information needed to secure a supply of biomass and manage the risks may not be available to the energy company or the licensee today.

The critical information needed to advance the BC bioenergy strategy is the annual area likely to be harvested over the next 30 years for at least the MPB damaged areas. MoFOR plays a critical role if tenure and other policies need adapting to facilitate bioenergy initiatives and provide information and support to facilitate business case development between major licensees and energy companies.

There are many factors that contribute to the construction of timelines for wood biomass supply. Information needed to advance the development of a sustainable bioenergy strategy immediately is listed below.

1) The amount of biomass that could be supplied annually from healthy forests,

2) The additional amount of biomass that could be supplied annually from MPB and other damaged stands.

The Ministry of Forests and Range and the licensees have the experience and historical data to provide the best estimates for both. In addition, the CFS MPB Initiative will be publishing a major report on (2) before the end of this year.

Data pertaining to (1) and (2) were not available to the Forintek project team and constructing biomass supply timelines were well beyond the scope of the Forintek project. However for the purpose of identifying potential bioenergy projects with the sector it was helpful to have an idea of the amount of biomass available from roadside residues. Bioenergy industry experts are well aware that roadside residue
biomass supply from the MPB damaged forests will decline over time and without doing a complete survey of licensee roadside practices it is difficult to provide a precise estimate for 2006. Needed by all was an order-of-magnitude for the additional biomass supply that might be available to assess the opportunity from roadside residues today.

A conservative estimate for the total volume of roadside residue biomass available in BC was estimated based on data from the FERIC case study, historical volumes harvested in the north central TSA’s and the experience of those working in MPB damaged areas.

Table 2 lists 2006 AAC’s (MoFOR) and historic AAC’s (Timberline, 2006) in the most heavily damaged TSA’s in the north-central interior. The amounts of biomass that could be available from roadside residues in each TSA were calculated based on FERIC results from the Quesnel TSA and the historical AAC’s.

The project team believes that an average merchantable volume of 250 m³/ha is reasonable for all the TSA’s in Table 2 and that 60 BDt/ha of biomass from roadside residues result from harvesting in 2006. The volume that will be harvested is the critical unknown. The volume of residues was conservatively estimated using historical AAC’s instead of the actual 2006 harvests in these TSA’s.

### Table 2: Estimated Volume of Biomass from Roadside Residues in 2006

<table>
<thead>
<tr>
<th>Timber Supply Area</th>
<th>2006 AAC (m³)</th>
<th>Historical AAC (m³)</th>
<th>Estimated 2006 Biomass from Roadside Residues* (BDt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quesnel TSA</td>
<td>5,280,000</td>
<td>3,248,000 (2001)</td>
<td>779,520</td>
</tr>
<tr>
<td>Williams Lake TSA</td>
<td>3,768,400</td>
<td>3,768,000 (2002)</td>
<td>904,320</td>
</tr>
<tr>
<td>100 Mile House TSA</td>
<td>2,000,000</td>
<td>1,334,000 (2002)</td>
<td>320,160</td>
</tr>
<tr>
<td>Lakes TSA</td>
<td>3,162,000</td>
<td>2,962,000 (2001)</td>
<td>710,880</td>
</tr>
<tr>
<td>Prince George TSA</td>
<td>14,944,000</td>
<td>12,244,000 (2002)</td>
<td>2,938,560</td>
</tr>
<tr>
<td>Morice TSA</td>
<td>1,961,117</td>
<td>1,961,000 (2002)</td>
<td>470,640</td>
</tr>
<tr>
<td>Bulkley TSA</td>
<td>882,000</td>
<td>882,000 (2002)</td>
<td>211,680</td>
</tr>
<tr>
<td></td>
<td>31,997,517</td>
<td>26,399,000</td>
<td>6,335,760</td>
</tr>
</tbody>
</table>

*Historical AAC x 60/250

The TSA’s in Table 2 are the most severely impacted by the MPB infestation, and will comprise the bulk of roadside residuals from harvesting in MPB-infested stands. The project team recommends that MoFOR and the licensees survey the locations of roadside residues in the Northern TSA’s and provide better information for energy planning purposes. Based on the results of the FERIC case study alone there is no question that the 2006 opportunity of obtaining additional biomass from roadside residues is significant.

McCloy (2006) used the Table 2 results to provide a conservative order-of-magnitude estimate of 7 million BDt of wood biomass available from roadside residues in areas affected by the MPB epidemic. His results are summarized in Table 3. Entries relate the order-of-magnitude of the biomass to the order-of-magnitude of the energy opportunity in 2006. It does not include potential biomass from agriculture, rangelands or other potential sources.
4.6 Energy Options from Biomass

Using the Table 2 estimates of biomass available in 2006 from roadside residues plus biomass available from an estimated 1 million BDt of sawmill residues currently being burned in beehive burners three options for using it for energy are provided in Table 3. (1) Suppose that all of it is used to displace natural gas; or (2) all of it is used to generate electricity or (3) all of it is used to make pellets. Annual GHG offsets if used by a pulp mill to offset coal or natural gas fuelled electricity generation are also provided.

Table 3: Additional Volume and Potential Uses for BC Biomass Available at $50/BDt in 2006

<table>
<thead>
<tr>
<th>Biomass*</th>
<th>Heat</th>
<th>Electricity</th>
<th>Pellets</th>
<th>Annual GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 million BDt</td>
<td>160,000 TJ</td>
<td>13,000 GWh</td>
<td>8 million tonnes</td>
<td>5 Mt (NG electricity offset)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9 Mt (coal electricity offset)</td>
</tr>
<tr>
<td>Comparisons</td>
<td>84,000*** TJ of natural gas was purchased by Terasen Gas industrial customers in BC in 2003</td>
<td>2005 electricity imports =7400 GWh</td>
<td>BC 2007 sales are projected to be 900,000 tonnes</td>
<td>Significant reductions from the current 67.5 Mt (million tonnes) of GHG emissions annually in BC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300,000 BDt's of biomass is sufficient feedstock for a 60 MW (gross) power plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site C is 900MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BC forest industry already generates 600 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversion Factors Used**</td>
<td>1 BDt = .020TJ</td>
<td>1000 BDt = 1.6GWh</td>
<td></td>
<td>Assume wood has only 80% of the efficiency of natural gas</td>
</tr>
</tbody>
</table>

* 8 million BDt = 7 million BDt of roadside residues PLUS 1 million BDt of residues currently burned in beehive burners. Using this wood for energy would not displace or interfere with the normal wood supply to the forest industry.

** These are approximate conversion factors and comparisons. Conversion factors rely on biomass content and moisture, the equipment used to convert the biomass to energy, and a host of other factors.

*** To be confirmed by Terasen Gas

The estimated cost from a case study area near Quesnel to process and transport biomass over an average distance of 100 km was $50/BDt. The project team assumed that similar haul distances and costs could be applied to the other TSA’s.

4.6.1.1 The Natural Gas Substitution Opportunity

There is more than enough biomass to displace all of the natural gas used by the forest industry in the MPB areas. The business case varies from mill to mill. (See McCloy 2006).

4.6.1.2 The Electricity Opportunity

- The electricity opportunity is significant. At $50/BDt the costs of buying energy at market prices or generating more from new sources may be high enough for a viable business case.
- The technology is available now. It would take approximately 2-3 years to build the facilities and transmission infrastructure once B.C Hydro awards a contract.
4.6.1.3 The Pellet Opportunity

- Pellet manufacturers locate their plants at, or near, sawmills for a reason.
- Delivered roadside harvesting residue costs at $50 per BDt far exceed the $20 per BDt (or less) delivered costs they currently enjoy for sawmill residues. Moreover, the pellet markets currently demand whitewood pellets that preclude the use of a significant amount of bark. The pellet opportunity is not significant without a further increase in market prices to support the higher cost of harvesting residues. However, it is getting close. Some producers are looking at surplus chips at $40/BDt as their next least cost source of wood pellet furnish. (Prices of surplus chips are rising at this writing.)

4.6.1.4 Conclusion

The additional biomass from roadside residues that could be used for energy purposes is significant.

It is recommended that a combination of energy uses be considered according to the amounts of bioenergy available in the vicinity of the energy project. There is a solid business case for bioenergy in BC and using roadside residues provide us with a strong advantage over the US and EU. There will be no “food or fuels” issues in BC using roadside residues.

Damaged wood is a reality in stands being harvested today and roadside residues may become a more frequent reality in the future. Results from the CFS MPBI have demonstrated that insect infestations in Canadian forests are likely to increase with global warming. CFS also advises that there is another forest pest damaging spruce in BC forests now. It just doesn’t receive as much press as the MPB. Sadly, the MPB has started impacting Alberta forests and communities as well. Canada is steward to 10% of the world’s forests and 30% of its boreal forests.

4.7 Next Steps for the Business Case

In 2006 there is an opportunity for BC Hydro to stimulate the addition of alternate electricity generating capacity. Scenarios and decision support tools can be developed to assess future opportunities to create synergistic biomass supply chains in strategic locations for the next century. Those same tools could be used to assist strategic planning by all of our resource stewards.

To further develop the Business Case referred to in 4.5.2 above, the following steps might be considered:

- Launch the BC Bioeconomy and actively support industry to achieve energy self sufficiency.
- Dedicate resources to MoFOR to lead the development of BC biomass supply information platforms in collaboration with MoEMPR.
- Proceed on a project by project basis with industry in BC to add capacity.
- Keep the business case document “live”. Use the recommendations to continuously improve the business case for bioenergy in BC.
- Work with the Institutes and their members to gain insights and continuously improve harvesting, processing and transportation costs.
- Focus on rapid project initiation in priority locations. Celebrate achievements. Learn from practical experience.
- Engage and inform the MPB emergency response teams. Engage and inform stakeholders through targeted communications and access to information and support.
➢ Engage stakeholder champions to counter perceptions about negative air quality of wood pellets and industrial bioenergy plants.

➢ Monitor progress and create success stories. Demonstrate and announce to the world that BC is the leading Bioeconomy in Canada

➢ Join forces with Alberta, Saskatchewan and Manitoba to become Canada’s Western Energy Superpower, create additional demand for biomass and attract “green” businesses to Western Canada.

➢ Develop a Western Canadian business-case-informed strategy for marketing, new product and process development and new sources and uses of technology and biomass jointly with the Prairies. Focus on strategies that attract new enterprises to Western Canada for sustainable economic development in First Nations and rural communities.

➢ Encourage the federal government to immediately develop a greenhouse gas action plan that will provide incentives for renewable energy producers and thereby reduce greenhouse gas emissions.

4.8 Communications and Public Relations

The Forintek project team has supported the communications needs of our sponsors, upon request.

A dilemma for our sponsors is balancing the desire to create another mechanism to sustain communities and the need to provide responsible stewardship of our forest resources. Actions on either front affect investment risks for bioenergy industry investors. Investment decisions by industry impact communities.

A key logistical challenge is managing, and communicating the opportunities and risks to both audiences.

Economic accessibility, supply chain logistics, sophisticated distribution channels and environmental sustainability of the forests are complex issues to communicate in simple terms. Careful consideration should be given to any public messages regarding just how much wood is available for sustainable economic use by industry and the communities in which they operate.

The communications strategy might be aligned with the business case

➢ Engage and inform the MPB Emergency Response Teams.

➢ Document and celebrate achievements.

➢ Engage and inform First Nations and rural communities about long term sustainable biomass supplies, and uses of bioenergy and the future bio fuels and products.

➢ Proactively provide informed assessments of the business case for future opportunities in their FN and rural communities

➢ Dedicate LOTS of resources to create an information hub, be responsive to and proactively support stakeholders

4.9 Engagement

4.9.1 The BC Bioenergy Industry

Forintek contacted and characterised the wood bioenergy industry embedded within the forest and energy industries. Bioenergy projects require collaboration among and within sectors. The development of
mutually supportive and productive working relationships among individuals from previously loosely related fields was facilitated by focusing on the business case. We listened and incorporated industry ideas for ways to create “win-win” partnerships. Exploring potential “win” situations for all took persistence and follow up. Wood bioenergy projects require that people be flexible and comfortable translating concepts and measures from energy, manufacturing and forestry. There are different criteria for success, different units of measurement, complicated conversions between measurement units and different time horizons. Large energy projects require a 15-30 year secure supply of feedstock to attract capital and provide a return to their investors. The major licensee’s shareholders expect returns on capital investments in 3 years, when lumber markets are good and shorter returns otherwise. Forest economists think of return on investment in terms of net present values on “crop” rotations exceeding 70 years.

In March, Brian McCloy started to engage members of the BC energy industry, wood biomass suppliers, commercial technology providers, and energy project financiers to help Forintek assess the business case for wood bioenergy. Initial meetings between the project team and individual companies and government groups were conducted throughout May and June. Contacts continued throughout the project. We are grateful to all those who shared their perspectives with us and helped us continue to refine the strategy options and business case well into September.

On June 7th David Cawood facilitated a meeting of industry experts who agreed to meet, share their perspectives with each other and some members of the Steering Committee. The group was very supportive of BC’s business case approach to strategy development, and verified, or corrected, the business case. Industry experts were generally supportive of BC’s emerging plan for increased bioenergy capacity and provided recommendations. Projects having a strong value proposition for both industry and government were identified with the Steering Committee at our second meeting on June 8.

Over the summer contacts between members of the Steering Committee and members of the energy and forest industries accelerated. In BC Hydro’s 2006 Call for Tenders which was completed in July 2006, the award of a contract to Mackenzie Green Energy Inc. is encouraging given that the levelized plant gate price for this size of project was greater than $74/MWh. While this project is based on sawmill residuals, the power price significantly narrowed the electricity price cost gap identified in the April 18 business case. The increase in the price that BC Hydro is now willing to pay for new power supply may enable the economic use of much more MPB killed pine for electricity.

Opportunity: The Bioenergy Strategy Branch, MoFOR and BC Hydro are well positioned to initiate bioenergy projects in BC. It is critical that the partners keep the industry informed and engaged.

Strength: The Interior BC industry will improve the business case if kept engaged. They are global leaders at using innovative ways to cut costs.

It will take the combined good will, innovative thinking and an eye to the future by the forest industry, government policy makers, independent power producers, pellet producers and BC Hydro to realize value.

4.9.2 Governments

The BC Government is only one example of an organization being challenged today by unforeseen external events. Many others are also dealing with new ways of breaking older barriers in the light of new externalities. The forest industry is consolidating in response to global competition. The energy industry has unprecedented opportunities, but face overwhelming pressure to change and become greener.
The BC government can use the Bioenergy Strategy to effect innovative industry change and positive growth. However, the Province must lead in that change and reorganise itself to do so. MoFOR, MoEMPR and BC Hydro have started, and accomplished positive and constructive change. Alberta has reorganized to facilitate the emergence of their bioeconomy. BC may be able to benefit from Alberta experiences.

Cross-sector meetings are becoming more common, and there is a call for a broader range of executive skills. The irony is that good strategic planning practice has dictated the need for tight Mission Statements, and these can easily lead to a strengthening of barriers to collaboration. Organisations like the National Institutes that bring Canada, the Provinces and the forest industry to the same table and reach out to others to find solutions to common problems are ideally structured to help their members break barriers when needed. At the April 18th meeting Jim Dangerfield joined the team to facilitate contacts and help build relationships between Steering Committee members and those working on related efforts in other Canadian jurisdictions.

Jim Dangerfield is on the Steering Committee of a related project in Alberta, also managed by Forintek. Alberta is actively planning for the transition to a “bio economy” as their fossil fuels diminish. Members of the Bioenergy Steering Committee have ensured that BC is actively engaged in Canada’s and Alberta’s emerging plans. They have positioned BC well to have BC priorities adopted by Canada and shared with Alberta.

Western Canada may be the securest place on the planet for an environmentally inclined, but now fossil fuel dependant, company (or any investor, for that matter) to make long term investments.

There are strong opportunities for BC, Alberta and other jurisdictions to leverage each other’s knowledge and resources to achieve common goals. Needed immediately are statements of Key Deliverables of Priority Projects that BC could do jointly with other jurisdictions.

4.9.3 Technology Providers and the Research Community

At the April 18th meeting it was noted that the long term competitiveness of the bioenergy sector in BC relies on an ability to innovate, focusing on the timely adoption by BC enterprises of technologies emerging here and elsewhere. Canadian industry technology providers, applied researchers at our National Institutes, government researchers and academic researchers are actively engaged and contributing now to the global development and commercialization of new technologies. Dr. Alan Potter, former Vice President of Technology at Nexfor and now Executive Director, Forest Research Opportunity BC joined the Forintek team. Alan contacted many individuals to seek opinions and produced a timeline for emerging technologies (Potter 2006). The timeline is presented in a way that makes it straightforward for decision makers to initially set and test Energy Plan alternate energy targets, and establish priorities for R&D with other partners.

Forest Research Opportunity is a unique BC strength which could be used to ensure collaborative research efforts going forward.

Technology that is available today? Technologies are available to convert wood residue into electricity and power for local thermal heating. The decision to use these technologies is driven by the cost of delivering the wood to the plant and the marker prices for energy. Similarly the technology for making solid fuel wood pellets is readily available, although there is scope for research to reduce the costs of delivery of fibre and the converting costs. The technology for using wood to generate a syngas to substitute for natural gas has been piloted and is becoming commercially available. The high prices of
natural gas are allowing the capital investment for such technology to be recovered in a 2-3 year time period.

**What innovation investments have the most potential to accelerate the commercialization of key technologies for BC adoption?** Over the next five years the technology will evolve to use syngas to substitute natural gas in pulp mill lime kilns and lumber kilns. Potential savings will likely encourage private sector investment.

The large scale conversion of wood to high hydrogen grade syngas to convert to hydrocarbons will also be demonstrated within 5 years, although the capital costs of such investments will be in the billion dollar region and not likely to happen without strategic government co-investment. It is a process however which could be combined with an existing pulp and paper mill complex and thus make some current mills more viable in their communities.

Ethanol production is receiving much interest at present given US and Canadian government policies to increase its usage in blends of gasoline for automotive use. Most of this will come from fermentation of the starch in grain. However the vision is to use the lignocellulosic material left over from crops to allow the use of the crop for both food and fuel production. The same technology can be applied to wood biomass. However there are still significant barriers to make the technology economical. One leading researcher quoted ‘$2 billion and 20 years’. Given the strategic importance in the US, a 10-20 year time frame is realistic.

The integrated biorefinery which can convert lignocellulose to pulp, energy, ethanol and a range of chemical intermediates through biological conversion processes is a noble long term vision. There are significant technical and business barriers to overcome. With research effort, and with disciplined networking and research collaboration, it will be viable but will likely take over 20 years.

**What investments in BC innovation infrastructure have the best potential to increase the timely uptake of new technology?** All the above technological advances require investment. BC needs to ensure that future investments it makes are leveraged with other investments in Canada and internationally. Using a cluster mechanism such as Forest Research Opportunity BC, or a mechanism through the new single Forest Research Institute are ways to ensure leverage and collaboration with the academic community and potential suppliers.
Summary Timeline of the Technologies and Barriers in Converting Wood to Energy and Fuels

### Technology

- **Wood to electricity by direct fire**
  - Technology available-economics drive the decision
  - Wood to electricity by direct fire

- **Wood to 'solid fuel' pellets**
  - Technology available-economics drive the decision
  - Wood to 'solid fuel' pellets

- **Wood to syngas for wood driers**
  - Technology available-economics drive the decision
  - Wood to syngas for wood driers
  - To be piloted - high probability of success

- **Wood to syngas for pulp mill lime kilns**
  - Significant barriers to maintain a clean stream, R&D needed
  - Wood to syngas for pulp mill lime kilns

- **Wood to clean syngas to power internal combustion engine for <10MW electricity generation**
  - Wood to clean syngas to power internal combustion engine for <10MW electricity generation
  - To be piloted - high probability of success

- **Wood to high hydrogen grade syngas for liquid fuel production - a basic biorefinery**
  - Needs R&D, large scale pilots and further R&D on catalysts to adapt current technology for coal conversion
  - Wood to high hydrogen grade syngas for liquid fuel production - a basic biorefinery

- **Wood to energy and biochemicals - an integrated biorefinery**
  - Needs extensive process R&D
  - Wood to energy and biochemicals - an integrated biorefinery

### Barriers

- **Recently implemented in BC - driven by high natural gas prices**
  - Wood to energy and biochemicals - an integrated biorefinery

- **Needs large scale pilots and further R&D on enzymes**
  - Wood to energy and biochemicals - an integrated biorefinery

- **Needs pilot scale trials & R&D**
  - Wood to energy and biochemicals - an integrated biorefinery
5 Conclusions and Recommendations

A Bioenergy Strategy for British Columbia has been jointly developed by Forintek and the Bioenergy Steering Committee. Results from the Forintek project clearly demonstrate that bioenergy is an important and timely strategic opportunity for BC today. This report is a call for action and presents a strong vision for the immediate development and future use of bioenergy, from all sources, in British Columbia.

Recommendation: The Province champion and implement the Bioenergy Strategy. BC Hydro issues a call for tender for cost-effective wood residue power.

Vision: To lead the bioeconomy in Western Canada with a strong and sustainable bioenergy sector.

5.1 BC Adopts the Bioenergy Strategy

Use the opportunistic and growing stockpile of Mountain Pine Beetle killed wood to mitigate impacts on First Nations and forest dependent communities and realize a sustainable supply of biomass from all sources.

- Attract capital to build the electricity infrastructure needed to match the long term, sustainable supply of biomass available for electricity from all BC sources.
- Leverage resources and attract capital to diversify the product mix from current BC forests and transform our industry into the future producers of bio-products, bioenergy and bio-fuels.
- Attract environmentally responsible enterprises that use bioenergy and diversify the BC economy.
- Leverage resources and attract investment to become a wood bioenergy technology hub and a global leader in wood biomass R&D and commercial adoption.
- Utilize as much of the biomass residues as possible in BC. Look for export opportunities for the remainder.

Desired Outcomes

- BC electricity self-sufficiency; possible export.
- Sustained economic development for First Nations and rural communities.
- New revenue streams to support natural resource stewardship.
- A global role model for the responsible stewardship and sustained use of natural resources.
- Decreased GHG emissions.

5.2 Grow the MoEMPR, MoFOR and BC Hydro Partnership

As already highlighted in this report, the partners are in a unique position to make bioenergy projects happen in BC. It is recommended that BC Hydro issue a CFT for biomass power.

Successful bioenergy projects and continuing engagement is critical to the initial and future success of the strategy. The strategy calls for the development a sustainable volume of economically accessible biomass from all sources for the future.
Strategy options provided in this document could double B.C use of alternate energy and mitigate the impacts of the MPB damage in First Nations and rural communities in 5 years.

While the total biomass is enormous, it can only be used for bioenergy as the integrated biomass supply chains and distribution channels, generating capacity and energy distribution systems become available in BC. The Province has a critical role to play to facilitate and help create a bioenergy culture and the infrastructure needed to effectively use our vast biomass resources for bioenergy.

**To further engage the bioenergy sector in BC, the province might**

- Document and communicate that British Columbia is the dominant bioeconomy in Canada. Update the Energy Plan to show that BC is the largest user of biomass for energy and intends to grow capacity and consumption as a component part of the planned sustainable use of our natural resources. Champion BC bioenergy and make it a priority.
- Maintain the mutually supportive working relationships established during the project. Use the business case for biomass energy (McCloy 2006) as a “live” document to facilitate communication and focus efforts. Implement recommendations. Continue to add elements, refine and adapt the business case with sector champions.

**To support sector growth, the partners might**

- Benchmark BC use of biomass for heat and power (including homes).
- Benchmark all BC generation capacity for bioenergy. Use incremental funding to actively stimulate industry innovation in BC, focusing on the timely adoption of technology emerging here and elsewhere, by BC enterprises.
- Engage the BC forest industry and benchmark their use of biomass for heat and power. Benchmark BC generation capacity for biomass electricity.
- Set 5, 10, 20 and 50 year BC targets for the proportions of bioenergy consumption versus consumption from all other energy sources. Establish key indicators, and performance measures relating progress towards BC’s Great Goals.
- Monitor and report on the rate that BC is substituting biomass for fossil fuels in collaboration with industry.
- Dedicate resources and proactively improve the business case for both biomass electricity and pellets on an energy project by energy project basis.
- Dedicate resources to support and accelerate growth of bioenergy generating capacity in BC
- Follow up on the recommendations provided in the business case to facilitate the use of the growing and opportunistic supply of MPB damaged wood as biomass feedstock to accelerate “home-grown energy” generation capacity in BC communities. Inform the MPB Action Plan.
To create an information hub to serve the sector and respond to stakeholders the partners might

- Construct MoFOR biomass supply platforms and timelines.
- Promptly respond to requests for information and proactively direct FN and communities to the resources they need to critically assess and make an informed plan for the future.
- Proactively assist communities to attract bioenergy using business enterprises.

To leverage resources, the Province might:

- Position BC to be a global role model for both the responsible stewardship and the sustainable economic use of our natural resources for energy.
- With Alberta, Saskatchewan and Manitoba create a competitive energy business investment climate and promote Western Canada as the securest place on the planet for environmentally and socially responsible energy company investment.
- Use incremental funding to actively stimulate industry innovation. Focus on the timely adoption of technology emerging here and elsewhere, by BC enterprises.

To expand the scope of the BC Bioenergy Strategy to include other sources of biomass the partners might:

- Engage key government officials, the energy industry, biomass suppliers, industry technology providers, and their financiers to assess the business case for biomass from such sources as agricultural crops.
- Facilitate honest and open discussions on potential “win situations for all”. Form strong and mutually supportive relationships.
- Initiate and follow through on bioenergy projects.
- Create more champions from successes.
- Stimulate the timely commercialization and uptake of technology in BC.
- Engage the research community for the purpose of planning. Map the timeline for emerging technologies BC needs.
- Use the technology intelligence to set and check the plausibility of goals and targets for BC.
- Link the BC Plan to the efforts of others.
- Leverage BC investments.
- Demonstrate that the achievement of BC targets will substantially help others reach their targets.
- Put the infrastructure in place to overcome the barriers of historical models.
- Actively track progress against the targets.
- Continuously improve the plan.
- Create a BC culture that embraces change.
- Deliver the plan.
6 References


Estimated Costs for Harvesting, Comminuting, and Transporting Beetle-killed Pine in the Quesnel/Nazko Area of Central British Columbia

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BC Ministry of Energy, Mines and Petroleum Resources
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Abstract

The Forest Engineering Research Institute of Canada (FERIC) estimated the costs of harvesting, comminuting, and transporting pine trees killed by the mountain pine beetle in the central Interior of British Columbia. Costs were based on computer models that used three different harvesting systems depending on the ratio of sawlogs to fuelwood in the stand. For stands with less than 50% fuelwood, the existing roadside harvesting system was used to harvest sawlogs and generate roadside residuals, followed by a separate operation to comminute and transport the feedstock. This system had the lowest cost. Stands with 50-95% fuelwood were costed using a satellite sortyard. This system was best suited to sort the sawlogs from stands containing predominantly fuelwood, but it also had the highest cost. Furthermore, stands suitable for processing through satellite yard comprised more volume than any other system in an example study area. Stands with more than 95% fuelwood were costed using on-site, full-tree chipping. According to FERIC’s shelf-life model for predicting fuelwood content, no stands suitable for this system exist at 5 years after mortality, but the number of full-tree chipping stands comprise about 40% of the total volume in the study area by 20 years past mortality.

FERIC conducted field measurements of the volume of residuals generated by roadside harvesting, and found that 14-55% of the original stand biomass remained at roadside after harvesting, depending on the sawlog utilization standards. There was also a substantial volume of biomass dispersed across the cutblocks, however, it was mainly in pieces too small for harvesting, and was not considered to be a potential source of feedstock.

KEYWORDS: Mountain pine beetle, harvesting system, comminution, transportation, costs, volume determination, interior British Columbia, fuelwood, bioenergy, biomass, residues
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1 Introduction

The current infestation of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is having a significant effect on the lodgepole pine (*Pinus contorta* Dougl.) forests of interior British Columbia. The impact of this infestation is unprecedented in recorded history, and the volume of pine that will be killed by the mountain pine beetle in some areas is forecast to exceed the capacity of the existing logging and milling industry to deal with it effectively. Forest companies have increased their harvest of dead pine, but despite this increased harvesting activity, significant volumes of beetle-killed pine will remain unharvested and its commercial value may be lost. One option for salvaging more value from the dead pine is to harvest it for fuelwood.

In 2005, BIOCAP (Kumar et al 2005) proposed to use the unharvested pine as feedstock for an electrical generation power plant located near the epicenter of the beetle infestation, at either Quesnel or Nazko. Such a power plant would consume approximately 65 million m$^3$ of pine over its twenty-year lifespan. The proposal was based on some elementary estimates of the pine volumes and spatial distributions, and of the harvesting and comminution costs. The Forest Engineering Research Institute of Canada proposed to review those volume and cost estimates to provide more confidence in their accuracy.

Near the same time, the BC Ministry of Energy, Mines, and Petroleum Resources (MoEMPR), BC Hydro and the BC Ministry of Forests and Range (MoFOR) partnered with Forintek Canada Corp. to provide information about ways that forest biomass could be included in BC’s energy strategy. The use of beetle-killed pine as feedstock for power generation would be included as one of the options. In order to properly address the dead pine in the energy strategy, such an analysis would require information about the harvesting cost.

As part of its mandate to the MoEMPR and MoFOR, Forintek Canada Corp. contracted FERIC to provide volume and cost estimates for harvesting, transporting, and comminuting beetle-killed pine to a site where it could be used for power generation. A companion report (McCloy 2006) examines the feasibility of establishing an energy industry based on wood biomass using the cost analysis from this report.

2 Objectives

FERIC’s analysis was to include:

- A description of the appropriate harvesting and transportation systems for the dead pine trees;
- Estimated costs of harvesting and comminuting the beetle-killed pine from typical harvesting sites using the most appropriate harvesting system;
- Estimated costs for transporting the feedstock from the harvesting sites to the potential sites for power generation; and
- An example of applying the costs and volumes to a specific area using the Quesnel/Nazko corridor as a case study.

FERIC’s analysis was for direct harvesting and transportation costs, and was not to include:

- planning and administration costs;
- road development, maintenance, and deactivation; and
- reforestation.

The primary goal of the project was to deal with costs; volumes were considered only as they influence machine productivity and to illustrate the effects of “scaling-up” the analysis from individual cutblocks to
a larger operating area. Determining the amount of annual harvest and the sustainability of the fibre supply were beyond the scope of the project.

This report is in fulfillment of FERIC’s contract with Forintek to document the harvesting costs and “orders of magnitude” volume estimates of biomass from the beetle-killed pine.

3 Methods and Results

A literature search was undertaken to determine what harvesting systems and equipment were being used in other jurisdictions to harvest, comminute, and transport residual and standing biomass (Badger 2002, Blair 1998, Bolding and Lanford 2005, Forrester et al 2006, Lewis and Hartley 2006, Loeffler et al 2006, Pottie and Guimier 1985). FERIC attended the “Smallwood 2006” conference (Forest Products Society 2006), which emphasized harvesting small trees for the purpose of supplying feedstock to power plants. After the conference, FERIC undertook a field tour through southeast USA to observe the systems and equipment that are commonly used for harvesting fuelwood in that area. FERIC met with operational planners in the BC Interior to discuss their ideas on harvesting in the beetle-killed stands. The information from these sources was used to specify the harvesting systems that will be appropriate for large-scale fuelwood salvage of the beetle-killed pine.

3.1 Field measurements of residual volumes

Potential fuelwood from the beetle-killed pine occurs in two classes: the residuals (tops, butts, and limbs) that are left after conventional harvesting operations, and dead standing trees from areas that are not harvested under current practices. Estimating the volumes in these two classes requires different approaches.

FERIC recently completed two projects (MacDonald 2004, 2006) to measure the roadside residual left after harvesting, however, these projects were conducted under significantly different conditions than the beetle-affected areas. Accordingly, FERIC conducted fieldwork to measure the volume of residuals after harvesting from pine-dominated stands in the Quesnel/Nazko corridor. In July 2006, the cooperating companies suggested cutblocks from their recent harvesting areas that would be appropriate for measuring the residual volumes. Parts of the cutblocks that were visibly associated with specific residual piles (e.g., between spur roads and bounded by the cutblock boundary) were used for measurement. The residual volume was measured in two categories: the tops, butts, and limbs that were piled at roadside, and the small, broken, or overlooked pieces that were dispersed across the cutblock.

The volumes measured for this project were meant to assess the biomass that was left on-site after conventional timber harvesting, and do not reflect on the measurement of avoidable waste as defined by regulations. Only gross volume was considered; there was no accounting for form or quality of the biomass, nor its suitability for conventional timber products. Likewise, any volume that was intentionally left on-site to meet non-timber objectives such as retaining coarse woody debris for wildlife habitat was not differentiated from any other volume.

3.1.1 Roadside residuals

Top piles are left near the roadside after the logs are processed mechanically, often by means of a dangle-head processor. Dangle-head processors retrieve whole trees from the supply pile, delimb and top them, pile the processed logs near the road, and discard the tops into piles (Figure 1). The top piles usually start about 10-13 m from the centreline of the road in order to leave enough room for the processed logs to be
piled. Subsequently, the log loader travels on the area where the logs are piled, unimpeded by the residual top piles yet within reach of log trucks on the road. Depending on the particular operation and the volume of residual material, the tops may take the form of continuous or discontinuous rectangular piles, or teepee-shaped discrete piles (Figure 2).

![Figure 1: Two dangle-head processors working in tandem in a roadside logging operation.](image1)

![Figure 2: Teepee-shaped piles on both sides of the logging road through a typical cutblock.](image2)

The volume of the roadside residuals was estimated by measuring the dimensions of every roadside pile in each measurement area. The bulk volumes of teepee piles were calculated using Hardy’s (1996) paraboloid equation, while the volumes of linear piles were calculated as irregular solids. The piles’ dimensions were measured directly using logger and carpenter tapes.

FERIC measured roadside and dispersed residual volumes from 15 areas in 12 cutblocks from four companies. Each company implemented a different utilization specification in regard to small-diameter tops, and these differences manifested themselves in different amounts of roadside residual volumes. One company routinely harvested tops to a 5 cm (2 inch) diameter, while others used 10 cm or larger for their target top diameter.
In the volume calculations shown in Table 1, the bulk volume includes all the airspace between the tops, butts, and limbs in the pile. The bulk volume was converted into residual volume, expressed as oven-dry tonnes per hectare, by multiplying the bulk volume by a bulk density factor, and dividing by the area of the cutblock that contributed to the residual pile. The cutblock areas were determined by GPS traverses of the areas associated with the specific residual piles. A bulk density of 200 kg/m$^3$ at 40% moisture content, or 120 kg/m$^3$ dry equivalent, was used for all piles. Owing to the constraints of this project, it was not feasible to conduct field measurements of the bulk density, therefore, the bulk density was adapted from previous FERIC field work and other sources (MacDonald 2006, Oregon Department of Energy 2006, Hamelinck et al 2003, WoodEnergy.ie 2006). The literature showed a wide range of bulk densities (~150 – 250 kg/m$^3$), and FERIC’s previous work was in spruce and aspen forest types in Alberta which may not be directly applicable to the pine forests of the beetle-affected area. FERIC felt that 200 kg/m$^3$ at 40% moisture content (120 kg/m$^3$ dry bulk density) was a reasonable value to calculate “orders of magnitude” volume estimates, but recommends that field measurements be undertaken to verify the value.

The inventory stand volume was taken from the MoFOR dataset for the Quesnel Timber Supply Area (TSA). Note that inventory volumes are not normally applied to individual cutblocks, however, this value was the only volume estimate that was available consistently for all cutblocks. The cutblocks were all in pine-dominant stands with at least 90% pine content according to the MoFOR inventory dataset. FERIC obtained some cruise-based, individual cutblock volume estimates from the cooperating companies, and these values were generally 3-5% higher than the inventory volume. The inventory volume was converted to estimated original biomass by multiplying the inventory cruise by 420 kg/m$^3$ and adding 5% to account for cruise overruns, then adding the volume of roadside residual. Finally, the volume of roadside residual was expressed as a percentage of the original stand volume.
Table 1: Roadside residual volumes expressed as a percentage of the original stand volume.

<table>
<thead>
<tr>
<th>Company</th>
<th>Cutblock</th>
<th>Area (ha)</th>
<th>Bulk Volume Including Airspace (m³/ha)</th>
<th>Residual Volume (ODt¹/ha)</th>
<th>Inventory Stand Volume (m³/ha)</th>
<th>Estimated Original Stand Biomass (ODt/ha)</th>
<th>Roadside Residual as Proportion of Original Stand Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>7.60</td>
<td>184</td>
<td>22.1</td>
<td>298</td>
<td>131</td>
<td>14%</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>4.51</td>
<td>317</td>
<td>38.0</td>
<td>279</td>
<td>123</td>
<td>24%</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>9.55</td>
<td>334</td>
<td>40.0</td>
<td>279</td>
<td>123</td>
<td>25%</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>17.90</td>
<td>313</td>
<td>37.5</td>
<td>218</td>
<td>96</td>
<td>28%</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>22.43</td>
<td>390</td>
<td>46.8</td>
<td>198</td>
<td>87</td>
<td>35%</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>14.19</td>
<td>399</td>
<td>47.8</td>
<td>219</td>
<td>97</td>
<td>33%</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>14.71</td>
<td>536</td>
<td>64.3</td>
<td>266</td>
<td>117</td>
<td>35%</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>4.66</td>
<td>265</td>
<td>31.8</td>
<td>243</td>
<td>107</td>
<td>23%</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>6.98</td>
<td>509</td>
<td>61.0</td>
<td>232</td>
<td>102</td>
<td>37%</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>3.62</td>
<td>824</td>
<td>98.8</td>
<td>265</td>
<td>117</td>
<td>46%</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>4.42</td>
<td>251</td>
<td>30.2</td>
<td>230</td>
<td>101</td>
<td>23%</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>8.24</td>
<td>1194</td>
<td>143.3</td>
<td>310</td>
<td>137</td>
<td>51%</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>0.72</td>
<td>596</td>
<td>71.6</td>
<td>273</td>
<td>120</td>
<td>37%</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>2.44</td>
<td>826</td>
<td>99.1</td>
<td>270</td>
<td>119</td>
<td>45%</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>0.45</td>
<td>1208</td>
<td>144.9</td>
<td>270</td>
<td>119</td>
<td>55%</td>
</tr>
</tbody>
</table>

Roadside residual volumes ranged from 14% to 55% of the original stand volume (Figure 3). FERIC observed that the company following the 5-cm top diameter utilization standard had among the lowest residual volume, while the company that targeted its top diameters at more than 10 cm had among the highest levels. Furthermore, FERIC observed many tops within these piles that were larger than 10 cm (Figure 4). The residual pieces with large diameter were usually affected by severe checking that made them unsuitable for sawlogs.

The volumes calculated here are significantly different than the cull volumes experienced by forest companies. FERIC was told by one cooperating company that the typical difference between gross cruise volume and as-delivered volume was about 20%, not the 45-55% that was shown here. This statement reaffirms the necessity to do additional measurements of roadside residual volume, especially to confirm the bulk density of the residual piles.

¹ ODt: Oven-dry tonne. Equivalent to bone-dry tonne (BDt)
3.1.2 Dispersed residuals

The dispersed residuals were measured using the line intersect method (Sutherland 1986). Plots with two, 20-meter perpendicular lines were established at random locations throughout the cutblock at a density of approximately one plot per hectare. Every sound piece of softwood residual with a minimum diameter of 1 cm and length of 60 cm was tallied. In addition, the length and mid-stem diameter of every piece over 5 cm diameter where the sampling line intersected the piece was recorded. Volume was converted into its biomass equivalent using a conversion rate of 420 kg/m³.

The line intersect method measures the total volume of all the dispersed residuals larger than 1 cm diameter and 60 cm long. Clearly such small pieces cannot be harvested economically, but they were measured in order to compare the total biomass between cutblocks. By collecting additional size measurements, FERIC calculated the dispersed biomass volume that met the strict, but more economically feasible, utilization specifications of 15 cm diameter and 3 m length (Table 2). FERIC made no attempt to assess the quality of these larger pieces, and it is unknown whether they meet sawlog quality specifications. FERIC also calculated the volume of pieces that were larger than the strict minimum size...
limit but smaller than 20 cm diameter and 4 m length; such pieces were deemed to be smaller than contemporary utilization limits. This volume (shown as the last column in Table 2) comprises the dispersed residuals that could be available as fuelwood because it is large enough to be skidded, yet is smaller than contemporary sawlog size limits.

**Table 2: Volume summary of dispersed residuals.**

<table>
<thead>
<tr>
<th>Company</th>
<th>Cutblock</th>
<th>Total Volume (m^3/ha)</th>
<th>ODt/ha</th>
<th>Volume of pieces larger than strict minimum size (m^3/ha)</th>
<th>Volume of pieces larger than strict minimum size and smaller than contemporary merchantable size limits (m^3/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>50.7</td>
<td>21.3</td>
<td>2.6</td>
<td>0.0</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>71.6</td>
<td>30.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>44.9</td>
<td>18.9</td>
<td>8.8</td>
<td>2.0</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>18.7</td>
<td>7.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>20.0</td>
<td>8.4</td>
<td>2.5</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>20.0</td>
<td>8.4</td>
<td>3.4</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>31.0</td>
<td>13.0</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>26.3</td>
<td>11.0</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>56.2</td>
<td>23.6</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>37.2</td>
<td>15.6</td>
<td>4.1</td>
<td>0.0</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>51.1</td>
<td>21.5</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>51.5</td>
<td>21.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>67.9</td>
<td>28.5</td>
<td>7.0</td>
<td>1.8</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>47.0</td>
<td>19.7</td>
<td>2.3</td>
<td>0.9</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>50.9</td>
<td>21.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 2 shows that the dispersed residuals comprise a significant volume, with an average volume of nearly 50 \(m^3/ha\) or 20 ODt/ha. Relative to the roadside residuals, especially in cleanly-logged cutblocks (Table 1), the dispersed residuals makes up a large part of the total residual biomass. However, most of the dispersed volume is from pieces that are much too small to be harvested economically; the dispersed residual volumes that are larger than the strict utilization limits ranged from about 1 - 5 \(m^3/ha\) (Figure 5). Furthermore, most of the volume that is over the strict utilization limit is also larger than more contemporary utilization limits, and may have been overlooked (intentionally or inadvertently) during skidding. The residual biomass volume that is large enough to be skidded but would also be available after exactly following contemporary sawlog specifications ranged from 0 – 2 \(m^3/ha\). FERIC observed a few sites where the number of unskidded pieces was clearly more than normal (Figure 6). For these areas, FERIC observed that the average diameter was less than 15 cm, and the stems would likely have been left as roadside residue if they had been skidded. This may explain why the buncher and skidder operators did not harvest all the trees from these areas. Such heavy residual loading was atypical.
3.2 Standing fuelwood volume calculations

Forest Analysis and Inventory Branch of the MoFOR provided a dataset of the Quesnel TSA forest cover. In addition to standard forest cover attributes, the dataset included attributes for ownership, timber harvesting constraints, biogeoclimatic zones and subzones, and Land Units for each forest cover polygon. Volume summaries and travel-time analyses for the case study were conducted using the Land Units as defined by the MoFOR database.
Several factors, including the actual land base, the suitability of harvesting systems, and the shelf life of the sawlogs and fuelwood, must be considered for calculating the volume of standing fuelwood. These factors will be described.

3.2.1 Case study area chosen using travel times and existing road development

For each of the Land Units in the Quesnel TSA west of the Fraser River, FERIC estimated the haul distance to Quesnel on highway, mainline, branch, and spur roads, then subsequently calculated the hauling time to Quesnel using the average travel speeds shown in Table 3.

Table 3: Travel speeds for log and chip trucks.

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Travel Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway</td>
<td>80</td>
</tr>
<tr>
<td>Main</td>
<td>60</td>
</tr>
<tr>
<td>Branch</td>
<td>45</td>
</tr>
<tr>
<td>Spur</td>
<td>20</td>
</tr>
</tbody>
</table>

Using the road network from the LRDW database (Ministry of Sustainable Resource Management 2006), FERIC estimated the existing road network density in three classes. Densely-roaded areas had a clearly-visible existing road network that serviced existing cutblocks. In the absence of other constraints, the leave strips between existing cutblocks in these areas could be harvested for fuelwood with a minimum of new road development. Sparse road-development areas lacked a mainline road system, and would require a significant amount of mainline and branch road development before harvesting could be undertaken. The remaining areas, i.e., those with some roads such as nearby mainline roads and only a few cutblocks, comprised the partially-roaded class. These partially-roaded areas would require some mainline road development and a significant amount of branch development before timber harvesting could take place. Partially-roaded areas offer few opportunities to harvest leave strips between existing cutblocks without a significant amount of new road construction.

The existing main road development in the three westernmost Land Units of the Quesnel TSA is intended for travel to destinations other than Quesnel so their round-trip travel time to Quesnel (excluding load, unload, and delay times) averaged more than 8 h. Since these three Land Units also have sparse road development, they were excluded from subsequent analysis. Accordingly, the land base used for the case-study analysis comprised all the Land Units in the Quesnel TSA west of the Fraser River, except for the three westernmost Land Units. The longest round-trip travel time for the included Land Units was almost 5 h. The Quesnel TSA and the case study area are shown in Figure 7.
3.2.2 Fuelwood harvesting potential

FERIC’s primary objective in this project was to calculate costs, but costs can be influenced by the total harvested volume. Accordingly, it was important to assess the total potential harvesting volume, even at a rudimentary level. FERIC made some assumptions about what stands could be available for harvest, but in practice many stands will need to be retained to provide for other resource values and objectives. Each landscape unit will have differing objectives and would need to be assessed for its acceptance to removal of existing leave strips. Any future analysis must consider all resource values when calculating the available volumes.

Stands within the study area were classified for their fuelwood harvesting potential by excluding all stands that were marked as non-forest cover, non-Crown ownership, or non-harvestable (i.e., had a non-timber harvesting constraint). Further, stands less than 25 years old, with less than 30% pine content, or with less than 75 m³/ha of merchantable volume were also excluded. The remainder was designated as potential for fuelwood harvest, and the distribution of land within the case study area is shown in Table 4.

The distribution of road density within the “potential fuelwood harvest” area is shown in Table 5.

Table 4: Land distribution within the case study area west of Quesnel.

<table>
<thead>
<tr>
<th>Fuelwood Harvest Potential</th>
<th>Area within Case Study Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-forest land</td>
<td>132 125</td>
</tr>
<tr>
<td>Non-crown land</td>
<td>51 386</td>
</tr>
<tr>
<td>Non-timber harvesting constraint</td>
<td>169 081</td>
</tr>
<tr>
<td>Age &lt; 25</td>
<td>111 579</td>
</tr>
<tr>
<td>Pine content &lt;= 30%</td>
<td>133 840</td>
</tr>
<tr>
<td>Volume &lt; 75 m³/ha</td>
<td>44 367</td>
</tr>
<tr>
<td>Potential fuelwood harvest</td>
<td>589 328</td>
</tr>
</tbody>
</table>
### Table 5: Road-density class distribution of the potential fuelwood harvest areas in the case study area.

<table>
<thead>
<tr>
<th>Road Density Class</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparse</td>
<td>259 728</td>
</tr>
<tr>
<td>Partially-roaded</td>
<td>127 780</td>
</tr>
<tr>
<td>Dense</td>
<td>201 820</td>
</tr>
<tr>
<td>Total</td>
<td>589 328</td>
</tr>
</tbody>
</table>

#### 3.2.3 Influence of fuelwood content on the harvesting system

While large-scale harvesting of beetle-killed pine will have similarities with biomass harvesting operations in other jurisdictions, FERIC believes that customized solutions will be required because of the overall volume to be harvested, the mixture of sawlogs and fuelwood within individual stands, the tree size, and unique terrain, climatic, and geographic conditions. As such, the cost and productivity information from other jurisdictions may provide useful starting points for cost analysis, but the only way to reliably determine the cost and productivity is to conduct operational trials under actual operating conditions. Such trials should be the subject of future research.

FERIC believes that the varying proportions of sawlogs and fuelwood within individual stands will have a significant influence on the selection of the harvesting system, and proposes to use different systems depending on the relative proportions of sawlogs and fuelwood.

In current salvage operations (i.e., with sawlogs as the primary focus), the forest industry harvests the beetle-killed stands using conventional roadside harvesting systems in which the trees are felled and bunched, then skidded to roadside where they are processed into sawlogs. The tops, butts, and limbs that are not suitable for sawlogs are left in piles near the roadside, to be burned when weather conditions are appropriate. FERIC believes that this system will continue to be used for as long as the forest companies can extract sufficient value from the stands to cover operational costs, fixed development costs, and administrative costs, and to generate a profit. However, at some point, stands will have deteriorated to a stage when the sawlog volume cannot cover the harvesting costs, and conventional harvesting will not be undertaken. FERIC assumed that this point will occur when 50% of the stand volume is fuelwood as determined by the shelf-life model described later. Some stands in which FERIC measured the residual volume are approaching the 50% residual level. Until the 50% residual level is reached, FERIC assumed that stands will continue to be harvested using conventional systems, and that biomass will be available only as roadside residuals.

A different harvesting system is indicated once the stand contains more than 50% fuelwood. The stand will still contain a significant proportion of sawlogs, and as with conventional harvesting practices, the sawlogs must be separated from the fuelwood at some selected location. Possible locations for the separation to occur are at the stump, at the landing or roadside, at a satellite yard, or at the final destination (mill or power plant).

One factor for deciding the location for the separation to occur is the production rates of the machines used in the harvesting system. The production rate of typical comminution equipment is much higher than the production rate for the bunchers and skidders, so pairing one comminution machine with a typical
roadside or landing logging operation would cause it to operate inefficiently through low utilization. Accordingly, FERIC concentrated its analysis on systems where several logging operations were combined with a single comminution site, i.e, in a satellite yard or at the final destination. This is the system FERIC proposes to use for stands in the second level of sawlog-to-fuelwood content.

Once the fuelwood content exceeds some high threshold, it will become uneconomic to separate the sawlogs from the fuelwood, and a third harvesting system will be warranted. Such a harvesting system should use on-site comminution, and haul the comminuted feedstock directly from the cutblocks to the final destination, resulting in significant cost savings compared to processing the volume through a satellite yard. At the same time, value would be lost because sawlogs would be chipped as fuelwood. FERIC assumed that stands with 95% or more fuelwood would be suitable for this harvesting system, but a thorough breakeven analysis would be required to determine the best threshold between the two systems.

Since the current industry practise is to harvest sawlogs, any indication of the thresholds when the industry will transition between these harvesting systems, or even if the systems as described here will be deployed, must be speculation. Depending on market conditions, as-experienced shelf-life, political conditions, regulatory conditions, advances in sawmilling technology, and other factors, the current industry will continue its current practises and stand-selection criteria for some undetermined time period. However, some assumptions were required in order to complete this analysis, but care must be exercised in predicting the path that the industry will take in the future.

In summary, and for the purposes of cost calculations for this report, the choice of harvesting system is governed by the percentage of fuelwood in the stand. Conventional harvesting with comminution of the roadside residuals is indicated for stands with less than 50% fuelwood content, a satellite yard would be used for stands between 50% and 95% fuelwood, and onsite comminution would be used for stands with more than 95% fuelwood.

### 3.2.4 Shelf-life estimates

As stated previously, the primary objective for this project was to determine harvesting and transportation costs, both for the individual harvesting systems and as an overall average from an example area. The harvesting system is determined by the form of the feedstock which is in turn influenced by the shelf-life of the dead pine. Some assumptions about shelf-life had to be made in order to complete the cost analysis, and it is expected that revisions to shelf-life estimates will be necessary as new information becomes available. Changes to shelf-life estimates will affect the volume estimates for the study area, the distribution of the harvesting systems within the study area, and the weighted cost of all harvesting, but will not affect the estimated harvesting costs for the individual systems.

Using the principles described by Eng *et al* (2005), FERIC created shelf-life models in which the pine volume deteriorated from sawlogs to fuelwood to non-recoverable volume at a rate that depends on the biogeoclimatic zone and subzone (Appendix 1). In principle, the pine in wet subzones deteriorates faster than in dry subzones; the various subzones were grouped into three shelf-life classes (short, medium, and long time periods, based on subzone classification) to calculate the shelf-life of pine sawlogs and fuelwood (Table 6, Appendix 2). For the case study analysis, it was assumed that 100% mortality had already occurred at the time of analysis, and that deterioration of all pine would commence immediately. It was further assumed that the pine would deteriorate from sawlog to fuelwood until 95% of the pine volume was suitable only for fuelwood. The stand would remain at the 95% fuelwood composition for a period of time, and then it would deteriorate until all the fuelwood had deteriorated. The model assumes that a minimum 5% of the pine volume will always be available as sawlogs.
Volumes and costs in subsequent analyses were calculated at 5, 10, 15, and 20 years past mortality (YPM). This model assumes that 100% of the pine volume will be recoverable as sawlogs or fuelwood during the early stages of degradation (e.g., Short class at 5 YPM), but that less than 100% of the pine volume will be recoverable during later stages (e.g., Long class at 20 YPM). The shortfall represents the volume that has degraded beyond the point where any commercial product can be made.

Table 6: Pine shelf-life: fuelwood and sawlog content in three classes based on biogeoclimatic subzone at 5, 10, 15, and 20 years past mortality.

<table>
<thead>
<tr>
<th>Years Past Mortality</th>
<th>Fuelwood (%)</th>
<th>Sawlog (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>95</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note the connection between the values used in the shelf-life model and the thresholds for the different harvesting systems. The shelf-life model generates fuelwood to a maximum of 95% of the pine volume, and the full-tree chipping harvesting system is implemented at 95% fuelwood content. If different values were used for these thresholds, the volume calculated for the study area would be impacted significantly.

3.2.5 Case-study area volumes

Using the fuelwood volumes as generated by the shelf-life model and the definition of the stand types that are suitable for the various harvesting systems, the volume of fuelwood and sawlogs that could be available from the case study area was calculated. The merchantable volume within the potential fuelwood harvest area was calculated using a 12.5 cm top diameter merchantability standard (Table 7) from stands with a minimum volume of 75 m³/ha (at the specified YPM) and a minimum age of 60 (current age at time of analysis). Volume was tallied as pine fuelwood and total sawlogs (i.e., live-pine sawlogs plus other species) at 5, 10, 15, and 20 YPM. The volume was further classified by the stand composition: mixed species (30% < pine < 90%) and pure pine (≥90% pine).

---

2 Wet sites have shorter shelf life than moist and dry sites. Warm sites have shorter shelf life than cool and cold sites. The short, medium, and long classes are consolidations of various biogeoclimatic subzones (Appendix 1).
Table 7: Volumes of pine fuelwood and sawlog from different harvesting systems at various years past mortality.

<table>
<thead>
<tr>
<th>YPM</th>
<th>Roadside Residuals</th>
<th>Pine Fuelwood Satellite Yard</th>
<th>Full-tree chip</th>
<th>Area (ha)</th>
<th>Total Sawlog Satellite Yard</th>
<th>Full-tree chip</th>
<th>Roadside Residuals Satellite Yard</th>
<th>Full-tree chip</th>
</tr>
</thead>
<tbody>
<tr>
<td>From mixed stands (30% &lt; pine &lt; 90%)</td>
<td>5</td>
<td>7 059 785</td>
<td>9 622 680</td>
<td>17 796 881</td>
<td>6 963 130</td>
<td>102 281</td>
<td>64 527</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>7 492 859</td>
<td>15 996 746</td>
<td>10 461 755</td>
<td>7 465 687</td>
<td>74 702</td>
<td>92 095</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2 186 513</td>
<td>9 555 872</td>
<td>9 284 223</td>
<td>3 747 976</td>
<td>83 125</td>
<td>59 435</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>648 323</td>
<td>7 931 340</td>
<td>7 990 697</td>
<td>3 703 562</td>
<td>63 346</td>
<td>57 528</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From pure pine stands (&gt;=90% pine)</td>
<td>5</td>
<td>11 878 626</td>
<td>30 265 833</td>
<td>28 963 662</td>
<td>11 802 673</td>
<td>202 094</td>
<td>181 140</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>42 473 329</td>
<td>19 612 862</td>
<td>19 778 002</td>
<td>1 103 159</td>
<td>286 898</td>
<td>96 093</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>256 027</td>
<td>12 645 082</td>
<td>409 616</td>
<td>1 913 405</td>
<td>1 312 175</td>
<td>64 624</td>
<td>137 444</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>10 305 734</td>
<td>20 448 261</td>
<td>1 140</td>
<td>1 867 626</td>
<td>1 288 623</td>
<td>15</td>
<td>61 567</td>
<td>126 521</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>18 938 411</td>
<td>39 888 513</td>
<td>46 760 543</td>
<td>18 765 803</td>
<td>304 375</td>
<td>245 667</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>7 492 859</td>
<td>58 470 075</td>
<td>10 461 755</td>
<td>27 243 689</td>
<td>1 030 159</td>
<td>378 993</td>
<td>96 093</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2 442 540</td>
<td>22 200 954</td>
<td>9 693 839</td>
<td>1 312 175</td>
<td>91 142</td>
<td>124 059</td>
<td>137 444</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>648 323</td>
<td>18 237 074</td>
<td>7 991 837</td>
<td>5 571 188</td>
<td>63 361</td>
<td>119 095</td>
<td>126 521</td>
<td></td>
</tr>
</tbody>
</table>

The volume calculations in Table 7 do not include growth of the non-pine or live-pine components in the stands, nor do they include depletions from harvesting. For example, the volume calculations at 20 YPM do not account for the sawlog growth that will occur or volume that will be harvested between 0 and 20 YPM. Since the volume that will be harvested from the study area depends on many factors that are outside the scope of this project, it was decided not to account for either growth or depletion. Any potential power plant development, whether for the study area or elsewhere, must include a more rigorous fibre-supply analysis than was done for this costing analysis.

At 5 YPM, there will be about 7.0 million m$^3$ of fuelwood that could be available as roadside residual from mixed stands that are suitable for conventional logging operations (i.e., less than 50% fuelwood content). In order to harvest the 7.0 million m$^3$ of fuelwood, an accompanying volume of 17.8 million m$^3$ of sawlogs would need to be harvested. Also at 5 YPM, the pure pine stands could generate approximately 11.9 million m$^3$ of roadside residuals, but would require 28.9 million m$^3$ of sawlogs to be harvested to achieve that volume.

Mixed stands that are suitable for harvesting via satellite yards (i.e., more than 50% fuelwood content) could generate about 9.6 million m$^3$ of fuelwood at 5 YPM, plus an accompanying 7.0 million m$^3$ of sawlogs. Pure pine stands could generate 30.2 million m$^3$ of fuelwood, while requiring 11.8 million m$^3$ of sawlogs to be harvested.

These volumes exceed the allowable cut for the entire Quesnel TSA and, depending on the cut allocated to the study area and the distribution of cut within various stand types, significantly less total volume would be expected to be harvested. However, these volume calculations are useful to illustrate the proportion of fuelwood to sawlog volume that could be expected when harvesting in these stands.
In pure pine stands, the volume from roadside residuals drops to zero at 10 YPM. This is because the dead pine will degrade until more than 50% of the stand is fuelwood, and very little non-pine component exists in the stand to generate sawlogs. This means that all the harvesting from pure pine stands should flow through satellite yards by 10 YPM; i.e., there is limited opportunity to harvest biomass from roadside residuals in pure pine stands. On the other hand, the volume of fuelwood generated as roadside residuals from mixed stands will remain high.

A simplification in the shelf-life model creates an apparent contradiction about roadside residuals from pure pine stands in Table 7: the volume drops between 5 YPM and 10 YPM, and then increases again by 15 YPM. To explain this apparent contradiction, recall that any stand with less than 50% of its total volume as fuelwood is classified for roadside residual. Depending on the site, a moderate percentage of pine is considered as fuelwood at 5 YPM, thus generating a roadside residual classification (the average fuelwood volume is less than 50% of the total stand volume). In other stands on other sites, the aggregate fuelwood percentage is greater than 50%, and the stand receives a satellite yard classification. By 10 YPM, almost all of the pine has degraded to fuelwood, thus generating a satellite yard classification (fuelwood comprises more than 50% of the stand volume). At 15 YPM, the pine on some sites has deteriorated beyond fuelwood to a point where it contributes zero volume to the stand, thus the total stand volume has also been reduced. At this point, the live pine and other species comprise more than 50% of the reduced stand volume, thus causing the stand to revert to a roadside residual classification. By 20 YPM the total stand volume has been reduced to less than 75 m³/ha and the stand is eliminated from the analysis.

Based on the 95% fuelwood threshold and the FERIC’s shelf-life model, full-tree-chip stands are non-existent at 5 YPM, but thereafter comprise a significant component of the volume. Note that only pure pine stands are designated for full-tree chipping; any amount of non-pine volume in the stand is sufficient to classify the whole stand for the satellite yard or roadside residual system. By 20 YPM, the full-tree chipping component comprises about 20.4 million m³, or about 40% of the total volume of 54.1 million m³.

### 3.3 Costs

As mentioned, the choice of harvesting system will depend significantly on the ratio of sawlogs to fuelwood in each stand. For stands with less than 50% fuelwood, conventional harvesting with subsequent recovery of the roadside residuals is appropriate. For stands with more than 50% fuelwood content, a harvesting system that involves a satellite yard is indicated. Stands with more than 95% fuelwood should be harvested with full-tree chipping at the cutblock. Each system requires a different complement of equipment (Appendix 3) as described next.

As a by-product of conventional harvesting, residual tops, butts, and limbs are left in piles approximately 10-13 m from the road. In the roadside residuals system, they are moved closer to the road using a hydraulic loader, then chipped directly into a semi-trailer chip van using a mobile chipper situated on the road. Costs for falling, skidding, and processing are excluded from the fuelwood costs because they are allocated to the conventional harvesting. In the satellite systems, costs for part of the falling, skidding, and loading are allocated to the fuelwood depending on its relative volume in the stand. Trees are hauled to a satellite yard where they are separated into streams of sawlogs and fuelwood. Sawlogs are processed using a pull-through delimer and saw, while fuelwood is chipped into B-train chip vans. For the “remote” scenario, trees are hauled full-length using off-highway trucks to a satellite yard situated near the cutblock. For the “in-town” scenario, trees are delimbed and topped before being hauled on highway log trucks to a satellite yard situated near the final destination. In the full-tree chipping system, 100% of
the stand volume, including any incidental green trees, is chipped on-site into semi-trailer chip vans. All the direct costs, including falling and skidding are allocated to the fuelwood.

Direct costs for these systems exclude the costs of road development, layout, administration, silviculture, or other overhead costs that occur during all timber-harvesting operation. Costs were calculated using FERIC’s standard costing methods (Appendix 4).

Note that the calculated costs do not represent real-world contract costs because they omit contractor profit, supervision, and transportation. Using the same productivities, machine costs, and methodology as described for the chipping systems, FERIC calculated the costs for conventional harvesting operations under similar conditions to provide a comparison with actual costs. In general, the model's conventional harvesting costs are about 15% less than average, as-experienced costs from similar operations. It is assumed that the same proportion would be true for the chipping costs; real-world costs would be about 15% higher than the calculated costs.

### 3.3.1 Roadside residuals

In roadside logging systems, the phases are separated from one another so that delays in one phase have little impact on the other phases, thus helping to reduce costs. The logging industry is unlikely to abandon roadside systems because of this major benefit, thus the harvesting of residuals must exist within the conditions created by roadside logging.

Transporting the roadside residuals to a central site for comminution is not economically feasible because of their low bulk density. MacDonald (2006) found that the actual payload of unprocessed roadside residuals loaded into a semi-trailer truck was only about 10% of its capacity because of low bulk density. On-site comminution of the residuals is required to increase the bulk density and reduce the trucking costs.

The residual piles from conventional harvesting operations have two characteristics of particular importance in the choice of comminution equipment: the residual piles are situated between 10-13 m from the centreline of the road and they are distributed along the full length of the road. These characteristics imply that the fuelwood harvesting system must be highly mobile (i.e., be able to move quickly between piles) and be able to retrieve the residuals over a distance of about 15 m. Most typical mobile comminution machines of sufficient size to handle the roadside residuals would be impractical to use because they require significant moving and setup time. Furthermore, many of the roads had steep banks or deep ditches that would prohibit most machines from leaving the road (Figure 8).
Figure 8: Roadside residuals may be situated across a ditch and away from the road.

When operating from a stationary location, it is common for comminution machines to load the trucks from the side, but this arrangement will not work on narrow logging roads unless the comminution machine can leave the road. As already mentioned, leaving the road may not be feasible in many sites because of steep terrain or ditches. A more practical arrangement is for the comminution machine and the truck to work in tandem on the road, with the truck being loaded from the end. Grinders are best suited for loading from the side because they discharge the feedstock at low velocity. Chippers discharge the feedstock at high velocity, and can load a van completely from the end, and are therefore more appropriate to use with this tandem arrangement.

Most chippers discharge the chips at an angle to their length, thus making it awkward or time-consuming to position the chipper and truck in tandem on a narrow road. Several manufacturers produce a track-mounted, mobile chipper with a straight-through processing path and rear-discharge, such as shown in Figure 9. This class of machine is a good candidate for processing the roadside residuals.

Figure 9: Track-mounted mobile chipper with integral grapple and straight-through processing path.

One drawback of this type of machine is that the integral grapple can only reach material that is piled close to the road, so a second machine would be required to reach the feedstock from the existing piles. A small excavator could easily move the material within reach of a chipper situated on the road. The
excavator could work ahead of or in conjunction with the chipper. FERIC has not observed this class of machine operating in roadside residuals, so the productivity information was adapted from the manufactures specifications and operational results from similar-sized machines in comparable conditions. The critical factor to achieve high productivity and the lowest costs will be to maintain a high utilization level. FERIC calculated the costs by assuming that the density of the roadside residuals will have a significant influence on utilization – widely scattered residual piles will require more moving time thus reducing the utilization. FERIC calculated costs for forwarding the roadside residuals with an excavator, then comminuting and loading with the mobile chipper using three values of residual residuals density (Table 8). An operational trial should be conducted to verify the productivity rates.

**Table 8: Productivity and cost for chipping roadside residuals.**

<table>
<thead>
<tr>
<th>Roadside residual loading</th>
<th>Estimated Chipping Productivity (ODt/PMH)</th>
<th>Chipping Cost ($/ODt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>20</td>
<td>21.56</td>
</tr>
<tr>
<td>Medium</td>
<td>25</td>
<td>17.25</td>
</tr>
<tr>
<td>Heavy</td>
<td>30</td>
<td>14.38</td>
</tr>
</tbody>
</table>

The loading arrangement and the requirement to work on steep, low-class logging roads preclude using B-train chip trucks with this system; semi-trailer trucks are more appropriate. While semi-trailer trucks are less economical for long hauls because of their smaller payload, their mobility will be advantageous, especially on steep logging roads when travelling empty. Cost calculations were based on 13.7 m (45-ft) chip vans with a payload of 13 ODt of chips.

Note that costs do not include any allowance for falling, skidding, or processing. It is assumed that the costs for these phases are borne by the conventional harvesting operations.

### 3.3.2 Satellite operations

At some point, as the ratio of fuelwood to sawlog in the stand increases, FERIC believes that the forest companies will find that conventional operations are no longer economically viable. At that point, which FERIC has assumed to be 50% fuelwood content, the focus will shift to extracting the fuelwood and producing sawlogs as a by-product. While it may be feasible to conduct such operations at roadside, the increasing amount of fuelwood will make such operations difficult and FERIC believes that efficiency will be gained by moving to a satellite yard. There are two considerations: 1) the space occupied by the large volume of residual material will make it awkward to work from roadside, and 2) the high production rate of the comminution equipment will require more volume than can be supported by a single logging operation. Moving the comminution to a satellite yard allows one machine to service several logging operations.

Two options exist for the location of the satellite yard, each with their own advantages and disadvantages. If the yard is located within a short distance of the cutblocks (“remote satellite yard”), then the stems can be hauled using off-highway log trucks without being processed at the cutblock. On the other hand, if the satellite yard is located near the final destination (“in-town satellite yard”), then the logs must be hauled on the highway, and will require deliming and topping before they can be hauled. Only a minimal amount of processing would be done in the cutblocks in order to maximize the fuelwood volume, but such processing still represents an extra cost that is not required for the remote satellite yard. While the
remote satellite yard system eliminates this extra handling, it also requires that several logging contractors operate in a small geographic location to supply a single satellite yard. This would require additional planning and coordination of harvesting activities. The in-town system would use one permanent yard, instead of several temporary yards. The operating costs for both options will be calculated.

For both satellite system, the stems would be unloaded from the trucks using a wheel loader and taken to a machine for chipping and processing. One appropriate machine for this purpose is the so-called trailer loader (Figure 10), which is rare in western Canada but common in southeast USA. Trailer loaders have a delimer/topping saw built onto the chassis of a hydraulic loader so they can process sawlogs as well as feed the chipper. An alternative to this specialized machine would be a conventional hydraulic loader paired with a pull-through delimer (Figure 11). With pull-through delimiters, the stems are pulled through the delimming knives using the loader, and the built-in hydraulic chainsaw is used to cut them to length. Both trailer loaders and pull-through delimiters use fixed-length stops to measure the logs to the correct length.

Figure 10: Trailer loaders include an integral delimer/topping saw for processing sawlogs. The loader also feeds the chipper.

Figure 11: Pull-through delimer and cut-off saw can be paired with conventional loader for processing sawlogs.
Trucks can be loaded from the side in a satellite yard, thus either chippers or grinders can be used although FERIC based the costs on chippers for consistency with the previous calculations. The fuelwood is hauled by B-train trucks, and logs are loaded onto conventional log trucks using the wheel loader.

The costs include falling, skidding, and loading because satellite operations are assumed to take place only after conventional harvesting methods have proven to be uneconomic; no other operation exists to provide the falling, skidding, and loading for free to the fuelwood operation as it did with the roadside residuals. In FERIC’s costing model, these costs are allocated between the sawlogs and fuelwood in proportion to their volume; volume distributions from the study area were used to prorate the costs. The costs for the in-cutblock processing for the in-town satellite yard are included and prorated between the fuelwood and sawlogs. The hauling cost from the cutblocks to the satellite yard is included, although hauling to the in-town satellite yard is excluded from the direct harvesting costs (hauling from the satellite yard to town is accounted separately in the hauling phase).

Costs in FERIC’s model for all phases except skidding are expressed as a function of tree size (Appendix 5). Costs were calculated for average tree sizes of 0.2, 0.3, and 0.4 m$^3$/tree, an appropriate size range to use for pine trees in the Quesnel area. Skidding costs were based on a simple model that uses skidding distance as its only independent variable, and uses average values for other variables such as slope, soil strength, and terrain condition. All costs shown here were calculated for 200 m average skidding distance. The cost summaries shown in Table 9 represent typical ranges of values; see Appendix 5 for the actual outputs from the cost model.

**Table 9: Summarized production costs through remote and in-town satellite yards (excluding haul costs).**

<table>
<thead>
<tr>
<th>Average tree size and stand type</th>
<th>Remote Satellite Yard</th>
<th>In-town Satellite Yard</th>
<th>Conventional Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chips ($/ODt)</td>
<td>Logs ($/m³)</td>
<td>Chips ($/ODt)</td>
</tr>
<tr>
<td>0.2 m$^3$/tree</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed stand</td>
<td>35-37</td>
<td>15-17</td>
<td>52-54</td>
</tr>
<tr>
<td>Pure pine</td>
<td>38-41</td>
<td>17-18</td>
<td>54-57</td>
</tr>
<tr>
<td>0.3 m$^3$/tree</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed stand</td>
<td>29-30</td>
<td>13-14</td>
<td>42-43</td>
</tr>
<tr>
<td>Pure pine</td>
<td>31-33</td>
<td>14-15</td>
<td>44-47</td>
</tr>
<tr>
<td>0.4 m$^3$/tree</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed stand</td>
<td>26-27</td>
<td>11-12</td>
<td>36-38</td>
</tr>
<tr>
<td>Pure pine</td>
<td>28-29</td>
<td>12-13</td>
<td>38-39</td>
</tr>
</tbody>
</table>

Costs for the remote satellite yard were less than for the in-town satellite yard because the in-town system requires additional processing to make the logs suitable for on-highway hauling. Logs produced through the satellite yard are more expensive than logs produced via conventional harvesting, again reflecting the additional processing that is required. The difference of cost between the mixed stands and the pure pine
stands is a reflection of the different proportion of sawlogs and fuelwood in the different stand types. In principle, the model uses the same productivity and machine cost values for both stand types.

### 3.3.3 Full-tree chipping

As the proportion of sawlog in the stand is reduced to nearly zero, a breakeven point exists where the extra cost required to sort the sawlogs from the fuelwood exceeds the additional value of the sawlogs. Beyond the breakeven point, stands should be harvested by full-tree chipping all of the volume in each cutblock. FERIC assumed the threshold level to be 95% or more fuelwood in the stand. Volume analysis for the study area showed that no stands were in this category at 5 YPM, but that the volume increased significantly until it comprised about 40% of the volume 20 YPM. According to the assumptions in the shelf-life model and the harvest-system classification, any non-pine volume in a stand will preclude it from being classified for full-tree chipping, and full-tree chipping will be applicable only to pure pine stands. Note that the volume of full-tree chipping stands is dependent entirely on the values selected for the shelf-life model and the harvest-system thresholds. Using values other than 95% of fuelwood for these parameters would result in much different volume results.

Full-tree chipping operations may be conducted at roadside, using equipment similar to the mobile chipper proposed for processing the roadside residuals, or may be done in a landing using a less-mobile chipper. Each equipment type has advantages and disadvantages. Roadside operations allow for separation of the phases, which may improve utilization for the skidders or chipper, but also requires that the logs be decked within easy reach of the chipper (i.e., deep ditches may hinder operations). Furthermore, an integral lightweight loader on the chipper may have difficulty extracting trees from high roadside piles. An auxiliary loader would alleviate these problems, but would also increase costs. Another way to address these issues is to conduct the chipping operations in a landing.

Costs for chipping were calculated using an integrated loader/chipper as in the roadside residual scenario, or a separate chipper and loader similar to Figure 12. Costs will be about equal for either system. Chipping costs were calculated using higher productivity values than for either of the other systems because no sorting or log-manufacturing will be required.

![Image of full-tree chipper](image)

**Figure 12: Full tree chipper situated on a landing, and loading directly into chip van.**

Costs for the falling and skidding phases in the full-tree chipping system were calculated using the same productivities as those phases in the satellite systems. In the satellite systems, a portion of the costs for
these phases were allocated to the sawlogs that were harvested, but the fuelwood must support the full costs of these phases because there are no sawlogs produced from the system. Also, the costs exclude layout, road development, silviculture, and other overhead activities that would be supported by the sawlogs harvested from the other systems. With full-tree chipping, the entire cost of these activities must be borne by the fuelwood.

As with the satellite systems, costs vary depending on the tree size (Table 10). Since other species would contribute green sawlogs, the costs for this system are applicable only to pure pine stands.

Table 10: Falling, skidding, chipping, and loading costs for full-tree chipping.

<table>
<thead>
<tr>
<th>Average Tree Size (m³/tree)</th>
<th>Chips ($/ODt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>27.11</td>
</tr>
<tr>
<td>0.3</td>
<td>23.49</td>
</tr>
<tr>
<td>0.4</td>
<td>20.91</td>
</tr>
</tbody>
</table>

3.3.4 Hauling

Costs were based on 13.0 and 21.5 ODt payloads respectively for semi-trailer and B-train trucks. Below a certain moisture content (typically about 50% moisture content, wet basis), chip vans are limited by volume rather than by weight. Once a truck is into the volume-limited condition, the payload expressed in terms of ODt is constant for all values of the moisture content. The truck weight may change as the moisture changes, but the dry-wood-equivalent payload does not change. The average moisture content of the dead pine is assumed to be about 25%, which is far below the threshold where loads become limited by volume. The average load size for off-highway log haul from the cutblocks to the remote satellite yard was set at 80 m³, as compared to the 60 m³ that was used for on-highway log trucks.

Loading times were calculated as a function of the chipper productivity, and averaged about 0.4-0.5 h for the semi-trailer trucks and 0.7-0.8 h for the B-train trucks. Unloading times and delay times were added to each trip. FERIC assumed that remote satellite yards will be located on all-weather roads, and will be accessible to B-train trucks.

Figure 13 shows the hauling cost for chips hauled using two truck configurations and logs using a conventional log truck. The B-train trucks will be used for remote satellite operations, while the semi-trailer trucks are suited for the roadside residuals and full-tree chipping. These costs are based on the travel speeds from Table 3 and the distribution of road classes from Table 11.
Table 11: Road class distribution for various total haul distances.

<table>
<thead>
<tr>
<th>Haul distance (km one way)</th>
<th>Highway</th>
<th>Mainline</th>
<th>Branch</th>
<th>Bush</th>
<th>Total haul distance</th>
<th>Two-way haul time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>10</td>
<td>25</td>
<td>5</td>
<td>50</td>
<td>2.19</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>20</td>
<td>25</td>
<td>5</td>
<td>75</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>30</td>
<td>25</td>
<td>5</td>
<td>100</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>40</td>
<td>40</td>
<td>5</td>
<td>125</td>
<td>4.24</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>40</td>
<td>40</td>
<td>5</td>
<td>150</td>
<td>5.24</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>40</td>
<td>40</td>
<td>5</td>
<td>175</td>
<td>6.07</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>40</td>
<td>40</td>
<td>5</td>
<td>200</td>
<td>6.90</td>
</tr>
</tbody>
</table>

Figure 13: Estimated trucking costs for biomass and logs.

For the remote satellite operation, FERIC assumed that the round-trip, off-highway haul time from the cutblocks to the satellite yard was 0.75 h, and that the haul time from the satellite yard to town would be reduced by the same amount. Costs for the off-highway portion of the haul were included in the processing costs.

For the in-town satellite operation, the round-trip rehaul time from the yard to the mill for both logs and chips was estimated as 0.6 h per trip. Logs were assumed to be hauled by a log truck with 50 m³ payload, and the chips were hauled with a semi-trailer van with a payload of 13 ODt.
3.3.5 Comminution and hauling costs

Using comminution costs and hauling costs discussed previously, FERIC estimated the total direct cost for harvesting, comminuting, and transporting the biomass over typical haul distances. The costs in Figure 14 were for 10 YPM, medium density of roadside residuals, mixed stands, and 0.3 m$^3$/tree average tree size. “Residuals” is for biomass generated from the roadside residuals after conventional harvesting, “Remote” is for whole trees hauled via off-highway truck to a remote satellite yard for processing, “In-town” is for delimbed and topped trees hauled via highway truck to an in-town satellite yard, and “Full-tree” is for on-site comminution of 100% of the stand.

![Processing and Hauling Cost](image)

**Figure 14:** Processing and hauling costs under average conditions for four methods of producing biomass.

Changing the model parameters will change the relative costs of the different systems. Heavier roadside residual density will reduce the cost of the residuals, but will have no effect on the two satellite yard scenarios. For light residual density, the costs for roadside residual and full-tree chipping are almost identical. Conversely, running the model with a larger average tree size will reduce the cost for the two satellite systems and the full-tree chipping, but not affect the cost of roadside residuals.

These direct costs omit several phases that would be required for a complete cost of delivered fibre, but are outside the scope of the project. They are covered in the discussion area.

3.3.6 Case-study area summary

Using the average hauling distance from the various Land Units in the case-study area, FERIC calculated the overall cost of comminuting and hauling the biomass (Appendix 6). As covered in the discussion section, additional phases must be included to estimate the total cost. The different costs for roadside residuals for the different values of YPM result from different average hauling distances; the actual processing costs are the same for each time period.
The cost for roadside residuals averaged about $45-54/ODt for all processing and hauling, depending on the concentration of residuals at the roadside. The costs for fuelwood depend on the average tree size, the stand type, the average haul distance as determined by the YPM, the satellite yard location, and the amount of sawlog in the stand. Costs from pure pine stands with 0.3 m³ average tree size and processed through a remote satellite yard are estimated at $63-65/ODt. Costs with an in-town yard would be slightly higher, at about $69-70/ODt. The satellite yard operations would also generate sawlogs, although their costs would be higher than sawlogs produced from conventional harvesting operations. Costs for falling, skidding, and hauling to the satellite yard are prorated between the sawlogs and fuelwood depending on their relative concentration in the stand, so the costs for the two products will vary depending on their relative proportions. Table 12 shows the fuelwood percentage at various times past mortality. The values in Table 12 apply only to stands that are designated for satellite operations, i.e., between 50% and 95% fuelwood as determined by the shelf-life model. Chip costs from full-tree chipping in pure pine stands with 0.3 m³ average tree size were $53-56/ODt.

Table 12: Average fuelwood proportion from stands designated for satellite operations.

<table>
<thead>
<tr>
<th>Percent of stand that is fuelwood</th>
<th>Stand Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>YPM</td>
<td>Mixed</td>
</tr>
<tr>
<td>5</td>
<td>60%</td>
</tr>
<tr>
<td>10</td>
<td>65%</td>
</tr>
<tr>
<td>15</td>
<td>68%</td>
</tr>
<tr>
<td>20</td>
<td>74%</td>
</tr>
</tbody>
</table>

The average haul distance used for each time period was the weighted average of the haul distance from each of the included Land Units in the case-study area. The average round-trip haul time varied between 4.1 and 4.5 h during each of the YPM periods. Using the values from Table 11, these times correspond to a one-way haul distance of about 125 km.

4 Discussion

The lowest-cost source for fuelwood is from the roadside residuals generated by conventional harvesting operations. The volume of roadside residuals is related directly to the harvest level of sawlogs, which is determined by the allowable annual cut and the licensees’ cut allocation within the TSA. In response to the beetle outbreak, the historic AAC of 2.3 million m³ in the Quesnel TSA was revised to 3.2 million m³ on a temporary basis in 2001 (Ministry of Forests 2001), then again to 5.3 million m³. Tree Farm Licence 52, which is also near Quesnel, has an allowable cut of 0.5 million m³ (Ministry of Forests 1996), therefore, the current AAC in the Quesnel vicinity is 5.8 million m³.

The roadside residual volume is also related to the utilization standard used by the company. The target top diameter for some cutblocks where FERIC conducted measurements was 5 cm; about 15%-20% (30 ODt/ha) of the original biomass of these cutblocks remained as roadside residuals. The roadside residuals in other cutblocks where the target top diameter was more than 10 cm comprised 40-45% (90 ODt/ha) of the original stand biomass. For these calculations, the residual percentage equals the residual volume divided by the sum of residual volume plus harvested volume. Harvested volume equals the merchantable inventory volume plus 5%.
Using an average of 60 ODt/ha, 6700 ha would need to be harvested each year to generate 300,000 to 400,000 ODt of roadside residuals, the approximate volume of feedstock required to supply a 60 MW facility (McCloy 2006). At an average merchantable volume of 250 m³/ha, this area represents an annual timber harvest of about 1.7 million m³, less than 30% of the current AAC in the Quesnel vicinity, and about 60% of the historic AAC.

Although it appears that sufficient area is harvested each year near Quesnel to generate 400,000 ODt of roadside residuals, some additional factors must be considered:

- There is no assurance that the allowable annual cut will remain at its current level; the AAC may be reduced below its historic level after the salvage operations are completed. Some scenarios of future cut level indicate that the AAC may be reduced to 0.4 - 1.1 million m³ (COFI 2006) after 20 years.
- If the licencees harvest from stands where pine is not the leading species such as in many stands east of Quesnel that are not pine-leading stands, the volume of roadside residuals may be less than indicated. FERIC measured residual volumes only from areas west of Quesnel, where the highest concentrations of pine occur.
- The biogeoclimatic zones east of Quesnel are wetter than in the west, which will likely result in shorter shelf-life for sawlogs and fuelwood.

This study considered two stand types that generate roadside residuals from harvesting sawlogs: mixed-species stands and pure pine stands up to 5 years past mortality. After 5 years past mortality, most of the volume of pure pine stands is forecast to degrade into fuelwood, and the sawlog content will decrease significantly. Without sufficient sawlog volume to justify the expense of layout, road development, silviculture, and other overhead costs, the licencees are unlikely to target these very-high-fuelwood stands for harvesting. FERIC assumed that stands containing more than 50% fuelwood will be avoided for harvesting sawlogs, and should no longer be considered as sources for roadside residuals. A more appropriate system for such stands would be to haul the logs to a satellite yard, where the fuelwood could be comminuted and the sawlogs sorted and processed more efficiently. Combining the production from several operations at a single satellite yard would allow for higher utilization of the comminution equipment, and reduce costs. A high level of planning and coordination would be required to ensure adequate volume from several operations would flow through the satellite yard to make it economically viable.

On-site full-tree chipping is the most appropriate system for stands with very high fuelwood content; FERIC used 95% fuelwood content as the threshold for full-tree chipping. No stands were classified for full-tree chipping at 5 YPM, but full-tree chipping stands comprised 40% of the volume by 20 YPM. Only pure pine stands were classified for full-tree chipping; any amount of non-pine volume caused the model to classify mixed stands as suitable for satellite yard operations. The direct costs for this system are about equal to the direct costs for roadside residuals, but some costs were omitted from the calculations, and the two costs are not directly comparable.

The costs that were omitted from the satellite and full-tree chipping operations include planning, layout, road development, road maintenance, silviculture, and overhead. These costs do not apply to the roadside residual scenario because they are included in the sawlog harvesting that occurs prior to salvaging. FERIC estimated that the additional costs are about $30/ODt for the satellite operations and about $41/ODt for the full-tree chipping scenario (Appendix 7). Stumpage is not included in any of the cost estimates.
More stands in the study area are suited to satellite operations than to either roadside residuals or full-tree chipping. However, satellite operations also have the highest cost of the three systems because they require the most equipment and handling.

The choice of harvesting system will affect the constant flow of feedstock to the power plant because poor hauling conditions will curtail in-block operations for several months each year. Storage will be required to ensure year-round flow, and the different systems have different suitability for storage. Satellite yards provide the best opportunity for storage because the biomass could be stored as logs. The roadside residual and full-tree chipping systems are poorly suited for storage because such storage would occur after comminution, and the comminuted material would deteriorate from inclement weather. Satellite yards would need to be constructed near all-weather roads to allow for year-round hauling.

Harvesting costs for the satellite and full-tree chipping systems were based on clearcut operations, although it may be feasible to harvest the dead pine in some stands and leave the live understory for future growth. FERIC is conducting trials to document the additional costs associated with such harvesting systems, but no results are available yet. Sauder and MacIsaac (2004) found that falling and skidding costs increased by 20-30% when using conventional equipment to harvest the overstorey and protect the understory in boreal mixedwood stands. Similar increases may be expected in the pine stands.

FERIC’s cost calculations are intended for comparison of two or more harvesting systems, and are not meant to represent contractors’ costs. In particular, they omit items such as supervision, transportation, overhead, and contractor’s profit. When compared to industry averages, the costs generated by FERIC’s model were about 15% low. A spreadsheet with the cost model is available upon request to FERIC member companies.

5 Conclusions

FERIC conducted a study to estimate the costs of harvesting, comminuting, and transporting beetle-killed pine to supply feedstock for a potential power plant. Three harvesting systems were examined, as determined by the ratio of fuelwood volume to sawlog volume in the stand. Costs were developed for the generic harvesting systems, then applied to the Quesnel/Nazko corridor in central Interior of British Columbia as a case study.

The cost models were based on the assumption that the beetle-killed pine will deteriorate from sawlog quality to fuelwood quality, and then to non-commercial quality at a rate determined by each stand’s biogeoclimatic zone. Three shelf-life classes were used to predict the proportion of fuelwood and sawlogs in each stand as a function of years past mortality. The model assumed that a minimum of 5% of the pine volume would remain as sawlog at all times.

For stands with less than 50% fuelwood, costs were calculated using the existing roadside harvesting system, followed by a separate operation to comminute the roadside residuals into feedstock. The system comprised a log loader to move the residuals closer to the road, a mobile, track-mounted machine on the road to chip the residuals, and semi-trailer chip vans to haul the feedstock to the plant. FERIC calculated that the direct costs were $45-54/ODt.

For stands with 50%-95% fuelwood, the entire volume was processed through a satellite yard to facilitate sorting the sawlogs from the fuelwood. Two satellite scenarios were considered: in the “remote” system, whole trees were hauled via off-highway trucks to satellite yards situated near the cutblocks, while the “in-town” satellite scenario used a satellite yard situated near the power plant. Since this latter scenario
Involves hauling trees on public roads, they were assumed to be delimbed and topped before hauling, which increased the cost compared to the remote satellite scenario. Costs for both satellite systems were substantially higher than with the residual system, due largely to the falling and skidding costs that were included with these systems. For example, costs for trees from pure pine stands with an average tree size of 0.3 m³ and processed through a remote satellite yard, were estimated at $63-65/ODt. Costs for the in-town scenario were $69-70/ODt. The model prorated the cost for falling and skidding between the sawlogs and fuelwood depending on their relative volume in the stand; larger volumes of fuelwood caused the cost of fuelwood to increase and the cost of sawlogs to decrease by a corresponding amount.

On-site, full-tree chipping was used for stands with 95% fuelwood, at a cost of $53-56/ODt in stands with 0.3 m³ average tree size. Only stands comprising 100% pine can generate a full-tree chipping classification because of the way the shelf-life model was defined.

The direct cost does not provide a complete comparison because the latter two systems omit some costs that are covered by the existing licencee in the roadside residual system (e.g., road development and silviculture), and are assumed to be provided for free to the biomass operation. These costs are estimated to add $30-41/ODt onto the direct costs of the satellite and full-tree chipping systems.

Based on FERIC’s assumptions for shelf-life and harvest-system selection criteria, “pure” pine stands (i.e., with more than 90% pine content) will be a significant source of sawlogs, and thus of roadside residuals, until 5 YPM. Beyond that time, these stands will generate more than 50% fuelwood, and the volume would be more appropriately harvested through satellite yards (where sufficient sawlog volume exists to justify the expense of sorting) or by full-tree chipping (where the sawlog component is insignificant).

Based on FERIC’s assumptions for shelf-life and harvest-system selection criteria, mixed stands will be a significant source of sawlogs and fuelwood using the roadside residuals system for most of the analysis time period. By 20 YPM, the roadside residuals volume from mixed stands will be reduced significantly. The pure pine stands are impacted more quickly; roadside residuals from these stands are a significant source of fuelwood only until 5 YPM, after which point their volume is reduced to zero. At 10 YPM, the majority of volume from pure pine stands is suitable for satellite yard operations, but full-tree chipping comprises more volume at 15 and 20 YPM.

FERIC conducted measurements of the volume of roadside residuals that remain after conventional roadside harvesting. Depending on the utilization specifications for sawlogs, there was 22-145 ODt/ha of roadside residual, representing from about 15% to over 50% of the original stand biomass. There was an additional 8-30 ODt/ha of residuals dispersed across the cutblocks, but almost all of that volume was in pieces too small to be harvested with existing equipment. When compiled to more contemporary utilization standards, the dispersed residuals represented less than 2 ODt/ha, and were omitted from any further consideration.

6 Recommendations for further work

The volume and extent of the damage caused by the mountain pine beetle will cause changes to harvesting systems that are unprecedented in British Columbia. As such, the costs and productivities in this report are from the best available information, but they are adapted from other locations and conditions that may not be directly comparable. Operational trials should be undertaken to:
Verify the productivity of the mobile chipper while working in tandem with a log loader for forwarding the residuals to roadside. Trials should be undertaken on a variety of road conditions (e.g., road grade, sideslope, ditch configuration, etc.) and roadside residual pile arrangements (e.g., distribution along the length of the road, distance from road centreline, volume per pile, distribution of tops and butts within each pile, etc.).

Verify the gradability of semi-trailer chip vans on steep logging roads.

Verify the productivity of full-tree chippers and chipper/processor combinations.

Verify payloads of dry pine for off-highway log trucks and B-train and semi-trailer chip trucks operating from satellite chip yards.

In addition to these operational trials, further work is required to:

- Improve the characterization of the roadside residuals, especially as result of different utilization levels (e.g., bulk density of piles, volumes, piece size distribution, etc.).
- Verify the shelf-life characteristics for sawlogs and fuelwood.

7 Bibliography


Appendices

Appendix 1: Shelf-life class by biogeoclimatic zone and subzone.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Subzone</th>
<th>Subzone Description</th>
<th>Shelf Life Class</th>
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<td>unp</td>
<td>Undifferentiated and Parkland</td>
<td>Long</td>
</tr>
<tr>
<td>BG</td>
<td>xh</td>
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<td>Long</td>
</tr>
<tr>
<td>ESSF</td>
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<td>Long</td>
</tr>
<tr>
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<td>Long</td>
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Appendix 2: Pine shelf-life: fuelwood and sawlog content in three classes by biogeoclimatic subzone at various years past mortality.

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<th>Years Past Mortality</th>
<th>Fuelwood Content (%)</th>
<th>Sawlog Content (%)</th>
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<td>Medium</td>
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<td>0</td>
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<td>19</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
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Appendix 3:  Machines used in each chip-harvesting system.

Direct costs for these systems exclude the costs of road development, layout, administration, silviculture, or other overhead costs that occur during all timber-harvesting operation.

<table>
<thead>
<tr>
<th>Machine name</th>
<th>Roadside Residuals</th>
<th>Remote Satellite</th>
<th>In-town Satellite</th>
<th>Full-tree Chipping</th>
<th>Hourly cost</th>
<th>Productivity or Payload</th>
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<tbody>
<tr>
<td>Feller-buncher</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>155</td>
<td>50-70 m³/PMH</td>
</tr>
<tr>
<td>Grapple skidder</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>105</td>
<td>58-65 m³/PMH</td>
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<tr>
<td>Butt ‘n top loader</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>125</td>
<td>120-170 m³/PMH</td>
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<tr>
<td>Log loader</td>
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<td>X</td>
<td></td>
<td></td>
<td>115</td>
<td>limited by companion machine</td>
</tr>
<tr>
<td>Wheel loader (unloading)</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>105</td>
<td>250-320 m³/PMH</td>
</tr>
<tr>
<td>Wheel loader (loading)</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>105</td>
<td>110-160 m³/PMH</td>
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<tr>
<td>Dangle-head processor</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>130</td>
<td>27-45 m³/PMH</td>
</tr>
<tr>
<td>Chipper - no operator</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>130</td>
<td>20-30 ODt/PMH</td>
</tr>
<tr>
<td>CTR Delimber</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>25</td>
<td>limited by companion machine</td>
</tr>
</tbody>
</table>

As a by-product of conventional harvesting, residual tops, butts, and limbs are left in piles approximately 10-13 m from the road. In the roadside residuals system, residuals are moved closer to the road using a hydraulic loader, then chipped directly into a semi-trailer chip van using a mobile chipper situated on the road. Costs for falling, skidding, and processing are excluded from the fuelwood costs because they are allocated to the conventional harvesting.

In the satellite systems, costs for part of the falling, skidding, and loading are allocated to the fuelwood depending on its relative volume in the stand. Trees are hauled to a satellite yard where they are separated into streams of sawlogs and fuelwood. Sawlogs are processed using a pull-through delimber and saw, while fuelwood is chipped into B-train chip vans. For the “remote” scenario, trees are hauled full-length using off-highway trucks to a satellite yard situated near the cutblock.

For the “in-town” scenario, trees are delimbed and topped before being hauled on highway log trucks to a satellite yard situated near the final destination.

In the full-tree chipping system, 100% of the stand volume, including any incidental green trees, is chipped on-site into semi-trailer chip vans. All the direct costs, including falling and skidding are allocated to the fuelwood.

SMH: Scheduled machine hour
PMH: Productive machine hour
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Full-tree chipper &amp; log loader</td>
<td>X</td>
<td>250</td>
<td>25-35</td>
<td>ODt/PMH</td>
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<td>Mountain goat chipper</td>
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<td>230</td>
<td>20-30</td>
<td>ODt/PMH</td>
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<td>Off-highway truck</td>
<td>X</td>
<td>110</td>
<td>80</td>
<td>m³</td>
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<tr>
<td>On-highway log truck</td>
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<td>95</td>
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<td>m³</td>
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<tr>
<td>In-town rehaul</td>
<td>X</td>
<td>85</td>
<td>50</td>
<td>m³</td>
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<tr>
<td>B-train chip van (highway)</td>
<td>X</td>
<td>116</td>
<td>21.5</td>
<td>ODt</td>
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<tr>
<td>Semi-trailer chip van (bush)</td>
<td>X</td>
<td>95</td>
<td>13</td>
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### Appendix 4: Cost components for selected machines.

<table>
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<tr>
<th>Machine description</th>
<th>20-tonne Excavator/Loader</th>
<th>Wheel-mounted chipper</th>
<th>Pull-through delimber</th>
<th>Track-mounted mobile chipper</th>
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<tbody>
<tr>
<td>Make and model</td>
<td>Komatsu PC200</td>
<td>Trelan 23</td>
<td>CTR 426</td>
<td>Morbark 50/48 Mountain Goat</td>
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<tr>
<td>Total purchase price ($)</td>
<td>370 000</td>
<td>450 000</td>
<td>45 000</td>
<td>675 000</td>
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<tr>
<td>Expected life (h)</td>
<td>16 000</td>
<td>10 000</td>
<td>8 000</td>
<td>9 000</td>
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<td>Residual value, % of purchase (%)</td>
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<td>Labour wages ($/h)</td>
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<td>22.00</td>
<td>22.00</td>
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<td>Fuel consumption per PMH (l/h)</td>
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<td>75.0</td>
<td>15.0</td>
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<td>25</td>
<td>15</td>
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<td>Repair &amp; mtce ($/h)</td>
<td>21.00</td>
<td>25.00</td>
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<td>Annual repair and maintenance ($)</td>
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<td>15 000</td>
<td>20 000</td>
<td>20 000</td>
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<td>Hourly rate ($/SMH)</td>
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<th>Item</th>
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<td>Wage benefit loading (%)</td>
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<td>Utilization (%)</td>
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<td>Fuel cost ($/l)</td>
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### Appendix 5: Chip and log costs from stands harvested primarily for fuelwood (excluding haul costs).

<table>
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<tr>
<th>Stand Description and Years Past Mortality</th>
<th>Average tree size and stand type</th>
<th>Remote Satellite Yard</th>
<th>In-town Satellite Yard</th>
<th>Conventional Harvesting</th>
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<tr>
<td></td>
<td></td>
<td>Chips ($/ODt)</td>
<td>Logs ($/m³)</td>
<td>Chips ($/ODt)</td>
<td>Logs ($/m³)</td>
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<tr>
<td>0.2 m³/tree Mixed stand</td>
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<td>34.50</td>
<td>15.34</td>
<td>51.40</td>
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<td>37.44</td>
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<td>0.2 m³/tree Pure pine</td>
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<td>37.00</td>
<td>16.57</td>
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<td>41.20</td>
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<td>58.10</td>
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<td>0.3 m³/tree Mixed stand</td>
<td>5</td>
<td>28.82</td>
<td>12.73</td>
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<td>31.20</td>
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<td>0.3 m³/tree Pure pine</td>
<td>5</td>
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<td>13.42</td>
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</table>

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9 Haul cost from cutblock to remote satellite yard using off-highway log trucks is included.
### Appendix 6: Processing and hauling costs for the case study area west of Quesnel.

#### Fuelwood from Roadside Residuals

<table>
<thead>
<tr>
<th>Stand Description and Years Past Mortality</th>
<th>Mixed stand</th>
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<th>Medium Residual Loading</th>
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<td>56.41</td>
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#### Stands Harvested for Fuelwood

<table>
<thead>
<tr>
<th>Stand Description and Years Past Mortality</th>
<th>Remote Satellite Yard</th>
<th>In-town Satellite Yard</th>
<th>Conventional Harvesting</th>
<th>Full-tree chipping</th>
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<td>Logs ($/m³)</td>
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<td>0.2 m³/tree Pure pine</td>
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<td>0.3 m³ Mixed stand</td>
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<tr>
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</table>
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<tr>
<th>Stand Description and Years Past Mortality</th>
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<th>In-town Satellite Yard</th>
<th>Conventional Harvesting</th>
<th>Full-tree chipping</th>
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<tr>
<td></td>
<td>Chips ($/ODt)</td>
<td>Logs ($/m³)</td>
<td>Chips ($/ODt)</td>
<td>Logs ($/m³)</td>
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<tr>
<td>0.4 m³/tree Mixed stand</td>
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<td>0.4 m³/tree Pure pine</td>
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<td>52.32</td>
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<tr>
<td>0.4 m³/tree Pure pine</td>
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<td>59.93</td>
<td>22.23</td>
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<td>26.14</td>
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Appendix 7: Estimated costs for items not included with direct harvesting cost.

The BC Interior Appraisal Manual (Ministry of Forests 2004) recognizes costs for road management (maintenance), administration, and silviculture. FERIC used values of $1.75/m³, $9.00/m³, and $1200/ha respectively for these costs. Using conversion rates of 0.42 ODt/m³ and 250 m³/ha, the total of these costs is $37/ODt.

FERIC developed estimates of road development costs based on three road-construction classes and three classes of existing road density. Using map measurements from the case-study area, FERIC estimated that 45 km of mainline is required to service an area 60 km by 30 km. Within that area, FERIC estimated that 66% of the land base was merchantable, and that the mainline would be written off over 20% of the volume (to account for periodic reconstruction over its lifetime). The resulting amortization rate for mainlines at a construction cost of $100 000/km is $0.75/m³.

Estimated costs for branch roads were based on developing an area 18 km by 6 km with 10 km of branch road. If the road cost is amortized over one-third of the merchantable volume within that area, the branch road amortization cost is $0.33/m³ using a construction cost of $30 000/km.

Costs for on-block roads were estimated using a net developed area of 25 ha per km of road (250 m net skid width). On-block road costs are $1.28/m³ if on-block roads are estimated to cost $8 000/km for construction.

For each of the road-development classes, FERIC assumed a proportion of the three construction classes that would be required. In areas with more existing road development, some of the volume can be harvested from areas of leave strips between existing cutblocks. The resulting road-development costs are shown in Table 13.

Table 13: Estimated road development costs by existing road development class.

<table>
<thead>
<tr>
<th>Existing road development class</th>
<th>Amount of Construction Required (%)</th>
<th>Weighted Road Development Cost</th>
<th>Proportion of potential fuelwood harvest area</th>
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</thead>
</table>
| Sparse                         | Mainline: 100 Branch: 100 Spur: 100 | $2.36/ODt
| Partially-roaded               | Mainline: 10 Branch: 90 Spur: 100 | $1.52/ODt
| Dense                          | Mainline: 0 Branch: 33 Spur: 75  | $1.07/ODt

Approximately 44% of the land base within the case-study area is in the sparse road-density class (Table 5). To see how the distribution changed with time, the volume of fuelwood in the sparse road-development class was tallied and expressed as a percentage of the total fuelwood that is available for each of the time periods (Table 14).
Table 14: Percentage of fuelwood in the sparse road-development class at selected time periods.

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<th>Stand Type</th>
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<th>Satellite</th>
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<td>Mortality</td>
<td>Residual</td>
<td>Yard</td>
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<td>Mixed stands</td>
<td>5</td>
<td>42%</td>
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<td>46%</td>
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<td>15</td>
<td>36%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>46%</td>
<td>50%</td>
</tr>
<tr>
<td>Pure pine stands</td>
<td>5</td>
<td>42%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>n/a</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>39%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>n/a</td>
<td>42%</td>
</tr>
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</table>

While there was some variation around the 44% overall average, the volume of fuelwood in the sparse road-development class generally remains between 40% and 50% for all analysis periods.

Using the area distribution from Table 5 and Table 13, the weighted average of road development costs is $4.10/ODt. If the sparse road development class is omitted, the average cost of the remaining two classes is $2.92/ODt.

The total for costs that must be added to the direct harvesting costs is $41.10/ODt. The full amount is applicable to any volume harvested via the full-tree chipping system, and part of the cost is applicable to the fuelwood for the satellite yard systems. The cost should be allocated in proportion to the amount of fuelwood in the stand, which varies with YPM and the stand type. The average fuelwood content of satellite-yard type stands in the study area was 75% of the volume, therefore, the costs for processing chips through satellite yards should be increased by about $30/ODt.
The Business Case for Wood Energy

B. W. McCloy, R.P.F.

President

Prepared for
BC Ministry of Forests and Range
BC Ministry of Energy, Mines and Petroleum Resources
BC Hydro

2006

BW McCloy & Associates
5284 Cambridge Court
Tsawwassen, BC
V4M 3Z1
Summary

BC has an opportunity to become a world leader in the production and technology development of wood energy. BC now leads the nation in wood energy production and consumption. The BC pulp and paper industry alone produces more than 600 MW of power for internal use. Wood residue is also widely used for heating within the forest industry as an alternative to natural gas. Many homes in the BC interior now derive their heat from wood pellet stoves. Despite this impressive record, there are still more than 1 million bone dry tonnes (BDt) of mill residues incinerated as wastes by BC interior sawmills.

In addition to surplus mill wood residues there are an estimated 7 million BDt of roadside logging residues in areas affected by the mountain pine beetle (MPB) epidemic that could potentially be utilized for energy purposes albeit at a higher cost than mill residues. In the longer term it may be economically feasible to harvest standing bug kill stands but the location and costs of road development and silviculture make this opportunity cost prohibitive at the current time, especially with the more affordable volumes available in the form of roadside harvesting debris.

In addition to these surplus energy sources, BC will export approximately 900,000 tonnes of wood pellets primarily to European markets in 2007. BC has an opportunity to lead the world in the use and development of wood energy. Further development of this opportunity will play an important role in the economic transition of communities affected by the MPB epidemic. The projected loss of high paying sawmilling jobs as a result of dwindling sawlog supply to interior sawmills can be partially offset by jobs created in wood energy facilities. For example, utilizing all of the surplus wood residue resources for power production would create an estimated 1,500 new direct jobs in areas of the interior that will be hardest hit by expected mill closures.

A number of potential uses for surplus wood residues were examined. Three uses that were widely supported and potentially have the best business case were:

- Energy self sufficiency in the BC forest industry
- Additional wood pellet production
- Additional independent heat and power production outside the forest industry

The wood pellet industry and independent power producers rely on a viable sawmilling industry for their wood fuel supply. Energy self sufficiency of the BC forest industry is therefore a key priority.

The business case for the substitution of wood residue fuel is robust and will not likely require any significant government policy change with the exception of accessing standing MPB timber. The business case for power production is not as strong. In particular the use of roadside harvesting debris in MPB stands to produce power is estimated to be significantly higher than the current market price for electricity. This price gap can be filled in a number of ways including:

- A Call for Tender for power from wood residue sources
- Implementing the federal government’s proposed $10/MWh Renewable Power Production Incentive (RPPI)
- Implementing a BC Hydro capital investment program to displace purchased power by the forest products industry

The opportunity to significantly increase the use of wood residue fuel in the Province is significant. For example the 8 million BDt of surplus mill wood residue and roadside residues could potentially produce approximately 1,500 MW of power or 13,000 GWh per year, approximately double BC Hydro’s 2005...
electricity imports. Alternatively, 8 million BDt of energy is sufficient heat to replace the natural gas in more than 900,000 homes in BC.

The potential benefits of using BC’s wood resources for home-grown energy production are significant:

- BC electrical energy self-sufficiency.
- Reduced energy costs and a potential new source of income for BC’s forest industry.
- The creation of approximately 1,500 well paying jobs in the BC interior replacing projected job losses in the sawmilling sector.
- Improvement in air quality resulting from the closure of beehive type incinerators.
- Greenhouse gas reduction when wood residue is substituted for natural gas.
- Reduction in the threat of forest fires.
- World leadership in the development of wood energy technology.
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1 Introduction

Biomass has been used for energy purposes for several millennia. Since the signing of the Kyoto Protocol on greenhouse gas (GHG) reduction, biomass fuel has been recognized as an important offset tool in replacing fossil fuels and thereby reducing GHG emissions. Today, biomass for energy production comes from two distinct sources – agricultural residues and forest residues.

BC is blessed with abundant forest resources. More than half the land area of BC is covered by forests that serve as a source of fibre for BC’s forest industry. The forests also serve as a primary source of energy utilized by the forest industry to produce both heat and electrical power. The industry’s current energy production however is primarily limited to the use of sawmill residues (hog fuel) for drying purposes at sawmills, and in the pulp, paper and plywood sectors to offset purchased heat and power costs. Despite the widespread use of sawmill residual wood fuel, there are still significant surpluses of sawmill residues in BC’s central and northern interior that are currently being disposed of as waste in beehive type incinerators. Moreover, the MPB epidemic has caused an increase in sawmilling capacity leading to a significant increase in sawmill residue as well as some surplus pulp chips. The MPB epidemic has killed vast areas of central interior lodgepole pine stands some of which will be utilized for traditional forest products. However, in some regions there is simply not enough mill capacity to keep pace with the volume of dead trees resulting from the insect epidemic. As a result, there will be millions of cubic metres of dead standing pine that will simply never be harvested unless some alternative use such as wood energy can be found for these stands.

Overall, BC’s agricultural residues are in short supply relative to the volume of forest residues that are available. A rough estimate of crop residues provided by BioCap indicates that there would be approximately 136,000 BDT of crop residues available annually for energy use in BC. While this is a relatively small volume compared to wood residue availability, it is often concentrated in certain geographic regions such as the Peace River region and the Okanagan valley. Wheat straw for example, is a potential feedstock in the Peace region but the cost of collection and transport of wheat straw is significantly higher than mill wood residues ($50/BDt vs $10/BDt for a 40 km one-way haul distance). Moreover, processing wheat straw would require new equipment and capital. It is therefore unlikely that agricultural residues will play a role in biomass energy development in the short term. In the longer term (>10 years) agricultural residues could help energy companies extend the life of their projects by replacing the dwindling supply of wood residue fuel especially in MPB affected regions.

2 Wood Energy Use in a Global Context

Worldwide, biomass is the fourth largest energy resource after coal, oil, and natural gas. Contrary to popular belief, there is more wood utilized throughout the world for heating and cooking than is utilized for forest product production. Much of the use for cooking is in third world countries where wood is gathered daily for both heating and cooking. In developed countries wood residues are widely used within the forest industry for both heat and power production. In Europe 54% of total energy consumed in 2004 by the Confederation of European Paper Industries (CEPI) members was wood based. In Nordic

1 Sokhansanj, S. Presentation to the IEA Biofuels and Bioenergy: Challenges and Opportunities Conference. Vancouver. August 2006.
2 http://www.cepi.org/files/Sustainability 05-173317A.pdf
countries, the percentage is even higher. In Sweden the percentage use of wood biofuels within their pulp and paper industry exceeds 80%.

The European Union (EU) has established a goal for renewable energy production – 12% by 2010. This target was agreed to by member countries as a result of growing concern about Europe’s reliance on imported fossil fuels and concerns about climate change resulting from GHG emissions attributed to the use of fossil fuels. Today, the EU’s total energy from renewable sources is approximately 6%, well short of the 12% target. The EU recognizes that wood energy will play an important role in helping the EU attain its goal. Currently, the EU meets about 4% of its energy needs from biomass. To boost the use of biomass energy, the EU published a Biomass Action Plan in December 2005 to double wood’s share by 2010. Attaining this goal would reduce oil imports by approximately 8% and create an estimated 300,000 additional jobs in Europe.

Doubling the use of biomass fuel in Europe will be difficult as Europe is essentially already consuming its low cost mill residues. Consequently in countries such as Finland and Sweden, higher cost forest harvesting residues are now being utilized. In some countries serious consideration is also being given to fuel crops including willow and switch grass. Europe was keenly interested in fuel crops during the energy crisis of the seventies but interest waned when the price of oil dropped due to increasing global supplies.

The EU has also now started to develop a biomass energy strategy for the longer term. “Biofuels in the European Union a Vision for 2030 and Beyond” was published in 2006. The focus of this document is on biomass transportation fuel substitution for gasoline and diesel fuels. The strategy suggests that by 2030, the European Union will produce as much as one quarter of its road transport fuel from biomass sources. This thinking parallels recent announcements from the US where the current administration has called for an increase in the use of ethanol and biodiesel fuels to reduce reliance on imported oil. Most of these substitutes will come from agricultural grain and corn sources but increasing emphasis is being placed on the potential of wood ethanol as it is potentially a lower cost feedstock with significantly lower embedded GHG emissions compared to agricultural crops.

In Sweden the goals of wood residue fuel use are even loftier. Wood energy currently provides approximately 16% of Sweden’s total heat and power energy. Wood biomass today provides 62% of energy used in Sweden’s extensive district heating system. At a recent wood energy conference, Göran Persson, the Prime Minister of Sweden, opened the conference with a declaration that Sweden will become independent of petroleum products for energy production, including the automotive sector, by 2020. One province in central Sweden already obtains 60% of its total heat and power from wood biomass sources. The province has set a goal of 100% of total wood energy consumption by 2020.

Asian countries have lagged North America and Europe in the move toward renewable fuels including wood residues. Pulp and paper mills in Japan for example are still heavily reliant on imported coal as their primary fuel source. However, Asian countries are quickly realizing the economic threat posed by rising oil prices and are now giving serious thought to the use of biofuels both to reduce dependence on imported oil but also to reduce GHG emissions.

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5 [http://www.sweden.gov.se/sb/d/3211/a/63708;jsessionid=a1yC-sKcATb4](http://www.sweden.gov.se/sb/d/3211/a/63708;jsessionid=a1yC-sKcATb4)
3 BC Use of Wood Energy

Sawmill wood residues have long been the primary source of energy within the BC forest industry. Rising natural gas prices have caused the industry to further increase its use of wood energy. Today approximately 69% of total forest industry energy consumption is derived from mill wood residues. Despite this significant consumption, pulp and paper companies are BC Hydro’s largest customers and the forest industry is collectively Terasen Gas’s largest consumer of natural gas.

Table 1: BC Forest Industry Energy Production and Consumption – 2003

<table>
<thead>
<tr>
<th></th>
<th>Pulp &amp; Paper</th>
<th>Solid Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>TJ</td>
</tr>
<tr>
<td>Purchased Electricity</td>
<td>8,961</td>
<td>32,260</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>27,030</td>
<td></td>
</tr>
<tr>
<td>Light &amp; Heavy Oil</td>
<td>6,578</td>
<td></td>
</tr>
<tr>
<td><strong>Total Purchased Energy</strong></td>
<td><strong>8,961</strong></td>
<td><strong>65,868</strong></td>
</tr>
<tr>
<td>Black Liquor</td>
<td>120,708</td>
<td></td>
</tr>
<tr>
<td>Hog Fuel</td>
<td>47,849</td>
<td></td>
</tr>
<tr>
<td><strong>Total Self Generated Thermal Energy</strong></td>
<td><strong>168,557</strong></td>
<td><strong>11,195</strong></td>
</tr>
<tr>
<td><strong>Total Energy Consumption</strong></td>
<td><strong>234,425</strong></td>
<td><strong>27,155</strong></td>
</tr>
<tr>
<td>Self Generated Electricity 7</td>
<td>3,991</td>
<td>14,376</td>
</tr>
</tbody>
</table>

In the BC interior, many sawmills have replaced natural gas with wood energy systems. As a result, the total mill residues incinerated as waste in the BC interior has fallen dramatically in the past decade from over 5 million BDt annually to an estimated 1.2 million BDt today. However, despite this trend there are still a significant number of BC interior sawmills burning natural gas for heat to operate their lumber dry kilns and at the same time incinerating mill wood residues as waste in bee-hive style incinerators.

The energy supply and consumption on the coast of BC is somewhat different than the BC interior. Coastal pulp mills are much older than those in the BC interior and were specifically designed to maximize the use of mill wood residue fuels. Over time a symbiotic relationship between coastal sawmills and coastal pulp mills has developed. Coastal mills send both their pulp chips and hog fuel to coastal pulp and paper mills. Relatively inexpensive ocean bargeing has facilitated this flow. Consequently there is a fine balance between coastal sawmill wood residue production and pulp mill consumption of these residues. However, in recent years some coastal pulp mills have experienced shortages of wood fuel as a result of coastal sawmilling closures and have been forced to increase their use of fossil fuels and in one instance the use of coal.

Beyond the forest industry, there is a growing interest in wood fuel in industries such as the hothouse growers. In recent years a number of lower mainland growers have switched from high priced natural gas

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*7 Self generated electricity is not included in the total energy consumption as it is derived from hog fuel and black liquor fuel sources.*

*8 BW McCloy & Associates mill database.*
to wood residue fuels including coastal hog fuel and wood pellets to reduce operating cost and remain competitive.

The use of wood fuel for home heating has changed dramatically over the decades. Prior to the development of natural gas fields and the attendant gas distribution systems in the 1960s, many homes in BC urban areas were heated with wood fuels. Today wood fuels are a thing of the past in urban settings such as Vancouver and Victoria. However, in the BC interior, many homes are still heated with wood either in log form or increasingly with more efficient and smokeless wood pellet fired furnaces.

4 Barriers to Increasing Supply of Wood Energy

4.1 Low Electricity Prices

Unlike natural gas and fuel oil, the price of electricity to consumers in BC has remained relatively unchanged for over a decade, until BC Hydro’s rates were increased in 2004. In part, this is the result of BC’s regulated utility rates that are intended to reflect the utilities cost of service (including operating costs, depreciation and financing charges) rather than market prices. In this regard, most of BC Hydro’s power supply comes from a hydro dam system built decades ago. While expensive in their time, the capital on these dams has now been essentially recovered and the cost of power from these dams reflects relatively low maintenance costs as well as transmission and distribution costs. Consequently the consumer cost of power in BC is the third lowest of any jurisdiction in North America. Moreover, BC’s regulated utility rates are even lower for large industrial users than for commercial or residential customers. Large industrial customers, such as kraft pulp mills, now pay $38/MWh as a result of a recent increase in rates approved by the BC Utilities Commission.

The stepped rate incentive program for industrial customers (see Section 5.5) has created some incentive especially for electrical energy conservation. However, potential increases in the Tier 2 rate (from $54/MWh to $74/MWh or higher) that might be triggered by the BC Hydro’s 2006 call for new energy supply will create a unintended disincentive as the Heritage portion could drop even further below the current rate of $24.28/MWh plus demand charges. At this price it will be virtually impossible to justify a wood residue power project that would displace this purchased electricity.

4.2 Stigma Associated with Wood Fuel

In certain regions of BC there is a negative stigma associated with wood fuels. At least one urban mayor has referred to wood as a “dirty fuel”. Health concerns associated with the inhalation of fine particulate linked to wood smoke have exacerbated this concern. In several BC interior communities there are still bee-hive wood residue incinerators operating near communities where visual smoke has often been a concern. In coastal areas, chlorine contaminated wood residue associated with storage of logs in salt water has raised concerns about dioxin emissions from boiler stacks. In Golden, the municipal council has passed a by-law banning wood fireplaces in new home construction due to concerns about air pollution.

4.3 High Cost of Wood Fuel and Lack of Capital within the Forest Industry

Wood residue fuel has traditionally been a much cheaper source of fuel than natural gas that is still widely used within the forest industry. The cost differential has significantly increased in recent years due to dwindling natural gas supply and the high cost of new gas exploration. Figure 1 indicates that while more
and more natural gas is being discovered and sold, consumption is now outstripping supply. Gas fields that used to last for several decades are now being depleted in a few years.

![Volume and Decline Rates of Natural Gas in the Western Canada Sedimentary Basin](image)

Figure 1: Volume and Decline Rates of Natural Gas in the Western Canada Sedimentary Basin

As a result, gas prices are significantly higher than recent years. In September 2005, North American consumers were faced with the highest natural gas prices in much of the world (see Figure 2). For industries such as the BC pulp and paper industry that compete in world markets, the issue of high gas prices and the rising Canadian dollar has significantly eroded the industry’s competitiveness.

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9 Arc Financial.
Despite the relatively robust business case for natural gas substitution utilizing wood residue, there is often a lack of capital constraint. The capital cost associated with fuel switching from natural gas to lower cost wood residue fuel can be significant. In many instances the return on this investment is lower than the hurdle rate for many forest companies despite high natural gas prices. The problem is most pronounced within the pulp and paper industry where there is often a simple lack of capital to even consider such projects.

### 4.4 Lack of GHG Reduction Policy

Despite concerns about rising carbon dioxide (CO₂) concentration in the earth’s atmosphere linked to climate change, Canada has yet to act to control GHG emissions even though this country has ratified the international Kyoto convention on GHG reduction. Unlike Europe, which has acted to regulate GHG emissions, there is no Canadian market for CO₂ credits generated by a fuel-switching project that results in the substitution of CO₂ neutral wood residue for natural gas. Forest industry competitors in Europe now enjoy significant revenue from GHG credit sales on completion of a project offsetting fossil fuels with wood residues. European prices for CO₂ equivalent (CO₂e) credits topped $30/tCO₂e in 2005. Canadian market prices are expected to be somewhat lower¹⁰ in the range of $10/tCO₂e.

To put this issue into perspective, a hypothetical BC sawmill wood energy project costing $15 million would see the displacement of 300,000 GJ of natural gas annually generating approximately 15,000 tCO₂e.

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¹⁰ Most Canadian companies are expecting market prices to be in the range of $10/tCO₂e. The federal liberal government had previously guaranteed the Canadian oil and gas industry that the price of carbon credits will be capped at $15/tCO₂e.
credits on an annual basis. At the present time, CO$_2$e credits are expected to only have value during the five year Kyoto Protocol reporting period. Assuming a mill could market these CO$_2$e credits at $10/\text{tCO}_2\text{e}$, the mill could expect revenue of $750,000 during the reporting period. In addition the mill would realize $15$ million in natural gas savings during this same five-year period. It is clear that the sale of CO$_2$e credits will not drive a business case for fuel switching, but they could be the tipping point for an investment decision.

### 4.5 Relatively Low Heating Value of Wet Wood Fuels

Typical BC interior wood residue fuels are 50% water. As a result, much of the inherent energy in wood fuels is consumed in simply boiling off this water before any useful energy is produced. With coastal wood fuels moisture content can be significantly higher sometimes exceeding 80% in the wet winter months. At such high moisture content, wood fuel is virtually impossible to incinerate. Consequently, some coastal pulp mills employ bark presses that literally squeeze water from coastal hog fuel to bring the moisture content down to a more manageable 55-60% range. As Table 2 shows, not only is there much less useful heat associated with wet wood residue but at high moisture content, the boiler efficiency is also affected. This is in part the reason why one coastal pulp mill decided to co-fire its boiler with coal to increase boiler efficiency.

#### Table 2: Useable Net Heat for SPF Hog Fuel at Various Moisture Contents

<table>
<thead>
<tr>
<th>Fuel</th>
<th>As fired Gross calorific value (GJ/t)</th>
<th>Typical burner efficiency (%)</th>
<th>Useable Net heating value (GJ/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood at 0% moisture content</td>
<td>19.8</td>
<td>80</td>
<td>15.8</td>
</tr>
<tr>
<td>10% m.c</td>
<td>17.8</td>
<td>78</td>
<td>13.9</td>
</tr>
<tr>
<td>20% m.c</td>
<td>15.9</td>
<td>76</td>
<td>12.1</td>
</tr>
<tr>
<td>30% m.c</td>
<td>14.5</td>
<td>74</td>
<td>10.7</td>
</tr>
<tr>
<td>40% m.c</td>
<td>12</td>
<td>72</td>
<td>8.6</td>
</tr>
<tr>
<td>50% m.c</td>
<td>10</td>
<td>67</td>
<td>6.7</td>
</tr>
</tbody>
</table>

### 4.6 High Cost of Fuel Wood Transportation

As mentioned in Section 4.5, fuel wood is often half water. Transporting water that has no heating value is expensive especially with today’s rising diesel fuel prices. As a rule of thumb, BC interior pulp mills do not transport sawmill hog fuel more than 150 km even though the fuel is often free on board (fob) the sawmill. This constraint explains why mills west of Fraser Lake and in the Peace River regions are still operating bee-hive incinerators as there is currently no alternative economic outlet for the bark portion of mill residues.

### 4.7 Lack of Guaranteed Fuel Supply

Wood residue cogeneration projects built by an integrated forest company typically rely on the company’s own wood residue supply. This can be hog fuel and chip rejects from the pulp mill’s own woodroom or hog and chip fines from company owned sawmills in close proximity to the pulp mill. Some mills also
rely on hog fuel from independent mills but normally the pulp mill cogeneration host has some control over this supply through pulp chip contracts with the same mills. In such situations, the long-term supply of hog fuel is a relatively small concern as long as the pulp mill and sawmills remain in business.

For independent power producers (IPP) a long-term fuel supply commitment is critical to financing a cogeneration project. Independent operators of wood power facilities such as the one in Williams Lake are typically seeking a long term guaranteed fuel supply tied to their power purchase agreement with BC Hydro. Independent power producers do not have the same leverage with sawmills as a pulp mill with a chip purchase agreement. Consequently some IPP project proposals have failed based on long term fuel supply commitment even though the immediate volume of fuel supply was more than adequate to operate the proposed facility.

Unlike natural gas offset projects, where capital is written off in a few years, power project financiers are often looking to pay back capital within 10 - 15 years. Sawmill operators today are reluctant to sign such long term agreements as they foresee future value in their hog fuel – in particular the whitewood portion (sawdust and dry planer shavings) even though markets may not exist today. This is despite the fact that they may currently be spending >$3/BDt to incinerate their hog fuel as waste. Power plant proponents therefore face a significant risk of rising wood fuel prices when they are locked into 15 – 20 year power purchase agreements with only inflationary price increases for their power production.

4.8 Alternate Demand for Wood Residues

In some regions of BC there is competition and a market price for mill residues, especially sawmill whitewood sawdust and mill shavings. This material is the furnish for a number of industries including, particleboard, MDF, wood pellets and sawdust pulp. Market prices vary regionally but usually start at $10/BDt fob the sawmill. As a result, some independent power proponents often find that 50-100% of a mill’s wood residue is committed to other users. Furthermore, if a sawmill is using natural gas to dry its lumber there is an expectation that the mill will eventually withdraw sufficient wood residues to provide sufficient fuel to offset its natural gas bill.

Most sawmill managers try to maximize the value of their wood residues. At today’s natural gas prices the value of a BDt of mill residues is greater than $100 if the mill is still using gas to dry its lumber (assuming the capital on the wood energy system has been depreciated). Similarly, sawdust pulp producers are able to pay significantly more than power producers for sawmill sawdust. Power producers can likely compete with particleboard, MDF and pellet producers for local wood residue supply, but their ability to compete is eroded when transportation costs exceed $20/BDt.

4.9 Labour and Capital Costs

The staffing requirement for first class steam engineers in BC appears to be inconsistent with some jurisdictions. Moreover, the manning levels do not appear to take into consideration the size of the power facility. For example, it takes the same number of first class steam engineers to man a 10 MW as a 20 MW or 40 MW facility. Currently, rules also require that a first class steam engineer be onsite when high pressure steam boilers are operating. In Europe, this is not the case. The 25MW Cuijk power plant operated by Essent Energie in the Netherlands operates 24 hours per day and is unmanned by steam engineers. Steam engineers are sent from a neighbouring plant only in the case of a problem.

In addition to the labour cost problem, small power projects also face capital cost challenges. The capital cost of traditional steam boilers does not drop appreciably below 20 MW. Consequently power projects
are typically cost prohibitive below 20 MW in most Canadian jurisdictions. Some smaller projects have been successfully completed in recent years in BC where developers have been able to reduce capital costs by purchasing used equipment. Most of these installations are at existing facilities such as plywood mills or pulp mills where steam boiler engineers are already on staff. An example of such an installation is the 17 MW (net) steam turbo generator installed by Riverside Forest Products at its plywood and sawmill complex in Armstrong, BC in 2003.

### 4.10 Environmental and Permitting Issues

In BC, the provincial Ministry of Environment requires a permit to operate a wood energy or power generation facility. The primary environmental concern with wood residue energy facilities is local air emissions. Typical permits will place limitations on particulates (both total particulate and sometimes PM$_{10}$), NOx and SOx emissions. SOx emissions are typically a non-issue with wood fuels unless the fuel is pulp mill black liquor. Similarly NOx is easily controlled with low NOx boilers that are the norm for new boilers. Particulates however can be problematic as the fine portion, PM$_{10}$ and PM$_{2.5}$, has been linked to decreased lung function by certain medical researchers. In most instances, particulates are controlled by a stack electro-static precipitator (ESP). The capital cost of an ESP can be several $million and have a significant negative impact on the return on investment for the project. Natural gas fired boilers do not require permits, as they are not a significant source of particulates.

Environmental assessment (EA) is also required for relatively small power projects. In BC for example, the trigger is 50 MWe. While environmental assessment can be costly and time consuming, the BC legislation has fixed timelines for approval. Moreover, the BC process also allows proponents to include provincial permitting approval as part of the EA review, shortening the approval process. The federal government’s trigger for power projects is much higher (several hundred MW) and therefore is unlikely to be a barrier to most wood residue power projects.

### 4.11 Road Standards

In some instances power producers are considering the transport of wood residues via forest roads. The movement of chip trucks carrying hog fuel particularly from harvesting residue sources will significantly increase the maintenance costs of such trucks as they are now designed primarily for highway haul. The improvement of road standards is likely unaffordable for power producers but could potentially be underwritten by a portion of the bug kill funding being provided by the federal government.
5  Incentives

While there are significant barriers to increasing the use of wood energy, a number of existing and potentially new incentive programs have been discussed or are already in place at both at the federal and provincial levels.

5.1  Federal Tax Incentives

Class 43.1 in Schedule II of the Income Tax Act allows the accelerated write-off of certain capital equipment associated with renewable energy development including wood residue energy projects. Class 43.1 was amended in 2005 to allow biomass cogeneration proponents to write off capital expenditures in 3 years rather than five. If a company can use this incentive, cash flow will be improved.

Class 43.1 write-offs previously disallowed pulp mill black liquor cogeneration capital expenditures even though black liquor is a by-product of the kraft pulping process and its energy is derived from lignin contained in pulp chips. The 2005 amendments to Class 43.1 will now include cogeneration equipment using black liquor. This will significantly enhance the tax write-off of recovery boilers and cogeneration equipment fired by black liquor in the kraft pulp industry.

Unfortunately, many pulp and paper companies will be unable to take advantage of these accelerated write-off provisions because of their financial losses. To encourage the development of low GHG electricity generation, the Electricity Table\textsuperscript{11} recommended that unutilized deductions from Class 43.1 expenditures be reclassified to allow these expenditures to flow-through to shareholders. They further recommended that a refundable tax credit be allowed for unutilized Class 43.1 expenditures for companies not able to utilize the legislated rate against other income.

Research and Development tax credits are an incentive to equipment developers of heat and power equipment. Unfortunately these credits are not available for commercial demonstration projects. Consequently many pilot project technologies are never commercialized. Extending R&D tax credits to first commercial demonstration projects would be an important incentive to technology developers.

5.2  Renewable Power Production Incentive (RPPI)

In 2005, the federal Liberal government proposed that $170 million would be committed to a Renewable Power Production Incentive (RPPI) program to parallel the Wind Power Production Incentive (WPPI) program previously announced. This program was intended to provide an incentive of $10/MWh to renewable energy producers. Although the program was not included in the Conservative government’s recent Clean Air Act, a RPPI that included biomass fuels as eligible would lessen the cost gap between wood residue power generation projects and conventional generation projects. Discussions are now underway that could provide some federal government cash incentive for renewable power production.

5.3  Green Tags

In the absence of a robust GHG emission trading regime, some Canadian utilities have attempted to create a market for renewable or “green” electricity sales. Most utility programs are of a voluntary nature.

\textsuperscript{11}  The Electricity Table is one of 16 Tables established by the Federal Government in 2000 to provide advice on climate change matters.
Customers are given the choice of paying a slight premium for the purchase of certified renewable electricity. After a variety of attempts to define green electricity sources, most Canadian utilities, including BC Hydro, have accepted the Environmental Choice EcoLogo\textsuperscript{12} definition that includes wood residue generated electricity. A number of pulp and paper mills are now certified green electricity suppliers under the Environmental Choice program.

In some jurisdictions, EcoLogo certified power generators have the option of marketing their green power at a premium or selling the green attributes of the electricity (‘green tags’) to generate a separate revenue stream. Green tags have a variable market value in Canada that currently ranges from $3 to $6.25 per MWh. While Canadian utilities pay a small price for green tags, the price to consumers is typically substantially more than the cost of the green tags to the utility. BC Hydro for example offers green electricity to customers at a premium of up to $15/MWh. It is worth noting that currently in BC, the sale of green tags does not drive the utilities’ energy acquisition process because the current electricity supply mix is already made up of more than 80% green electricity, which is significantly more than the clean energy commitments in the 2002 Energy Plan and the minimal customer demand for green tags. Moreover, most pulp power generators are simply displacing a portion of their purchased electricity when they produce power and are not able to take advantage of premium power pricing.

5.4 Property and Sales Tax Incentives

Property taxes can be more than 15% of annual operating and maintenance costs for cogeneration facilities and exceed $1 million annually. Some BC municipalities have offered a property tax holiday for up to five years to encourage industrial investment. The provincial government offers school and property tax exemptions for run-of-river hydroelectric projects if they are EcoLogo certified. Unfortunately, this program does not appear to apply to wood residue heat and power projects.

5.5 Two Tier Power Pricing Incentive

A 2002, review of energy policy in the Province recommended that the Province move toward “market prices” for electricity over time. In response, BC Hydro implemented a two-tier electricity pricing in 2004. Today, industrial customers pay a weighted average price of $38/MWh but the invoices are divided into two tiers. For industrial customers, 90% of a power bill is at so called Heritage Rates\textsuperscript{13} which lock in the value of existing low cost generation assets for an extended period of time. The remaining 10% (Tier 2) is set at market rates ($54/MWh in 2004) or essentially BC Hydro’s cost of new power acquisition\textsuperscript{14}. Existing BC Hydro industrial customers therefore pay a significantly higher price for the last 10% of their purchased power, creating a new incentive to reduce this portion of their power bill either by conservation measures or building new cogeneration facilities to offset ten percent of their purchased electricity supply\textsuperscript{15}. While $54/MWh is still a marginal price for capital return purposes, the RPPI incentive ($10/MWh) could provide sufficient incentive to move a few pulp mill cogeneration projects forward.

This new power pricing arrangement has created new interest in pulp and paper cogeneration as the return on investment for such projects is significantly greater than when all power was priced at $35/MWh. However, this program is much more advantageous to large integrated companies that can pool their Tier

\textsuperscript{12} The EcoLogo certification program is administered in Canada by TerraChoice.
\textsuperscript{13} The heritage rate is currently $24.28/MWh plus demand charges.
\textsuperscript{14} This rate is could increase to $74/MWh or more as a result of BC Hydro’s recently completed F2006 call for new power.
\textsuperscript{15} Companies with more than one facility paying the industrial rate can group their industrial load and build a cogeneration facility to offset up to 10 per cent of the company’s entire industrial electricity purchases.
2 power from a number of facilities into one power project. Ten percent of the purchased power at a single mill would not justify a viable project in many instances.

5.6 Canadian Industry Program for Energy Conservation (CIPEC)

The Canadian Industry Program for Energy Conservation was established by the federal government to help educate, encourage and finance energy efficiency programs within Canadian industry. CIPEC has been effectively targeting both the Canadian pulp & paper and solid wood industries with their programs. Unfortunately, the mandate of CIPEC does not include simple fuel cost reduction by means of fuel switching from fossil fuels to wood residues. Therefore, while federal government funding is being spent on projects that have a solid business case, the cost savings to individual mills are relatively minor.

5.7 Renewable Energy Deployment Initiative (REDI)

The Renewable Energy Deployment Initiative (REDI) was designed by the federal government to encourage the reduction of GHG emissions in Canadian industry. The program grants are simply too small ($80,000) to attract the interest of even a medium size sawmill planning to substitute wood residues for natural gas. Such projects normally exceed $10 million. The REDI program is scheduled to expire in March 2007.

5.8 National Research Council of Canada (NRC), IRAP

NRC’s Industrial Research Assistance Program provides grant money to small and medium-sized Canadian enterprises for technology development. The program has historically provided important seed money to wood residue technology developers in BC. Grants are typically less than $100,000 per project.

6 Sources of Wood Fuel Supply for Heat and Power

6.1 Surplus Mill Residues

The vast majority of mill wood residues are generated by the sawmilling industry. Despite significant usage of sawmill residues for forest product production as well as combined heat and power production, there are still more than 1 million BDt of mill residues incinerated annually by BC interior sawmills.

A typical interior sawmill consumes approximately 25% of its mill wood residues to dry its lumber. For those mills within a 150 km radius of a pulp mill or some other user such as a particleboard mill, there is a potential outlet for their remaining mill residues. But for those mills that are not within an economic haul distance it typically means incineration of their remaining mill residues. Some of these mills are now considering alternative products such as wood pellets but at the moment, wood pellets are manufactured strictly from mill sawdust and/or planer shavings leaving the mills with a bark disposal problem. Table 3 indicates the relative production and consumption of mill residues in the BC interior in 2004.
Table 3: BC Interior Mill Wood Residue Summary -2004 (BDt)

<table>
<thead>
<tr>
<th></th>
<th>Bark BDt</th>
<th>Sawdust BDt</th>
<th>Shavings BDt</th>
<th>Total Volume BDt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>2,981,633</td>
<td>2,057,163</td>
<td>1,514,958</td>
<td>6,553,754</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
<td></td>
<td>4,388,894</td>
</tr>
<tr>
<td>Export</td>
<td></td>
<td></td>
<td></td>
<td>349,905</td>
</tr>
<tr>
<td>Surplus</td>
<td></td>
<td></td>
<td></td>
<td>1,814,955</td>
</tr>
</tbody>
</table>

Since this survey was conducted, there has been a slight increase in production resulting from the completion of several sawmill expansion projects. However, this volume increase has been more than offset by several new pellet, power and heating projects including:

- Canfor’s 50 MW cogeneration expansion at Prince George Pulp and Paper.
- Weyerhaeuser’s cogeneration and sawdust pulp digester expansion project at their Kamloops pulp mill.
- Canfor and Pinnacle Pellets planned pellet mill and mill wood energy system at Houston BC.
- The recent approval of the Mackenzie Green Energy project that will consume an additional 600,000 BDt annually.

The Mackenzie Green Energy Centre has been awarded a long-term contract from BC Hydro to supply clean power as a result of their 2006 Call for Tenders. Pristine Power and Balanced Power Engineering are the principals behind the 50 MW power project. The project will allow Pope and Talbot to shut down their power boiler by providing high pressure steam to the kraft pulp mill avoiding costly capital expenditures on the existing power boiler stack. The project is also intended to supply low pressure steam to Canfor’s nearby sawmill complex reducing the use of natural gas that now fuels Canfor’s lumber kilns. In addition, the project will result in the closure of up to six wood residue incinerators at a variety of sawmill sites. While the contracted power price is confidential, the weighted-average levelized power price for the F2006 Call awards was $74/MWh for large projects greater than 10 MW.

6.2 Surplus Pulp Chips

Several BC interior sawmills have significantly expanded their lumber production as a result of uplifts in the Annual Allowable Cut (AAC) caused by the MPB infestation. While there has been no formal survey, anecdotal comments from industry fibre supply managers suggest that mill pulp chip production has also increased by as much as 25% in the BC central interior. At the same time, the pulp mills located in this region have not expanded their production to any degree and consequently a glut of surplus pulp chips was created. Consequently, the market price of pulp chips has declined from more than $80/BDt two years ago to approximately $40/BDt at some sawmill sites. Moreover, some smaller secondary
manufacturers that produce dry pulp chips have had difficulty getting any price for their pulp chips. In addition to surplus pulp chips, there has been an increase in pulp chip fines due to the brash nature of MPB killed timber that can potentially be utilized in energy projects.

To alleviate the pulp chip surplus situation, interior fibre supply managers have been able to market a percentage of their surplus chips to coastal pulp and paper companies where there has been a chronic shortage of pulp chips extending for more than a decade. Fibreco has also been able to successfully export a portion of these surplus pulp chips to offshore markets. Mills have received $40 - $50/BDt from Fibreco fob their sawmill. In recent months prices have improved even further up to $60/BDt due to coastal pulp chip shortages and market demand in the US Pacific Northwest. However, this robust market is not anticipated to last and there could potentially be 200,000 - 400,000 BDt surplus in BC within two years. This potential surplus does not take into consideration potential closures of any of BC’s pulp mills.

At $40/BDt, pulp chips may be an attractive back-up source for some wood energy projects especially if the sawmill is close to an energy project so that additional transportation costs can be minimized. Furthermore, the use of surplus BC pulp chips for energy purposes rather than for the manufacture of pulp and paper in offshore markets should only help the competitiveness of BC pulp producers. Because of the historically low price for pulp chips, sawmill managers will undoubtedly be somewhat reluctant to sign long term supply agreements with energy companies. Nonetheless, surplus pulp chips could form an important source of surplus wood energy supply in the coming decade if only on a spot basis.

### 6.3 Dead Standing Timber

The MoFOr current estimates suggest that there is more than 700 million cubic metres of dead standing lodgepole pine in the BC interior. This estimate could further increase in coming years if the MPB epidemic continues. Figure 3 indicates the expected kill of lodgepole pine in 2004. Surveys taken in 2005 indicate that the beetle is spreading at a much more rapid rate and the peak of the infestation is expected to occur as early as 2006. This will undoubtedly shorten the timing and intensify the wave of bug kill volume that will be available for traditional forest products as well as new products such as wood pellets and wood energy. In this regard, wood energy proponents need to be cognizant that their wood fuel supply will eventually decrease as the supply and quality of MPB timber declines.

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16 Dry pulp chips are created when kiln dried lumber is chipped. The moisture content of these chips is approximately 12% making them more difficult to pulp than fresh chips in kraft mill digesters.
17 Fibreco was created in 1977 by a consortium of BC sawmills interested in creating off-shore markets for pulp chips. Fibreco exports >1 million BDt of BC and Alaska pulp chips annually primarily to the Japanese market.
18 Fob prices vary with transport distance from the port of Vancouver. Mills north of Prince George receive significantly less for their pulp chips than those in the southern interior.
19 Personal communication with Grant Watkins Pres. And CEO Fibreco July 2006.
20 Personal communication with Grant Watkins Pres. And CEO Fibreco July 2006.
Figure 3: Cumulative Volume of MPB Killed Timber in the BC Interior

Figure 4: Gray and Red Attack MPB Stands West of Quesnel - 2006
The volume of dead standing timber that might be available for energy purposes is unclear and will ultimately be dependent on the volume of timber utilized for traditional forest products. But recognizing that it would be virtually impossible to convert all of the MPB killed timber into traditional forest products; in 2005 the BC MoFOR issued requests for proposals for parties interested in acquiring Timber Sales for non-traditional use of bug killed timber. This resulted in the issuing of two non-renewable Forest Licenses to an OSB manufacturer. Also in October 2005, the MoFOR awarded four major Forest Licenses to a renewable energy company interested in salvaging attacked stands for the production of industrial wood pellets. In total, the Ministry awarded more than 30 million cubic metres with these sales.

It should also be noted that MoFOR volume estimates of MPB kill are based on merchantable volume. It is now clear that many immature stands are being hit by the MPB and this unknown volume should also be considered as a potential source of wood energy.

The volume of standing bug kill that will ultimately be available for wood energy purposes will be significantly affected by the “shelf life” expectancy for traditional forest products. Studies are now underway to determine this shelf life. Initial indications are that the shelf life could extend beyond ten years on some drier sites. However, already veneer manufacturers are adverse to utilize bug killed peeler logs as checking significantly reduces full sheet veneer yield. In the much larger sawmilling sector, new equipment including scanners that can detect checks in logs and rotate the log accordingly to maximize lumber yield are being installed by some mills. But shelf life is also a function of the market price of lumber. Recent low lumber prices combined with record low pulp chip prices do not bode well for the BC lumber industry. Any mill closures or cutbacks in lumber production due to market conditions will only decrease bug kill timber utilization. Over the coming decade mill lumber recovery factors will also decrease further, negatively impacting on the economic health of the sawmilling industry which has become increasingly reliant on bug killed timber.

The shelf life of MPB timber for energy purposes is currently unknown. But initial indications are that there is significant energy value in a tree so long as the tree is still standing. This could exceed 20 years on some drier sites in the BC interior. Figure 6 gives some indication of logs that are no longer suitable for lumber production but are of high quality for energy production due to the dry nature of the residue.

The new timber pricing system and changes to cut control for beetle killed wood have inadvertently affected the Major Licensee’s perspective on removal of bug killed timber. Under the previous policy a significant portion of bug killed timber was priced at $0.50 per cubic metre. Furthermore this volume was not charged to a Licensee’s cut control creating an incentive for the removal of bug killed timber. The changes have resulted in the Licensees leaving more bug killed wood at roadside. Their decision is economic. Even with a full stumpage penalty, it is a least cost decision to leave lower grades behind at the roadside. While the new system has arguably increased roadside volumes making greater quantities potentially available for energy purposes, over the longer term the pricing system will likely constrain major Licensees from harvesting some marginal bug kill stands and force energy users into harvesting more expensive bug killed stands, thus driving up the cost of wood energy.

The cost of removal of standing bug kill timber is today likely cost prohibitive from a wood energy perspective. Envirochem recently reviewed alternative uses for bug killed timber in a report for the MoFOR. Their report compares estimates of delivering processed wood from bug killed stands to a central location in the BC interior. Estimates range from a low of $68/BDt\(^{21}\) to a high of $106/BDt\(^{22}\). A

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Pacific Forest Centre report estimates a delivered cost of $75.44/BDt for a 110 km haul, which lies between the values in the Envirochem report. The report further estimates that the actual harvesting of bug kill logs and skidding them to the roadside, costs over $16/m³. Assuming a delivered cost of $80/BDt equates to approximately $50/MWh or $4/GJ. This compares to sawmill residue that is typically delivered for heat and power applications for <$20/BDt ($12/MWh or $1/GJ) for a comparable haul distance. The $80/BDt cost estimate for standing bug kill wood is likely too expensive for most energy applications based on discussions with industry representatives familiar with energy pricing.

A FERIC field study conducted in 2006 indicates that the cost of harvesting, processing and delivering standing bug kill could range from $53 - $56/BDt but this cost does not include the costs of layout, road development, silviculture and overhead estimated at an additional $30 - $41/ODt in the FERIC report. Total delivered costs would therefore range between $83 - $97/BDt exclusive of stumpage payments.

6.4 Roadside Harvesting Debris

A potential lower cost source of bug kill wood energy are the vast piles of harvesting debris left at roadside after Licensees have completed their removal of sawlogs. Anecdotal information obtained from Licensees operating in bug killed stands indicate that volumes left at roadside can range up to 25% of merchantable volume. This compares to debris left in live tree operations that typically is less than 5% of merchantable stand volume.

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Figure 5: Contiguous Piles of Harvesting Debris in Red Attack Stands - FERIC 2006

FERIC’s 2006 field study in MPB stands west of Quesnel indicates that 45%-50% of the original cutblock total biomass was left in roadside residuals where the log top diameter was more than 10 cm. Bucking sawlogs to a 15 cm top is becoming more commonplace due to the checking of tops in MPB stands and their unsuitability for lumber production.

Figure 6: Example of Log Checking Associated with MPB Killed Timber – FERIC 2006
The percentage of harvesting residues appears to vary by the stage of pine beetle attack. In red attack stands, harvesting residues appear to be limited to tree tops. Even so, the volume of such piles is as much as 50% of the original stand volume by weight. But in older gray attack stands harvesting debris piles are even larger containing not only tops but whole logs with either checking or scars rendering them unsuitable for lumber production (see Figure 7). Butt logs with associated heart rot are also a feature of debris piles in such stands.

![Figure 7: Example of Roadside Debris Piles in Gray Stage MBP Stands](image)

There is significant experience in Europe and eastern Canada with the utilization of harvesting debris for energy purposes. Based on this experience, it should be possible to deliver processed wood fuel from debris piles for <$50/BDt for a distance of approximately 100 km one-way. As a result of their 2006 field study, FERIC has developed a transportation cost curve that confirms this estimate. Roadside debris piles have somewhat less volume than standing bug kill due to the removal of merchantable sawlogs. But this loss is more than offset by the cost savings from avoided road building, silviculture, stumpage, felling and skidding and should therefore have an inherent cost advantage compared to standing bug kill.

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25 Gray attack stands are where the needles have turned gray and are beginning to fall from the tree. This typically occurs >3 years after bug kill.
Processing and Hauling Cost for Roadside Residuals

$/ODt

Haul Distance (km one way)

$90

$80

$70

$60

$50

$40

0 50 100 150 200 250

Figure 8: Processing and Transportation Cost Curve for Average MPB Stand Conditions – FERIC 2006

Figure 8 also confirms that it is significantly cheaper to process standing MPB timber for fuel at the harvesting site rather than transporting whole logs and processing “in-town”.

The FERIC study concludes that based on average stand conditions (60 ODt/ha of roadside residues) “6 700 ha would need to be harvested each year to generate 300,000 to 400 000 ODt of roadside residuals, the approximate volume of feedstock required to supply a 60 MW facility (McCloy 2006). At an average merchantable volume of 250 m³/ha, this area represents an annual timber harvest of about 1.7 million m³, less than 30% of the current AAC in the Quesnel Timber Supply Area, and about 60% of the historic AAC”26.

Assuming the FERIC study is representative of bug kill stands in the BC interior, there could potentially be more than 7 million BDt of roadside residues generated on an annual basis. Combined with 1.0 million BDt of surplus mill residues there is sufficient wood residue to potentially produce approximately 1500 MW of power or 13,000 GWh per year, approximately double BC Hydro’s 2005 electricity imports. Alternatively, 8 million BDt of energy is sufficient to replace the natural gas for heating in more than 900,000 homes in BC.

26 FERIC 2006.
The utilization of roadside harvesting debris also avoids potential conflict with Major Licensees that might occur when harvesting standing timber. In fact there may be potential cost savings as Licensees avoid the cost of burning debris piles. Coordination between Licensees and energy companies will be important for a number of reasons including:

- Coordination of road maintenance
- Scheduling debris removal
- Optimizing the location of debris piles for ease of processing into hog fuel
- Potential synergies of transportation of logging debris at the time of harvesting

In addition to cost advantages there are several forest management advantages to the utilization of roadside debris for energy purposes. The MoFOR has identified a number of concerns with the current practice of roadside processing in bug killed stands and the subsequent incineration of these debris piles.

- Reduced stand productivity in the next rotation as debris may limit the ability to fully restock the site with healthy trees
- Intense heat from the incineration of debris piles likely to cause site degradation
- An increase in the amount of area harvested relative to the AAC
- Increased fire hazard resulting from excessive wood residue fuel
- Reduced mobility and potential danger to cattle as much of the range of lodgepole pine overlaps with dedicated rangelands
- Public concerns with visible concentrated wood residues
- Forest Health concerns as debris piles may serve as a breeding ground for other forest pests

All of these concerns will be alleviated if the roadside debris piles can successfully be utilized for energy purposes.

As previously indicated, a key to the utilization of wood residue for power production is a long term secure supply of wood residues at a known cost. Harvesting residues can potentially supply a much more secure supply than mill residues where mill managers are reluctant to enter into long term supply agreements. Furthermore, the costs of processing and transporting harvesting residues, while high compared to mill residues, can be fixed for a long term with some certainty. To create this certainty, it should be feasible for the MoFOR to enter into salvage tenure arrangements with energy companies. This is particularly important to independent power producers that have no forest rights and must convince lenders that their fuel supply is locked up for the term of a power purchase agreement. It is less important to a pulp mill that is part of an integrated forest company that also holds existing forest tenure rights including the rights to the harvest residues. However, the pulp and paper industry is rapidly deintegrating and therefore security of fuel supply will also become as important as security of pulp chip supply.

A simple salvage agreement for harvesting residues for a given geographic area for a period tied to a power purchase agreement would provide the necessary security. As the tenure would only provide salvage rights to harvesting residues, there should be little or no conflict with Major Forest Licensees. Discussions with some large integrated companies have confirmed this opinion.

While there are currently significant volumes of harvesting debris associated with MPB stands, this volume will only be available so long as Major Licensees are able to economically harvest such trees. Over the longer term, the wood energy strategy should recognize the inevitable demise of a portion of roadside harvest debris and the need to move to higher cost standing timber. Hopefully this transition will
not be necessary for at least another decade and during this period there is also some hope that energy prices will increase further to permit the economic removal of standing timber for energy purposes. Over the longer term (>20 years) it may be necessary for energy providers to consider alternate fuels such as agricultural residues, municipal solid waste and possibly coal if they expect to prolong the life of their energy assets.

6.5 Wood Energy Crops

Interest in growing industrial wood fuel crops began in Europe during the energy crisis of the 1970s. Experimental plantations of fast growing willow and switch grass were planted based on the notion that this fuel source would eventually be cheaper than the rapidly rising cost of imported oil. In Sweden, for example, 11,000 hectares of short rotation (3 to 4 years) willow were planted and harvested for energy use. Denmark and Great Britain also established similar willow plantations. Austria and Germany have established poplar energy plantations on an experimental basis. In Italy, Robina species were planted together with poplar species and eucalyptus. All of these plantations were established with the thought of converting wood into hog fuel to supply electrical co-generation facilities.

Two factors negatively impacted on the expansion of fuel wood plantations in Europe:

- Oil prices fell as a result of new supply
- North Sea oil discoveries meant that Europe was now less reliant on imported oil.

As a consequence of these events, interest in fuel wood plantations waned in the 90s but today there is renewed interest in fuel wood plantations spurred by rising oil prices, concerns about energy security as well as climate change concerns and the possible use of CO₂ neutral biomass to offset fossil fuels.

The US Department of Energy's National Renewable Energy Laboratory developed a model to estimate the future cost of fuel crops. Their model predicts "Woody Crop Costs" between $58 and $62 per BDt in the year 2005 (Sheehan 1998). This is a high cost fuel supply relative to surplus mill wood residues that are typically delivered for $20/BDt for a 100 km haul in the BC interior. But the costs are not excessive if one compares to the $50/BDt estimate for MPB roadside wood debris or the $80/BDt estimate for harvesting standing bug kill. However, the economics of utilizing forest land for fuel crops needs to be considered in the context of alternate land use for the purpose of growing traditional forest crops for forest product manufacture. At the present time in BC, the value of wood fibre for forest product production far outweigh its value as an energy source. However, it is interesting to note that at current pulp chip and natural gas prices pulp chips have more value as an energy source to offset natural gas at a sawmill than as furnish for pulp production.

A further impetus for the consideration of afforestation²⁷ plantations is the potential for CO₂ sequestration and the development of carbon credits. Using fuel wood to displace natural gas directly produces GHG offsets or carbon credits. Equally important is the potential to also sequester carbon from the earth’s atmosphere in growing woody fuel crops. The Kyoto Protocol agreement on climate change recognizes the legitimacy of forest sinks as an offset mechanism to reduce CO₂ concentration in the earth’s atmosphere. In BC there are thousands of hectares of marginal agriculture land that were once forested that could be converted back to forest land as energy crops. All of the CO₂ sequestered in the first crop would be considered as carbon credits under Kyoto sequestration rules. Moreover, these new plantations

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²⁷ Afforestation and reforestation have been recognized by the International Panel on Climate Change as a legitimate offset mechanism in reducing GHG emissions.
could provide fibre and employment during the predicted fall down in the AAC resulting from the MPB epidemic.

7 Potential Markets for Wood Energy

7.1 Large Scale Power Development

BioCap Canada has published a paper suggesting that a 300 MW circulating fluidized bed designed power plant be constructed in the Quesnel area to utilize MPB timber that will not be utilized by the forest industry. The estimated cost of the power in the study ranged from $68 to $74 per MWh. The wood costs for such a facility are estimated at $55/BDt ($32.81/m3). Capital cost estimates are based on a similar size project located in Finland visited by the authors of the study. However, since this report was written, the capital costs for large construction projects in BC have increased significantly for two primary reasons:

- Rising labour costs driven by demand for skilled labour in the Alberta tar sands development
- The doubling of the price of commodities such as copper, as well as significant price increases in steel and record high concrete prices.

As a result, the current bid price for a 300 MW MPB fuelled facility is estimated at approximately $95/MWh based on a feedstock price of $50/BDt and similar technology as recommended by the BioCap report. This price is significantly higher than the average winning bid price ($54/MWh) in BC Hydro’s 2002/03 green calls and also higher than the weighted-average plant gate price ($74/MWh levelized) for the F2006 call for power from projects exceeding 10 MW. Assuming FERIC’s 2006 minimum cost estimate for delivering MPB standing timber ($83/BDt) would only serve to further increase the cost of power from standing bug kill to well over $100/MWh.

The BioCap report does not address the potential for significant conflict between existing Forest Licensees and the use of standing MPB killed timber for power development other than to state that it would utilize timber in excess of sawmilling industry demands. The report assumes that all of the necessary fuel wood will be delivered from within a 145 km radius of Quesnel. As this is also the breadbasket of sawmills in the Quesnel area there will undoubtedly be conflicts with Licensees who now control virtually all of the apportioned crown timber in the Quesnel Timber Supply Area. There are also significant private timber land owners in the Quesnel area especially in close proximity to Quesnel. These land owners would likely expect some stumpage payment reflecting the transportation cost savings of delivering their wood to Quesnel relative to more remote Crown timber sources.

7.2 Alberta Gas Substitution Opportunity

Alberta heavy oil developers are now extracting a significant portion of their supply from Steam Assisted Gravity Drainage (SAGD). This process typically utilizes natural gas fired steam boilers to produce this steam that in turn is injected into the underground heavy oil formations improving the viscosity of the oil for extraction. Further gas is also consumed in upgrading tar sands as well as heavy oil at oil upgrading facilities located near Edmonton. The price of natural gas has risen significantly in recent years averaging

29 IPP 2006 pre-engineering estimate.
$6.26/GJ\textsuperscript{30} year-to-date at the AECO hub in 2006. Additional transmission costs would likely add an additional $1.50/GJ making the total cost at the burner tip approximately $8/GJ. Gas prices are forecast to rise further in coming years due to reduced supply, rising costs of discoveries and increasing demand.

To offset high cost natural gas, some oil companies are considering the gasification of waste bitumen, a by-product of oil upgraders. While this product has significant heat value and is lower cost than gas, it also has higher carbon content than natural gas, exacerbating GHG emissions. A logical substitution that would also lower GHG emission is wood residue fuel.

Alberta SAGD and oil upgrading now consumes 210 million GJ natural gas annually at an average cost of $7-$9/GJ in 2005. This gas consumption is expected to increase to 500 million GJ once the announced expansion projects are completed. Assuming this gas was replaced by wood fuel would require approximately 28 million BDt annually or approximately 70 million m\textsuperscript{3} per year. This approximates the total annual log harvest from BC in a given year. Given that there is roughly 700 million m\textsuperscript{3} of dead pine in the BC interior, dead pine would provide the heating needs of the Alberta oil industry for seven years after adjustments for boiler efficiencies.

While the Alberta oil industry gas substitution appears to be a large and lucrative opportunity for BC wood energy with significant GHG reduction benefits, it is not likely to happen simply because the cost of moving bug kill hog fuel from Prince George to Edmonton are significant. FERIC estimates the cost of processing and moving bug kill fuel from Prince George to Edmonton to be in the range of $120/BDt or $6/GJ. By comparison the landed cost of wood pellets is expected to be $150/t or $8.30/GJ. While there is some cost saving resulting from the substitution of hog fuel with gas costing $8/GJ, the savings are unlikely to cause an oil upgrader to spend the significant capital it would require to install a wood energy system. As Canada has yet to regulate the reduction of GHG emissions, there is no compelling reason for the Alberta oil industry to switch to renewable fuel source such as wood residue. Should the oil industry be required to reduce GHG emissions, the Alberta industry would likely source wood residue fuel from within Alberta as there would likely be significant transportation cost savings.

### 7.3 Biorefining Opportunity

Many US and Canadian pulp and paper mills are no longer cost competitive and therefore government and industry are considering the possibility of converting some of these mills into biorefiners. Pulp and paper mills have an obvious advantage of available capital equipment that can potentially be utilized to make a variety of new bioproducts including the potential for wood ethanol. Hemicellulose and cellulose components of wood can also be used to produce building block chemicals for a vast range of end products. Of particular interest are large market products such as resins, polymers, and food additives: for example, structural plastics made from polymers have a world market similar in size to that for paper products. Similarly lignin can be converted into phenols, resins and many polymers.\textsuperscript{31}

Despite the promise of biorefining of wood residue, the fact is that most of the identified products are still far from commercial and in many instances (wood ethanol) are still at the laboratory stage of development. The ultimate development of this concept is likely more than 6 years away and technology developers will need to convince investors that there is a reasonable expectation of return on investment capital. In the interim, there is significant capital and interest in agricultural bioproduct development. At


least two companies are looking to commercialize agricultural lignocellulosics ethanol production. This is in part due to the relatively simple chemical structure of some agricultural feed stocks compared to wood residues. The US DOE has issued a Request for Information for a pilot facility for the conversion of lignocellulosic biomass to fuels and coproducts and is currently looking for an industrial partner to build the demonstration facility.

Most of the investment capital in Canada is being directed at renewable transportation fuel development including biodiesel from canola and ethanol from grain and corn. Husky Oil for example is currently investing $95 million in a large (130 million litres per year) grain ethanol facility in Lloydminster, Saskatchewan. A comparable size wood ethanol facility is estimated to require five times the capital investment. Iogen, an Ottawa based company, has developed a lignocellulosic technology pathway based on the conversion of corn stover into ethanol. Iogen has expressed some longer term interest in converting hardwood species into ethanol but has pointedly steered away from softwood species because of the higher lignin content of softwoods and the higher percentage, of the more difficult to ferment, five carbon sugars.

### 7.4 Wood Pellet Opportunity

The BC wood pellet industry is amongst the largest in the world with shipments of more than 500,000 tonnes in 2005. The BC wood pellet industry has grown significantly in recent years from a wholesale/retail based home heating supplier to a world class bulk commodity supplier to European utilities that typically use BC wood pellets as a coal substitute. Only part of the European demand is attributable to rising fossil fuel prices. All Member States must now comply with the EU directive for renewable energy (see Section 2).

BC wood pellets are now made exclusively from sawmill whitewood residues (sawdust and planer shavings). As a result, sawmills now enjoy revenues from their whitewood residues that were previously incinerated as wastes or given away to pulp mills where the residue was in turn used to fire hog fuel boilers. While wood pellet production has significantly increased the utilization of mill residues, sawmills are still left with a bark disposal problem unless they are in proximity to a pulp mill power boiler that will take a mill’s excess bark.

The possibility of producing pure bark pellets is technically feasible but there are a number of problems including boiler corrosion and wear on pelletizing equipment that require further study before the industry decides to market a bark pellet. In the interim it should be possible to market a blended whitewood/bark pellet that could potentially utilize all of the mill residues from some BC Interior sawmills. Such is the case at the Nova Scotia based MacTara sawmill that has been producing a mixed pellet for the past few years that is marketed in Europe.

The demand for wood pellets is burgeoning. The European market alone is estimated at 3 million tonnes and expected to eventually grow to 10 million tonnes. Delta Research Corporation has estimated that wood pellets could conservatively fill 10% of the EU demand for biomass energy, equating to an annual demand of 7.5 million tonnes of wood pellets by 2010. The US home heating market is a more traditional market with an annual demand of approximately 1 million tonnes.

New markets are now developing in Asia. In response to their commitment to reduce GHG emissions, the Japanese government has set a target to increase renewable energy to 1.35% of power supply. This

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32 D. O’Connor S&T2. Personal Communication.
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presents a potential wood pellet opportunity of approximately 2 million tonnes per year. BC interior pellet producers are well located to take advantage of this new market. The new Pinnacle Pellet/Canfor pellet mill now under construction in Houston BC will see a portion of its production marketed in Japan.

The growth of the wood pellet business in BC has also meant a new revenue stream for the sawmilling industry. Mills that previously gave away their sawdust and shavings now on average receive $10/BDt fob the sawmill. As most pellet mills are located in close proximity to sawmills, their furnish costs are typically <$20/t including transportation. Market prices in Europe have recently increased from $160/t to approximately $200/t reflecting the growing European demand for wood pellets. Transportation costs to Europe from the BC interior are approximately $90/t resulting in a pellet mill fob price of approximately $110/t. Labour and other expenditures are approximately $20/t resulting in a profit before taxes of approximately $20 - $70/t depending on market conditions.

In 2005 the MoFOR awarded a series of standing bug kill timber licenses to a company interested in potentially processing MPB timber into wood pellets. A variety of estimates peg the cost of delivering this MPB timber for further processing into pellets at a minimum of $80/BDt. It is evident that even with today’s market price of $200/t it would currently be uneconomic to harvest MPB timber and make a return on invested capital. Pellets based strictly on MPB timber sources would likely be a blended whitewood/bark unless some other use can be found for the bark portion of the tree.

Processing roadside harvesting residue into wood pellets may be an interim strategy that is economical until such time as market prices support the processing of standing MPB timber into wood pellets. However, at the present time all of the existing wood pellet producers in BC are focused on mill whitewood residues including the growing volume of pulp chip fines. Some processors are looking at surplus pulp chips at $40/BDt as their next least cost source of wood pellet furnish.

7.5 BC District Heating and Non-forest Industry Heat and Power Opportunities

For decades, wood fuel has been the primary source of heat energy for the BC pulp and paper industry as well a significant portion of the solid wood industry. In the last decade new industries have discovered the benefits of mill residue as a source of heat and power.

Several growers in the hydroponic hothouse industry in the Fraser Valley have discovered that they can significantly reduce their annual heating bill by switching from natural gas at >$10/GJ in 2005 to wood residue hog fuel at <$2.00/GJ. Some smaller growers have decided to utilize wood pellets as an alternative to natural gas. The price of wood pellets in the Fraser Valley is significantly higher than mill hog fuel (>7.00/GJ) but the capital cost of a wood pellet burner is significantly less than most step grate hog boiler systems. Wood pellets also have the advantage of convenience and burning much cleaner than mill hog fuel thus avoiding the need for stack emission controls such as an electrostatic precipitator.

In Europe, significant wood residue fuel is consumed in district heating systems that are common throughout the region. In BC, there are limited examples of district heating systems despite the obvious efficiencies of such systems.

- The Revelstoke Community Energy Corporation has built a new 1.5 MW wood residue boiler that will consume ~6,600 tonnes of hogged wood residue annually. The boiler provides heat energy to meet the heating requirements of Downie St. Sawmill’s dry kilns. The boiler also produces hot water piped in a district heating system to meet the heating requirements of several public and private buildings in the City core.
Victoria’s Dockside Green condominium project is currently assessing the feasibility of the use of gasified hog fuel to provide district heating to the complex.

VANOC has looked at the feasibility of utilizing wood residue fuel during the 2010 Winter Games. One potential showcase is the potential use of gasified wood residue to fuel the Olympic flame.

Further, but unexplored opportunities exist at UBC as well as Central Heat in downtown Vancouver where natural gas and oil are now used to fuel district heating systems.

Vancouver based Nexterra Energy are now working with Johnson Controls on the installation of a wood gasification system at the University of South Carolina in a district energy configuration.

Several other BC communities including Prince George and Nakusp are also investigating wood fired district heating applications.

The Federation of Canadian Municipalities is interested in the development of district energy systems. In this regard, the Federation was responsible for a $95,000 grant from the Green Municipal Fund (GMF)\(^{33}\) awarded to Aquatera Utilities Inc. to develop a community energy plan for Grande Prairie, Alberta. This project is tied to a wood residue cogeneration project developed by CanHydro with wood residue supplied by Canfor’s Grande Prairie sawmill.

### 7.6 Small Scale Power Development

Small scale wood residue power development has been constrained in BC by the requirement to employ first class steam engineers to operate high pressure steam vessels. Consequently the only power development <20 MW has been at plywood mills that typically already have steam engineers on staff. This is also the primary reason why BC sawmills employ indirect fired hot oil energy systems rather than steam boilers to dry their lumber production. The employment of steam engineers is not a requirement throughout much of the USA and Europe. As previously indicated, Dutch based Essent Energy remotely staffs several wood fuelled power plants significantly reducing labour costs compared to similar plants in BC.

Medium to large BC sawmills have an electrical energy demand of 5-10 MW of power. While the business case for replacing natural gas at such mills is relatively robust, the business case is less than robust for power production using traditional steam boiler technology. However, the development of an internal combustion engine fired by clean wood residue syngas may overcome this barrier. Nexterra Energy is exploring this possibility with Tolko. The first stage in this important development is to demonstrate that the gas cleanup stage is doable and also economic. Should this technology prove feasible, the predicted energy efficiency is expected to be approximately 45% which compares favourably with simple cycle natural gas turbines at <35% efficiency.

Even smaller scale wood residue power development may be feasible in off-grid communities. BC Hydro currently operates several diesel powered generators in off-grid locations throughout BC. The rising cost of diesel and the cost of transporting this fuel mean that wood residue power generation could be feasible providing there is a source of wood fuel such as mill residues or harvesting debris. The use of wood residue syngas and internal combustion engines would appear to be an obvious solution for communities now paying in excess of $170/MWh for diesel generated electricity compared to BC Hydro on grid residential rates at $67/MWh.

\(^{33}\) GMF are made available via the Federation of Canadian Municipalities (FCM) under a $550 million program directed by Natural Resources Canada (NRCan).
7.7 Forest Industry Energy Self-Sufficiency

Despite some diversification in the provincial economy, the forest industry remains the workhorse of the BC economy. The value of the industry’s sales -- including both solid wood and pulp/paper products -- should top $18 billion this year. Forestry supplies more than 40 per cent of BC’s international exports and manufacturing shipments. It accounts for some 85,000 direct jobs, plus many more indirect ones once multiplier effects are taken into account. Even in the population-rich Greater Vancouver region, estimates suggest that forestry supports up to 120,000 direct and indirect jobs. Outside of south-western BC, it is the leading source of private sector income in scores of communities. The BC forest industry is a very significant source of revenue for all levels of government. The forest industry and its employees contribute some $4 billion per year to government coffers. Moreover, the BC sawmilling industry is the primary source of wood fuel for the BC pulp and paper industry, wood pellet industry and non-forest industry users of wood energy. Ensuring the continued health and viability of the forest industry is therefore a key objective for a viable wood energy strategy.

The BC forest industry is by far BC’s largest energy user. In 2000, the industry consumed 351 PJ of energy in the form of wood residue fuels, fossil fuels and electricity. This represents 63% of total industrial energy consumption in BC. Fortunately, more than 69% of the forest industry’s energy consumption is self-generated from its own wood residues in the form of mill hog fuel and black liquor. Purchased fossil fuel energy consumption has decreased significantly in recent years as prices for natural gas, propane and heavy fuel oil has risen. Rising fuel prices have also caused the industry to become more conscious of energy use leading to investment in fuel efficiency projects. In this regard, BC Hydro has a very effective Power Smart program whereby BC Hydro provides guidance, expertise and funding toward energy efficiency projects.

While the degree of energy self-sufficiency is laudable, it pales in comparison to the Nordic pulp and paper industry where many mills are 100% energy self-sufficient with a number of mills net electrical energy producers. Not only do competing Nordic mills have an operating cost advantage they also enjoy significant revenues from electricity and GHG sales. This fact is recognized by many BC pulp producers some of whom have established a long term goal of energy self-sufficiency.

7.7.1 Sawmill Energy Perspective

Rather than transporting mill wood residues for off-site applications, it would appear logical to utilize wood energy where it is generated for both heat and power production. In this context, the value of a tonne of mill residues is highest at the site where it is generated. Transportation costs quickly drive up the cost of mill residues. Traditionally it has been uneconomic to transport hog more than 150 km in the BC interior. Rising natural gas prices have likely increased this economic haul radius but the fact remains that hog fuel still has its highest value at the site where it is generated especially if it can be utilized to offset high cost natural gas or propane. For example a sawmill using natural gas at $10/GJ would realize operating fuel cost savings of at least $9/GJ by switching from natural gas to its own hog fuel. When measured against today’s natural gas prices, the value of a tonne of mill hog fuel often exceeds $100/BDt, well in excess of what mills are now receiving for their pulp chips. A barrier preventing mills from making this switch is often the high capital cost of traditional wood energy systems. Current quotes on a typical step grate hot oil wood energy system for a medium to large interior sawmill can exceed $15 million. Even with today’s high gas prices, the payback on this capital can exceed five years which is

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34 Finlayson J. You call this an economic boom? Some sectors of British Columbia’s economy may be in an upswing, but the forestry industry faces continued challenges. National Post/Financial Post, August 17, 2006
35 CIEEDAC. 2003.
often beyond the payback hurdle for some forest companies especially during periods of depressed earnings and internal capital availability.

Switching from natural gas to a mill’s own wood residues will reduce the amount of mill residues that must be shipped off-site or incinerated as waste. But a typical sawmill only requires approximately 25% of its total bark, sawdust and planer shavings to dry its lumber production. Therefore, unless the mill is able to sell its whitewood to a potential customer such as a pellet producer or is within proximity of a kraft pulp mill that can utilize bark in its power boiler, the sawmill is simply forced to dispose of its surplus residues in a wood residue incinerator. Power generation is an obvious potential use for the remaining wood residues. However, the volume of wood residue produced by most interior sawmills would produce less than 20 MW of power - typically the economic threshold for small scale power production employing traditional steam turbine technology. The potential to gasify wood residue and produce power utilizing an internal combustion engine may overcome this economic barrier (see Section 8.2).

### 7.7.2 Pulp and Paper Perspective

The Canadian pulp and paper industry, unlike the sawmilling sector, has suffered from poor markets and earnings for several decades. As a result, there has been a lack of investment to keep mills competitive in world markets. Several mills in Ontario, Quebec, New Brunswick and Saskatchewan have been forced to close as a result of continued financial losses. BC mills are faced with the same poor markets. Fortunately, and somewhat ironically, the MPB epidemic has lead to an oversupply of sawmill residual chips that has depressed the price of pulp chips and improved earnings in the pulp sector. While sawmills have seen their chip revenue decline, BC pulp mills now enjoy some of the lowest fibre costs in the world. Coupled with relatively low electricity prices, BC pulp mills have a significant economic advantage compared to eastern Canadian mills. Despite this economic advantage many BC mills are still losing money and failing to invest in equipment renewal. Mills in tropical countries such as Brazil and Indonesia are more modern and four to five times larger than BC mills and thus enjoy economies of scale. These mills also have an advantage of much lower labour costs. It is therefore imperative that BC mills lower their operating costs. One of the few cost items that the mills can influence is purchased energy by self generating all of their energy needs and reducing energy costs to virtually zero.

Pulp and paper mills consume significantly more energy than sawmills. To control energy costs BC kraft pulp mills employ power boilers and recovery boilers that self-generate heat and power from sawmill wood residues and black liquor recovery. Indeed the BC pulp and paper industry now produces more than 600 MW of power primarily for its own use in cogeneration configurations. However, most pulp mills are still net purchasers of electricity. Kraft pulp mills also consume a significant volume of natural gas in their lime kilns. Despite significant recent progress to further increase energy self-generation, the BC’s pulp and paper industry is still collectively BC Hydro’s largest industrial customer and Terasen Gas’s largest gas customer. Therefore the largest and most immediate opportunity to utilize wood energy is within the BC pulp and paper industry.

The business case for natural gas displacement in the BC pulp industry utilizing wood residue fuel is strong. Paybacks range from 2-5 years dependent on the cost of delivered wood residue fuel, the application and the price of gas. Gas is used in two distinct applications in the pulp industry. Either in power or package gas boilers or in kraft pulp lime kilns. Gas substitution in power boilers is relatively straightforward although some boilers are forced to use some gas simply because the boiler can not physically take more wood fuel which would be required to account for its lower relative unit energy

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36 Craig Campbell Price Waterhouse Coopers.
value. This problem is exacerbated with wet wood fuel. Lime kiln gas substitution is also a challenge as the lime mud produced in the kiln must meet certain quality criteria and can not be contaminated with particulates produced by the direct incineration of wood residue fuel. The gasification of wood residue fuels could effectively deal with both the power boiler capacity issue as well as the lime kiln particulate contamination issue. Nexterra Energy is currently working with several pulp and paper companies to determine the feasibility of these two important applications. The projected payback on capital for these applications is typically <2 years.

Unlike greenfield power projects, as recommended by the BioCap report, kraft pulp mills have the advantage of having steam engineers already on staff. Additional power production therefore bears virtually no added operating labour costs. In addition, many mills have existing hog fuel unloading and storage facilities that are added costs for greenfield power projects. New kraft pulp mill power doesn’t necessarily need to be based on the utilization of significant amounts of new wood residue fuel. Boiler upgrades at existing kraft mills have the potential to generate several hundred more MW of power. Most BC pulp mills operate power and recovery boilers built in the 1960s and 70s that operate in the range of 600 psi, whereas boilers focussed on power production, such as Epcor’s facility in Williams Lake, operate at >1200 psi thus improving the efficiency of converting wood residue into power. Boiler replacement however is very capital intensive and there would likely need to be another business case driver such as increased pulp production, or the simple need to avoid maintenance costs on aging boilers to justify the investment in power production.

All BC Pulp and paper mills and some larger sawmills are considered as industrial customers under the regulated utility rates approved by the BC Utilities Commission. As such these mills pay much lower rates than commercial or residential power consumers. In 2006, the industrial power rate was increased to $38/MWh. This is well below BC Hydro’s cost of new power acquisition that averaged $74/MWh in the 2006 contract awards resulting from an open call for new power supply. It makes economic sense therefore for BC Hydro to encourage such customers to generate additional power and wean themselves off the grid.

This was the basic motive behind BC Hydro’s Load Displacement Program that existed until 2004 and saw BC Hydro invest in two pulp mill load displacement projects. This program was essentially a win/win program. The two pulp mills reduced their purchased electricity costs to virtually zero and the payback on this cost saving investment was vastly improved by BC Hydro’s investment. This was a particularly attractive program for pulp mills lacking capital to complete projects simply to keep mills operating efficiently. The lack of investment capital is the result of more than a decade long slump in world pulp markets.

From BC Hydro’s perspective the Load Displacement Program meant the lost sale of power at a rate of $35/MWh. However, their investment costs amortized over the life of the contract were less than $15/MWh. BC Hydro’s total cost was therefore $50/MWh. Losing customer sales by investing in customer power projects would normally not be a wise business decision. However, BC is currently a net importer of power \(^37\) and BC Hydro’s other supply-side options were to increase power imports at a cost of $57/MWh in 2005 or buy power from new independent power projects in BC which in 2006 averaged $74/MWh. For BC Hydro, Load Displacement was a least cost business decision. Moreover, BC Hydro was able to take this displaced power and sell it at more lucrative residential and commercial rates.

\(^{37}\) BC Hydro has been a net importer of electricity in each of the last five years, and demand is expected to grow significantly in the next 20 years resulting in an estimated gap between supply and demand of 25 to 45 per cent. BC Hydro 2006.
In 2003, Canfor entered into a 15-year commitment with BC Hydro for a power displacement agreement to build an electrical co-generation facility at Canfor's Prince George Pulp and Paper mill. Under the agreement, BC Hydro contributed $45.8 million toward the project's capital cost under its load displacement program, with Canfor contributing the balance. When amortized over the life of the contract (15 years), the cost of this power to BC Hydro is only $8.37/MWh. The project was completed in the second quarter of 2005 at a net cost to Canfor of $69.6 million. Under the agreement Canfor is required to generate a minimum of 390 gigawatt hours of electricity per year.

The Load Displacement Program was replaced in 2006 with a two tier pricing system for industrial customers. Effectively industrial customers are now charged for power consumption at two different rates. Ninety per cent of the power bill is sold at so called Heritage rates which lock in the value of BC Hydro’s existing low cost generation assets for an extended period of time. The remaining 10 % is set at market rates ($54/MWh) or essentially BC Hydro’s cost of new power acquisition in the 2004 call. The weighted average price remains at the industrial tariff rate that Hydro has applied to increase to $38/MWh. Mills planning new self generation power projects or energy conservation projects can offset their purchased power at the higher incremental rate. This creates a significant new incentive for load displacement that did not exist when all power was sold at a flat rate. The program is particularly attractive to large integrated forest companies that may have several pulp mills and sawmills paying industrial rates. In this instance mills are permitted to pool their industrial power consumption and offset up to ten percent of the total corporate industrial load in a single project. While effective in providing incentives for power conservation projects, the program has yet to spawn any apparent interest in industry self power generation. Perhaps the main reason for the lack of interest in customer power generation is the simple fact that the $54/MWh Tier Two rate is simply insufficient to justify capital investment. The Tier Two rate will be adjusted on April 1, 2008 to reflect the cost arising from BC Hydro’s province-wide CFTs in F2006. An adjustment of the Tier Two rate to $74/MWh to reflect the average rate in the 2006 BC Hydro call for new power generation would likely create significant industry interest in this program. However, an upward adjustment of the Tier Two price would automatically lower the Heritage Rate, creating an unintended disincentive for mills to give up the bulk of their even lower cost purchased power. Finally some companies have already invested in Tier Two projects and their remaining Tier Two power load is simply too small to justify a project. A new BC Hydro investment program in customer power generation at existing pulp mills is likely warranted as a least cost method of acquiring new energy.

Several BC pulp mills are already essentially electrical energy self sufficient as a result of wood residue power generation. Some of these mills are interested in becoming net exporters into the BC grid. Current BC Hydro policy prevents customers from bidding into calls for independent power generation based on projects within the mill. As such mills are essentially no longer customers of BC Hydro, it would make sense to encourage these mills to self generate additional power for sale into the grid assuming they are cost competitive. Given the previous arguments favouring power generation at existing mill sites, it is likely that such projects would be more cost competitive than greenfield power projects where the cost of necessary electrical infrastructure is not prohibitive.

38 The Heritage rate is $24.28/MWh plus demand charges.
Even with an adjustment of the Tier Two pricing mechanism to reflect the current cost of new power acquisition, wood residue power generation is still likely to be marginally competitive especially with run-of-river power generation that dominated BC Hydro’s 2002-03 contract awards\(^{39}\). Wood residue power generation has an inherent advantage over all other renewable power sources as its availability factor can be higher than 90% compared to wind and run-of-river projects that have availability factors between 20 – 40%. The higher availability factor makes this power a much more valuable asset to a utility such as BC Hydro. Because of the crisis situation associated with the MPB and the firm energy advantage of wood residue power, there is an argument for removing wood residue power projects from open calls and instead arranging for an exclusive competitive wood residue power call.

Alternatively, BC Hydro, with approval of the BC Utilities Commission, could establish a so called “feed-in tariff” (or standing offer) for wood residue electricity. Feed-in tariffs essentially require the utility to establish market prices for electricity supply around which proponents can attempt to build a business case. Feed-in tariffs are widely used throughout Europe. The use of this tool might prove difficult in BC given the wide range in feedstock costs and the inherent cost advantage of locating at a pulp mill site. Moreover, feed-in-tariffs require the utility to accurately gauge market forces to determine appropriate power rates. This is a difficult task in a period of rapidly rising construction costs.

### 7.8 Renewable Power Export Opportunity

California has established a renewable portfolio standard that will require 20% of electricity sales to come from renewable sources by 2017. The States Energy Action Plan is attempting to accelerate the 20% target to 2010. Given the availability of MPB roadside residue, there is potentially an opportunity to export renewable wood residue power to the California market. In this regard, Pacific Gas and Electric Company has filed a request for transmission line upgrades with the Public Utilities Commission of the State of California to specifically access renewable power from BC\(^{40}\). As part of these efforts, PG&E intends to fund a pilot program, utilizing the existing transmission infrastructure, under which they will attempt to bring up to 100 MW of capacity from BC. The filing indicates the expected cost of power will be approximately US$0.08 per kilowatt-hour (C$0.09/MWh) at current exchange rates.

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\(^{39}\) Note: 60% of the energy contracted in the 2006 call was from non-hydro sources  
8  New Commercial Wood Energy Technology Opportunities

Two relatively new technologies have emerged as significant alternatives to the direct firing of wood residues for heat and power production. These extremely important technologies, that are being spearheaded by BC based companies, are both at the commercial demonstration stage of development. One of the difficulties in demonstrating new technologies in Canada is the lack of research and development tax credits. Too often technology is developed in the laboratory or at a pilot plant but never demonstrated commercially because industrial partners are unwilling to finance the risk of being the first proponent. Extending R&D tax credits to the demonstration stage of technology development would spur technology implementation as would the flow through of tax credits to investors.

8.1  BioOil

Pyrolysis BioOil is a combination of oils and tar produced when heat (<1,100°F) is applied to wood residue in an oxygen free environment. The resulting syngas can be used directly as a fuel, or cooled to produce a liquid fuel (BioOil) that can be used a substitute for fossil fuels such as natural gas or diesel. BioOil is liquid and pourable at room temperature. Its higher heating value is less than most fossil fuels but compares well with other bio-fuels. A by-product of BioOil production is charcoal, which can in turn be used for briquette production or upgraded into activated charcoal.

In Canada, BioOil is being produced by Vancouver based DynaMotive Energy. DynaMotive perfected the technology in a 15 tpd pilot plant at BC Research. DynaMotive’s first commercial project is at Erie Flooring in West Lorne, Ontario where they have established a 100 tpd BioOil facility produced from wood flooring waste. A portion of the BioOil is being used to produce power in a 2.5 MW gas turbine. Trials have also been recently conducted to demonstrate that BioOil can be used as a substitute for natural gas in a kraft lime kiln application. One of the key advantages of BioOil is its portability. Unlike hog fuel that is often 50% water, BioOil is typically 23 % water. Moreover it is a densified fuel that can be transported in tanker rail cars or other liquid fuel vessels. A disadvantage of BioOil is its relatively high cost of manufacture. Feedstock preparation is a significant cost as the wood residue must be dried and then refined to a virtual dust. Consequently the cost of BioOil will likely approximate $5/GJ at a 100 tpd scale41.

The Ontario government has provided $771,000 to Advanced BioRefinery to develop portable BioOil equipment capable of processing harvesting residue into BioOil as part of the McGuinty government’s strategic five-year ReNew Ontario, $30-billion infrastructure investment plan.

8.2  Gasification

Wood residue gasification is similar to pyrolysis BioOil production. BioOil synthesis takes place in a virtual oxygen free environment at relatively low temperature. Gasification is essentially pyrolysis of wood at high temperatures exceeding >1300°F. With gasification, all of the wood is converted into syngases. Unlike BioOil, there is no residual charcoal, creosote oils or tar. The burnable components of the syngases are carbon monoxide, hydrogen and methane. In BC, Westwood Fibre, Heuristic Engineering and Nexterra Energy are all producing commercially available gasification units. Unlike

41   Richardson B. CFO DynaMotive Energy. Personal communication.
pyrolysis BioOil, the resulting syngas is most often utilized at the point of production although it is technically feasible to transport the syngas in a gas pipeline. Also, gasification technology does not require any significant fuel preparation. Consequently the cost of syngas produced and utilized at a sawmill is typically <$1/GJ.

Nexterra Energy has recently completed a Heffley Creek application that gasifies a portion of the plywood mill’s own hog fuel to supply heat to veneer dryers as well as to log conditioning vats. An added environmental benefit of this project is the ability to incinerate volatile organic hydrocarbon (VOC) emissions from the veneer dryers in the gasifier oxidizer thereby avoiding air pollution.

![Aerial View of Tolko/Nexterra Heffley Creek Gasifier Project](image)

In addition to plywood applications, gasification technology can also be utilized to displace natural gas in sawmill dry kilns as well as pulp mill lime kilns and power boilers. Beyond the forest industry, Johnson Controls and Nexterra are currently installing a district energy system at the University of South Carolina where heat and power for the university campus will now be produced from gasified mill hog fuel.
A new wood gasification system is converting about 25,000 BDt per year of mill wood residue produced on-site at Tolko's Heffley Creek plywood mill into a new low-cost, clean, thermal energy “syngas” that is replacing high-cost natural gas and moving the mill closer to energy self-sufficiency. The gasification system will not only save the mill more than $1.5 million in annual fuel costs, but will also improve local air quality and reduce Tolko’s greenhouse gas emissions by 12,000 tonnes per year. This is equivalent to taking almost 3,000 cars off the road.

The project is displacing approximately 235,000 GJ per year of natural gas that was used at the mill to produce hot water for log conditioning and to dry veneer – enough energy to heat approximately 1900 typical residential homes in British Columbia.

Nexterra’s gasification technology is very cost competitive with traditional step grate wood energy systems. Depending on the application and the price of natural gas, paybacks on capital typically range from 1.5 to 3 years, an attractive return rate even for cash strapped forest product companies.

9 Wood Energy Research, Development and Demonstration

In addition to BioOil and gasification technologies that are now at the demonstration and commercial stages there are other wood energy technologies that could potentially be applied to the wood resources of BC. Ethanol BC was created in 1999 to fund research development and demonstration of new wood energy technologies that would ultimately lead to the closure of wood residue incinerators in the BC interior. In this regard, funding for projects sponsored by Ethanol BC comes from regulated increases in Waste Discharge Permit fees imposed by the provincial Ministry of Environment on wood residue incinerators. Companies have the option of paying the fees as invoiced or redirecting the increase in fees to Ethanol BC. Ethanol BC is administered by Forintek Canada Corp. with a board comprised of government and forest industry representatives. Grants averaging $75,000 per project have resulted in the start up of several new BC based technology companies including DynaMotive Energy, Nexterra Energy and Lignol Innovations. The wood pellet industry has also received a grant for a market feasibility study. Typically grants from Ethanol BC are used as seed money to lever larger grants from federal research funding agencies such as Technology Early Action Measures (TEAM) or Sustainable Development Technology Canada (SDTC). For example, a recent grant to Lignol Innovations ($75,000) was imperative in the approval of a $1.6 million award from SDTC.

Ethanol BC funding has provided important seed money to wood residue energy technology companies. But the funding is minor in comparison to funding available from the federal government. In this context, the Premier’s Alternative Energy and Power Technology Task Force has recommended that the BC government establish a $50 million Sustainable Energy Fund that would be used to demonstrate made in BC energy technologies within BC. Examples of new research and demonstration include:

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42 J. Rhone CEO Nexterra Energy.
Wood gasification and BioOil development have now reached commercial scale development for some applications. However, further research, development and demonstration is required for certain applications. For example, wood gasification and application to a kraft lime kiln has been done but only on a limited scale in Europe. Nexterra Energy and DynaMotive are both expecting to develop and demonstrate this application within the next year. The development of these applications is an important step in weaning BC’s kraft pulp mills off fossil fuels and reducing purchased energy costs.

The inability to cost effectively produce wood fuel generated electricity on a small scale using traditional steam turbine technology is a significant barrier to the sawmilling industry’s move toward energy self sufficiency. The clean up of wood residue syngas and its application to an internal combustion engine to produce electricity on a small scale will be critical to the sawmilling industry in this regard.

The BC wood pellet industry is currently utilizing exclusively whitewood mill residues. Research and market opportunity studies are required to determine the feasibility and opportunity for a blended bark and whitewood pellet. The costs of separating bark from whitewood are significant especially if harvesting debris becomes a significant source of wood pellet furnish. Moreover, new opportunities would have to be found for the surplus bark resulting from such a process. From an end user perspective there are some issues with ash and boiler corrosion associated with bark pellets but these are currently being investigated. Ultimately, there is very little difference in the higher heating value of a whitewood versus a bark pellet. The BC Wood Pellet Association has recently funded a Chair at UBC headed by Dr Shahab Sokhansanj, formerly associated with the US DOE Oakridge laboratory, to work on some of the above problems. But R&D support for the wood pellet industry pales in comparison to the support given the wood pellet industry in Europe. More than 130 scientists support the industry in Europe. At the present time the only government support for one of BC’s fastest growing industries comes from NSERC.

The development of transportation fuels from wood residue has received significant attention in recent years due to the rising price of fossil fuels, concerns about energy security and GHG emission reduction.

Wood residues are potentially an important feedstock to the production of ethanol. However, at the present time wood ethanol is uncompetitive with grain, corn and sugar cane based ethanol production. There are several technology pathways to convert wood residues into ethanol including the conversion of wood residue syngas into ethanol. However, one of the more promising pathways is being developed by Lignol Innovations at their BC Research laboratory. The Alcell biorefining technology acquired by Lignol was developed by a General Electric subsidiary and Repap Enterprises at a cost of $200 million. The process produces two products, lignin that can be used as a substitute for industrial glues such as phenol formaldehyde as well as ethanol and other valuable extractives. Traditional acid hydrolysis ethanol technology destroys the binding properties of lignin rendering it useless for adhesive applications. The potential advantage of Lignol’s technology is summarized on their web-site. “The estimated cost of production from a Lignol biorefinery is CDN $0.30 per litre. It is the value of co-products that drives down Lignol’s cost of ethanol production. This compares to a corn/ethanol industry standard cost of CDN $0.35 per litre and another cellulose/ethanol proponent’s

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43 Melin S. Aug. 2006. Address to the Canbio Conference Vancouver BC.
target cost of CDN $0.40 per litre, on the same basis." Unfortunately wood ethanol technology is still at the laboratory stage.

The demand for renewable transportation fuels has sparked the worldwide development of the biodiesel industry. Biodiesel is a diesel blended fuel with the additive made from grain oils such as canola or animal fats or greases such as recycled restaurant grease. It is also potentially feasible to utilize wood residues for biodiesel production. Gasification of wood residues followed by the catalytic conversion of the syngas in a “Fischer-Tropsch” reactor yields an additive that can be mixed with diesel to form biodiesel. Unlike wood ethanol, this technology is in the early stages of development and much more research and development is required before this technology would be ready for commercialization.

Further wood energy research opportunities were identified in a July 5th meeting of specialists in the BC academic community organized by Allan Potter, Director, Forest Research Opportunity BC. The notes and the summary of this meeting are included in Potter 2006. At the national level, BioCap has been created as a cluster of Canadian university academics focused on biomass energy R&D. BioCap has received funding from the BC MoFOR to examine opportunities focused on the MPB epidemic.

The July 5th meeting of academia (Potter 2006) is a symptom of a problem with R&D wood energy development. Wood energy technology development is being spearheaded by world renowned experts at several BC based organizations including UBC, Forintek, FERIC and Paprican as well as the private sector. So while BC has world class expertise, there is very little coordination of this research effort especially between the private and academic sectors. Companies such as Nexterra Energy that have attempted to work with UBC have been told that any new intellectual property rights developed by UBC scientists working with Nexterra are the property of UBC. This is an untenable situation for Nexterra and consequently there is no R&D cooperation.

Serious consideration should be given to the creation of a bioenergy research network that would bring together the research efforts of UBC, Paprican, Forintek, FERIC, the provincial and federal governments as well as the private sector. The bioenergy network could be focused on renewable biomass energy development and possibly housed in a CANMET Energy Technology Centre specializing in biomass energy development similar to the CANMET Devon centre that supports Alberta’s tar sands development. It is important that a BC centre work on and support industrial development in western Canada and in this sense the R&D program should be driven by a government/industry board.

BC has a significant opportunity to showcase its wood energy technology at the upcoming 2010 Olympic Winter Games. In addition to the potential of cogeneration of heat and power using a combination of gasification and BioOil technologies, there is the potential to operate fleet vehicles on ethanol derived from BC wood residues. Perhaps the most symbolic opportunity is the potential to fuel the Olympic torch with syngas produced by BC developed wood gasification technology.

10 Recommendations for Implementation

Based on the review of options included in this report as well as interviews held with a variety of industry and government officials, it would appear that there are two potentially economically viable options for utilizing the wood energy resources in BC.

The first option is to expand the burgeoning wood pellet industry in BC but at the same time create a domestic market in BC so that this important source of renewable energy is used as much as possible to supply the energy needs of BC.

The second and most important option in the eyes of both government and forest industry officials is energy self-sufficiency for the BC forest industry. Not only is the forest industry an important user of wood energy, it is also critical to the success of the delivery of wood fuels to itself and other users such as the wood pellet industry. The following recommendations are therefore focused on accomplishing these two objectives.

**BC Hydro Power Acquisition Financing** – Reinstate BC Hydro’s capital financing program for new wood residue power development with existing industrial customers.

**RFP Process** - Have BC Hydro consider a dedicated wood residue Call for Tender.

**Fuel Price Risk** - Encourage BC Hydro to consider taking on some of the fuel price risk for wood residue fuel above a certain baseline in the same way they were prepared to take the gas price risk for Combined Cycle Natural Gas (CCNG) projects.

**Amendment of the Tier Two Power Price** – BC Hydro apply for an upward amendment of the Tier Two industrial power rate based on the results of the 2006 independent power contract awards. [Under the BCUC-approved Stepped Rate program, BC Hydro is obligated to change the Tier Rate on April 1, 2008.]

**Federal incentives** - The federal government should
- Implement the Large Final Emitter System and GHG Offset Trading system as soon as possible
- Implement the RPPI program immediately.
- Extend R&D tax credits to first commercial demonstration projects and permit the flow through of losses to shareholders of technology companies.
- Expand the Market Incentive Program for Distributors of Electricity to include more provincial and private utilities.
- Allow the Canadian Industry Program for Energy Conservation (CIPEC) to consider funding biomass fuel switching and cogeneration projects in addition to its energy efficiency mandate.
- Increase the level of funding for all CIPEC energy programs. Extend the Renewable Energy Deployment Initiative (REDI) beyond its planned end in March 2007, and specifically increase the level of funding for projects from $80,000 to $1 million per facility.

**Biomass Inventory** – The provincial MoFOR should attempt to quantify the volume and cost of wood energy sources including mill residues, pulp chip surpluses, harvesting residues and finally that portion of the MPB affected timber that will not be utilized by the forest industry but might be available for energy purposes. Similarly the Ministry of Agriculture should attempt to determine the volume and cost of utilizing agricultural residues for energy purposes.
**Shelf Life of MPB Timber for Energy Purposes** – Studies should begin immediately to determine the longevity of MPB timber for energy purposes.

**Salvage Tenure for Harvesting Residues** – The MoFOR should consider the issuance of long term salvage licenses for those energy companies that require such security.

**Upgrading Forest Roads** – The MoFOR should use a portion of their MPB funding to upgrade forest roads so they are suitable for the transport of forest fuels.

**Public attitudes toward wood residue projects** - The government should undertake a public education program on the benefits of replacing fossil fuels with BC wood residues.

**Property and sales tax incentives** - The Province should consider sales tax exemptions for wood residue cogeneration projects as BC has done for run-of-river projects.

**Research and Demonstration Tax Credits** – Both the federal and provincial governments should consider the extension of R&D tax credits to first commercial demonstration projects and the flow through of tax credits to shareholders in publicly traded companies.

**Lack of Capital for Forest Industry Heat and Power Development** – The BC government should encourage the forest industry, independent power producers and BC Hydro to work collaboratively on developing, financing and operating new wood energy facilities.

**Reduce the Cost of Delivery of Harvesting Residues** - The BC government, FERIC, IPPs, wood pellet producers and the forest industry should work collaboratively on reducing the cost of delivering harvesting residues for energy purposes. In this regard, field trials should be conducted under the direction of FERIC to determine the most cost-effective method of delivery.

**Review Steam Engineer Staffing Requirements** – The BC government should review the staffing requirement for steam engineers operating high pressure steam vessels to make them consistent with jurisdictions such as Holland.

**Research and Development Funding** – As recommended by the Premier’s Alternative Energy and Power Technology Task Force - the BC government should establish a $50 million Sustainable Energy Fund that would be used to demonstrate made in BC energy technologies within BC.

**Coordinate Wood Energy R&D** – The wood energy R&D efforts of Forintek, Paprican, FERIC, academia and existing BC based wood energy companies should be coordinated, and the intellectual property rights policy of UBC with respect to contracted research should be reviewed.

**Create Bioenergy Research Centre** - A Bioenergy Research Centre should be located on the UBC campus. It should be focused on renewable biomass energy development and housed in a new CANMET Energy Technology Centre specializing in biomass energy development with the R&D program driven by a government/industry board.
The Timeline for Emerging Bioenergy and Biorefining Technologies

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Prepared for
BC Ministry of Forests and Range
BC Ministry of Energy, Mines and Petroleum Resources
BC Hydro

2006

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Summary

There is much debate in BC and internationally surrounding the conversion of wood to bioenergy (electrical, thermal, or substituting for natural gas), its conversion to transportation fuels (ethanol or hydrocarbons), and its potential use as a base for a broad range of biomaterials. This debate is driven by the recent 3 fold increase in global crude oil prices and 4 fold increases in North American natural gas prices. In BC bioenergy and biorefining are seen as areas which could address the increasing inventories of dead pine from the mountain pine beetle epidemic. On a global scale the use of biomass as the base for a bioeconomy is seen as a solution to greenhouse gas accumulation and global warming.

The object of this paper is to answer the question “what is the timeline for the successful implementation of emerging technologies which will be capable of converting wood biomass to energy in the forms of electricity, substitutes for natural gas, or fuels in either liquid or solid form?”. The conclusion is that the technologies are already readily available to convert wood residue into electricity and power for local thermal heating. The decision to use the technologies is driven by the cost of delivering the wood to the plant and the marker prices for energy. Similarly the technology for making solid fuel wood pellets is also readily available, although there is scope for research to reduce the costs of delivery of fibre and to optimize conversion costs. The technology for using wood to generate a syngas to substitute for natural gas has been piloted and is becoming commercially available. The high prices of natural gas are allowing the capital investment for such technology to be recovered in a 2-3 year time period. Over the next five years the technology will evolve to use syngas as a substitute for natural gas in pulp mill lime kilns and lumber kilns. The large scale processing of wood into high hydrogen grade syngas for conversion to hydrocarbons will also be demonstrated within 5 years, although the capital costs of such investments will be in the billion dollar region and are not likely to happen without strategic government co-investment. It is a process however which could be combined with an existing pulp and paper mill complex. Ethanol production is receiving much interest at present given US and Canadian government targets to increase its usage in blends of gasoline for automotive use. Most of this will come from fermentation of the starch in grain. The vision is to use the lignocellulosic material left over from crops for both food and fuel production. The same technology can be applied to wood biomass. However there are still significant barriers to make the technology economical. One leading researcher quoted ‘$2 billion and 20 years’. Given the strategic importance in the US, a 10 -20 year time frame is realistic. The integrated biorefinery which can convert lignocellulose to pulp, energy, ethanol and a range of chemical intermediates through biological conversion processes is a noble long term vision. There are significant technical and business barriers to overcome. With research effort, and with disciplined networking and research collaboration, it will be viable but will likely take over 20 years.

BC has a core of research talent in this area. However progress in developing knowledge that can be implemented in BC will require incremental funding. Such funding should be strategically managed to ensure there is focus on technologies which can be readily implemented in BC, and also to ensure collaborative participation in longer term projects that are happening globally.
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Summary Timeline of the Technologies and Barriers in Converting Wood to Energy and Fuels
Attendees for BC Bioenergy Strategy Meeting with Academic Community, July 5th 2006, Vancouver
Objectives

The objective of this report is to try to answer the question, “What is the timeline for the successful implementation of emerging technologies which will be capable of converting wood biomass to energy in the forms of electricity, substitutes for natural gas, or fuels in either liquid or solid form?”.

Work Performed

A two prong process has been used:

- Review current activities in this area
- Consult with the Western Canadian academic community via a seminar of academics involved in bioenergy research.

Review of Current Activities

The area of bioenergy has been receiving a great deal of attention globally. Consequently there has been opportunity to tap into much current thinking. Examples include:

- Participation in global seminars:
  - World Congress on Industrial Biotechnology and Bioprocessing, Toronto, July 2006
  - International Energy Agency Workgroup, Vancouver, August 2006
  - Industry Canada sponsored workgroups to develop ideas for the installation of a biorefinery in Canada, November 2005

- Strategic development initiatives:
  - Forest products/bioenergy strategies in Europe (Forest Bio Platform) and the US (Agenda 2020)
  - Initial strategic development for the new amalgamated Canadian forest research institute

The current interest in BC has been driven primarily by the mountain pine beetle epidemic which is going to leave much of the commercial pine in the province dead. Much research is ongoing to establish how long this material can be used in conventional forest products, and also to find alternative uses for the wood. The Chief Forester has increased annual allowable cuts to use the fibre while it still has economic value. Non-traditional options that have economic merit and are key considerations in the larger body of the BC Bioenergy study include its use for energy (either for electricity generation, or to burn and substitute for natural gas), or its conversion to solid wood fuel pellets.

A larger context is also emerging both in North America and globally. In Europe there is a drive for green energy supply in order to meet Kyoto commitments. Diversification of energy supply away from dependence on Middle Eastern oil and Russian natural gas are policy drivers. Similarly in the US there is a strategic drive to reduce dependence on Middle Eastern oil. Hence there is now significant interest in developing economic technologies to convert biomass to energy and fuels. The “One Billion Ton” challenge is a study carried out by the US Department of Agriculture to determine if it is feasible to supply over one billion tons of biomass per year in the US for the sole purpose of conversion to energy and fuels. The study concluded that the residues from crops and fast growing fibres, such as switch grass, could indeed supply close to the desired one billion tons per year. US forests could also supply a further 300,000 tons. For perspective the estimated amount of pine that will be devastated by the beetle in BC over the next 20 years is 800 million m$^3$, or approx ½ billion tonnes.
The North American and European forest products industries also need to reinvent themselves. There is a realization that the industry can offer more than the conversion of logs to lumber, pulp and paper. Much thinking has gone into the future research and technology agenda in Europe. Driven largely by Finland and Sweden, the EEC has developed a very comprehensive Forest Technologies platform. Key elements in this platform are the energy self-sufficiency of the sector, and the development of an alternative array of commercial products from the ligno-cellulose material from which wood is formed.

In the US, Agenda 2020 developed by the American Forest and Paper Association and the Department of Energy has presented a similar vision, i.e. product diversification from a sustainable forest base by advancing the wood products revolution, moving pulp and paper mills to biorefineries, and becoming a net producer of energy.

The US agricultural sector is a big driver. Policy changes to encourage the use of ethanol, (10% ethanol blended gasoline is widely used in the US), are often driven by state emissions regulations. As a result, the US will soon be in an ethanol deficit situation. Corn will be grown and used for the manufacture of ethanol, but this will also be competing with its use for food and animal feed.

In the last year there have been strategic studies funded by Industry Canada to evaluate the concept of turning pulp mills to biorefineries for the manufacture of a wider array of products. Alberta is developing a strategic plan to capitalize on its renewable plant fibre from forest and agricultural crops.

Critical questions on all these strategies relate to what technologies are currently available given capital limitations, what needs to be developed, what technology barriers remain, and what is a realistic time estimate before commercialization. These were the questions raised and discussed at a meeting of Western Canadian academics on July 5, 2006.

**Consultation with Western Canadian Academic Community**

The meeting with academics involved in bioenergy research was held on July 5, 2006. It consisted of a series of presentations followed by round table discussions. Some of the discussion and points raised are highlighted in the Discussion Summary below.

The agenda attempted to cover the following areas:
- Direct fired electricity generation into the provincial grid
- Conversion of wood and black liquor for local heat and electricity
- Wood gasification as natural gas substitute and/or electricity generation
- Conversion of wood to solid fuel
- Conversion of wood to liquid fuel, Biodiesel, Fischer-Tropsch
- Conversion of wood to ethanol
- Other key technologies?

**Discussion Summary**

**Conversion to Electricity**

The option of using dead pine for conversion to electricity in a state-of-the-art, direct fired power plant has been researched. A presentation was made by Dr. Amit Kumar of the University of Alberta. The
The report concludes that at $70/MWh electricity pricing such a project is breakeven. There was some discussion that this may be low and further analysis is required through detailed engineering proposals to flesh out better the current cost information. It was raised that the current costs of capital construction have escalated over the last year. A key component in the cost analysis is the delivered cost of harvested wood as opposed to the lower cost of using residues generated from sawmills. Recent proposals for tender approved by BC Hydro have included some projects selling power at ~$80/MWh.

The state-of-the-art technology in Finland is a plant based on circulating fluidized bed combustion technology which generates 200MW+ electricity. The plant is flexible to burn 100% biomass, 100% coal or combinations in between. Further technology development in this area will revolve around maintaining longevity of circulating fluidized beds and reducing slagging i.e. the formation of mineral deposits from the wood which compromise the efficiency of the fluidized bed. This technology is ready to go if payback on capital can be made. Lead time to build a facility is 2-3 years.

Similar economic feasibility studies on mountain pine beetle killed wood also suggest that ethanol could be produced at 40c/litre, making it possible to compete with oil on conversion costs. There is a need to consider capital requirements/logistics etc. A more thorough discussion on ethanol was held later in the meeting.

There was discussion in the forum that rather than build 300MW plants, a less risky approach would be to install 60MW plants at strategic locations. For example, current pulp mills could be refurbished with new equipment to not only produce power for site consumption but also to supply power to the grid. Much of the necessary infrastructure exists at pulp mills e.g. steam engineers and technical capability. Such a strategy is also predicated on a long term belief in the business viability of the specific pulp mill. Even if this were not to be the case, as long as it is strategically well located a power generation component could be economically viable after a pulp mill closed.

**Gasification of Biomass**

An emerging issue is the potential gasification of the extracted lignin from the Kraft pulping process (black liquor). Dr. Paul Watkinson of UBC gave an overview on gasification technologies. Burning black liquor is currently done to generate thermal energy…could it be gasified to power a steam turbine for power generation and thus increase overall energy conversion efficiency? There are some teething problems here and solutions require further development work.

The whole area of gasification of biomass is large and complex. Much work has been done on coal. Wood can be considered just another solid fuel but there would be some technical issues. The generation of ash can be problematic. Partial oxidation of the solid fuel is required to drive the thermodynamics of the reaction…in this sense wood is partially oxygenated and has some advantages. The result of gasification is ‘Syngas’ but this varies in constitution. The syngas with the highest energy value contains high levels of methane. Medium energy syngas is mainly hydrogen and carbon monoxide and the most likely product from wood. Lower energy syngas is also carbon monoxide and hydrogen but well diluted with atmospheric nitrogen. Gasification technology can range from simple to very complicated in plant scale. A recent development being demonstrated by Nexterra in BC is to gasify wood waste at a Tolko plywood mill and replace natural gas used in wood driers. More than 235,000 GJ/year of natural gas is being displaced thus offsetting an annual cost of approximately $2 million. An emerging opportunity is to combine such gasification technologies and use the product to substitute for natural gas in lime kiln operations in Kraft pulp mills. The cleanliness of the gas and freedom for tar deposits is a critical issue which could be overcome through applied R&D, thus paving the way for commercialization of the technology.
There are no standard gasifiers; they are custom designed for specific applications. The objective is to maximize throughput and provide cost effective gas supply.

**Conversion to Solid Fuel**

The technology to convert wood biomass to solid fuel i.e. wood pellets, is established technology. It is an area which is growing in BC as there is a ready market in Europe for wood pellets, and the process is very amenable to using dead pine. BC currently supplies 1/6 of the EU market in wood pellets. As there is also increasing demand in North America for home heating use, it may make sense to promote this technology for home and localized industrial use in BC e.g., greenhouse heating.

Research in the area is being led by several professors at UBC. Dr Shahab Sokhansanj gave an overview of a 5 year program. Although old technology, there are opportunities for development and improvement in economics. The most energy intensive (and costly) part of the process is the drying stage…..new technology which will dry the pulverized wood by centrifugal force (First American Corporation) may offer significant savings. Consistency of product standards, the optimum white wood/bark mix, and slagging problems caused by bark ash in high pressure coal boilers, are technical barriers that should be addressed if BC is to be a leading supplier. There was a discussion on the economics of the process. Currently if surplus mill residues are used there is a strong business case. However, if the wood is priced to recover the full costs of harvesting and transportation to the mill site the business case may be marginal unless there are savings in the conversion costs or prices increase. A full analysis is provided by B Mcloy (2006).  

**Conversion to Liquid Transportation Fuels**

Technologies to convert wood to transportation fuels are a subject of much international debate. Dr Jack Saddler of UBC gave an overview. The discussion is driven by oil security concerns in the US and Europe, and partly a desire for renewable energy sources which reduce greenhouse gas emissions. Sweden wants to have 100% renewable energy by 2020. There are essentially two technology platforms; the platform for the biological conversion of wood to ethanol, and the thermochemical platform of gasification to syngas and subsequent conversion to organic chemicals.

The conversion to ethanol from lignocellulose (either agricultural residues or wood) is an emerging technology. Currently ethanol is made from the hydrolysis and fermentation of starch (usually from corn, grain or sugar cane) and is well established technology. Corn and grain have competing markets in food and agriculture. The conversion of low cost lignocellulosic residues is desirable. The biological conversion of lignocellulose to ethanol requires further development work and breakthroughs in enzyme technology. What is ultimately required is a mix of enzymes (or organisms) which will convert to ethanol the mix of C6 and C5 sugars derived from the hydrolysis of the cellulose and hemicelluloses from wood or agricultural fibre. The commercial development of lignocellulosic ethanol is likely to begin with corn stover (where there is a ready input into existing corn fermentation facilities) rather than wood residues.

The thermochemical platform is through wood gasification which converts the biomass to a syngas (carbon monoxide and hydrogen) followed by chemical conversion, either catalyzed chemically or with bacterial fermentation, to ethanol. This platform can also be used as a base for other chemicals. One commonly called Fischer-Tropsch could produce hydrocarbons compatible with transport fuels. Most of

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the work to date has been done with syngas from coal gasification. It is well established in South Africa. It was widely used in Germany during WW2 when oil was in limited supply. At current oil prices it is probably economical, but some good engineering analyses are required. The technology barriers for using wood are similar to gasification i.e. ensuring the syngas is sufficiently clean and chemically consistent to allow catalysts to perform and give the required reaction yields. Fischer -Tropsch fuels from wood are being developed in new plants in Germany (Choren) but are still in the development stage.

**Other Technologies**

An interesting area that came up in discussion was the concept of removing the hemicellulose portion of the wood ahead of mechanical pulping. Mechanical pulping is the front-end of the papermaking process at mills on the BC Coast. In fact, these operations are very intensive on electrical energy and use ~10% of the electricity generated in BC. The removal of the hemicellulose portion could lead it to be used as a chemical feedstock, reduce energy consumption in the refining process and may lead to improved paper grades. Projects are already underway at UBC on finding process control methods to reduce the energy consumption in wood pulping and refining. Although the area of bio-oil was not discussed, there is expertise at UBC looking at the development of oils from fat & oil residues. The technology to pyrolyze wood into bio-oil materials was developed in BC by Dynamotive and is currently being commercialized in Canada to use the wood residues from a wood furniture plant.

Some of the thoughts are summarized in the attached table below.
<table>
<thead>
<tr>
<th>Use of Wood</th>
<th>Technology Status</th>
<th>Further Technology Barriers</th>
<th>Time to Develop &amp; Implement</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Conversion of wood biomass to electricity | • 200+ MW biomass and/or coal circular fluidized bed reactor operating, although still new technology  
• Scale up to over 300MW should be possible | • Further efficiencies could be gained from gasification and combined cycle technologies | Is ready now                | • Can be implemented. Key business issue is the return on investment for given wood supply costs and the market price of power  
• Ability to maintain the longevity of fluidized beds is uncertain,  
• Slagging of bed from prolonged use of biomass may be a problem |
| Increased heat/power from existing pulp mills | • 60MW size biomass generators are standard technology |                                                                                             | Is ready now                | • Standard technology to implement |
| Wood gasification                         | • Low, medium and high calorific value gases can be produced  
• Variety of gasification technologies available; custom made for desired end-use  
• Can be a base for substation of natural gas (methane)  
• Can be a base for synthesis gas (CO and H2) to make chemicals | • Cleaning gas from wood gasification is critical  
• Link to lime kilns in pulp mills saves natural gas usage and offers payback  
• Commercial demonstration of converting wood to high energy grade syngas is ongoing  
• Catalysis to reduce tar yield requires further R&D | 1 – 3 years  
1 – 3 years  
2 – 4 years  
2 – 4 years | • Actively being developed due to interest in natural gas substitution, which has rapid economic payback |
<table>
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<th>Use of Wood</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Process to solid fuel (pellets)</td>
<td>• Drying, hammer milling and extruding technology are already standard</td>
<td>• Improve grade consistency</td>
<td>1 – 2 years</td>
<td>• A growing market internationally, and could be grown domestically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Improve shapes for easier handling</td>
<td>1 – 2 years</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Use centrifugal drying technology to reduce cost of drying step (main cost factor in conversion)</td>
<td>2 – 3 years</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Alternative to gasification as feedstock to lime kilns?</td>
<td>5 + years</td>
<td></td>
</tr>
<tr>
<td>Conversion of wood to liquid fuels/chemicals</td>
<td>• Conversion of syngas stream from coal to biofuels, alcohols and chemicals is available technology</td>
<td>• Process and catalysts to use syngas from wood</td>
<td>2 – 4 years</td>
<td>• Is being piloted in Europe.</td>
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<td></td>
<td></td>
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<td>• Full scale installation in the US possible.</td>
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<tr>
<td>Conversion of wood to ethanol</td>
<td>• Significant advances in enzyme technology to convert wood sugars to ethanol</td>
<td>• Efficiency of enzymes on C6 sugars on commercial scale</td>
<td>2 – 3 years</td>
<td>• Economics are getting close but still a lot of research to do.</td>
</tr>
<tr>
<td></td>
<td>• Hydrolysis of wood celluloses/hemicelluloses to C6 and C5 sugars is available technology</td>
<td>• Enzymes to ferment C5 sugars</td>
<td>4 – 5 years</td>
<td>• Being driven by agricultural sector to utilize all of crop for both food and fuel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mixed sugar fermentation systems on a commercial scale</td>
<td>10+ years</td>
<td></td>
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<tr>
<td>Integrated biorefinery</td>
<td>• A ‘concept’ more than technology</td>
<td>• Efficient conversion of wood to syngas and subsequent conversion to chemicals</td>
<td>5 – 10 years</td>
<td>• Still a long term vision, but requires up-front research and development</td>
</tr>
<tr>
<td></td>
<td>• Can combine many of the above</td>
<td>• Fit with existing pulp mills</td>
<td>5 – 10 years</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• If using biological platform, single line conversion to ethanol by hydrolysis &amp; fermentation</td>
<td>10 – 15 years</td>
<td>• Large capital investment required</td>
</tr>
<tr>
<td>Use of Wood</td>
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<tr>
<td>Other Technologies</td>
<td>• Researchers are currently seeking methods to improve the refining of wood to reduce electrical demand</td>
<td>• Process control loops, refiner plate design, chip geometry</td>
<td>3 – 5 years</td>
<td>• 10% of BC’s electrical energy is currently used to refine wood for mechanical paper grades</td>
</tr>
<tr>
<td></td>
<td>• Removal of hemicellulose ahead of mechanical pulping to provide chemical feedstock &amp; reduce electrical energy in refining</td>
<td>• Process conditions need to be defined</td>
<td>3 – 5 years</td>
<td>• Opportunity to use the hemicellulose portion as feedstock to other chemicals, needs market development</td>
</tr>
<tr>
<td></td>
<td>• Internal combustion engine fired by clean syngas</td>
<td>• Cleaning the gas stream</td>
<td>1 – 3 years</td>
<td>• Large opportunity for small scale electrical generation if it can be developed</td>
</tr>
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</table>

Notes:
- Opportunity to use the hemicellulose portion as feedstock to other chemicals, needs market development
- Large opportunity for small scale electrical generation if it can be developed
Timelines to Implementation

Predicting when some of the further out technologies will be implemented is by definition “crystal ball gazing”. Much of course depends on resources being available to overcome technology barriers. However, some prediction can be reasonably determined.

The technologies to convert wood to electricity either through self standing power plants, or cogeneration plants sited at pulp mills are available and already implemented in BC. The economics are the key issue and require some pre-engineering projects to better elucidate. A stand-alone wood burning power plant greater than 200MW has been built in Finland; but building one greater than 300MW could have some unanticipated scale up issues.

Projects which can gasify wood to produce medium energy syngas for immediate use as fuel will have an economic driver due to the likely ongoing high cost of natural gas. However, there are technology barriers which need collaborative R&D and implementation. Nexterra has an operating plant in BC that gasifies wood to produce an uncleaned syngas which can be indirectly fired to heat a veneer drier. Pilot projects are underway to produce a syngas which can be directly fired along with natural gas in pulp mill lime kilns, and also a cleaned syngas to operate lumber kilns. They will likely be fully implemented within 2-3 years.

The use of dead pine for pellets is an obvious application but there will have to be significant reductions in the real delivered cost of the wood to the site, or significant reductions in the conversion cost to make it a viable use for harvested dead pine. There are opportunities in this area for collaborative R&D to improve quality standards and reduce manufacturing costs. The economics of wood delivery, and market pricing will probably be the key business drivers, not technology.

The conversion to transport fuels by either the biological or thermochemical platform, as part of upgrading present pulp mills, is an area that is currently receiving much attention and research funding. The technical barriers for implementing a thermochemical platform are likely lower than those still to be overcome in the biological platform. In that sense, this is closer technology; but is still likely 5 years away from commercial implementation in North America. Initial installations will very likely be helped by strategic government investment in addition to private capital.

R&D and Technology Resources in BC

BC is fortunate in having locally based technical talent in the areas of bioenergy and biorefining. Several start-up companies are beginning to show significant commercial success, e.g., Nexterra in wood gasification, Dynamotive in wood pyrolysis to bio-oils, Lignol Innovations in alcohol pulping and lignin derivatives. Significant experience in the engineering and construction of power generation facilities resides at BC Hydro, the independent power producers, and local engineering consultancies. The seminar with Western Canadian academics illustrated the talents at UBC, and the University of Alberta, in conversion of lignocellulose to ethanol, wood gasification, fibre handling and conversion to pellets, pulp and paper engineering, and in the energy systems used in these operations. The three national forest research institutes (Feric, Forintek, and Paprican) all have facilities on the UBC campus. These three institutes are currently amalgamating and will direct some of their research resources to the emerging area of bioenergy and biorefining to support their forest industry members goal to become energy self sufficient. There is significant expertise residing at the three institutes on fibre harvesting and transportation, economics, and pulp mill engineering including cogeneration.
A challenge for BC is to ensure that the scientific community is involved in the leading edge research, and to ensure that the findings are implemented in BC. UBC has a pool of research talent which is actively engaged and, under a suitable funding and intellectual property sharing framework, could be further very well utilized in developing technologies to make better use of wood resources in energy and fuel conversion. The intellectual property issues are significant and have discouraged industry co-investment in the past. There is also strong interest in Alberta in bioenergy and biorefining, although it is driven by a strong interest in diversifying the economy rather than utilizing dead pine. Under the recent MOU on technology exchange signed by BC and Alberta, opportunities to pool resources should be further explored. Similarly, efforts should be made to integrate into national efforts on bioenergy which will be spearheaded by the federal government, likely with input from the new National Institute.

Further development in bioenergy and biorefining requires incremental funding. Such funding should be directed strategically and focused on projects with strong economic justification and effective delivery mechanisms. The overall strategic thrust is to accelerate the uptake in BC of technology solutions with real potential commercial application. Projects which clearly show collaboration and clear deliverables should be given priority. Such a portfolio could be managed by the province through a suitable funding agency although it would be critical that projects are reviewed by a committee process with sufficient expertise.
Summary Timeline of the Technologies and Barriers in Converting Wood to Energy and Fuels

**Technology**

- **Now**
  - Wood to electricity by direct fire
  - Wood to ‘solid fuel’ pellets
  - Wood to syngas for wood driers

- **2010**
  - Wood to syngas for pulp mill lime kilns
  - Significant barriers to maintain a clean stream, R&D needed
  - Wood to clean syngas to power internal combustion engine for <10MW electricity generation
  - Wood to high hydrogen grade syngas for liquid fuel production – a basic biorefinery

- **2015**
  - Wood to energy and biochemicals - an integrated biorefinery
  - Needs extensive process R&D
  - Wood to ethanol – a basic biorefinery

**Barriers**

- Technology available - economics drive the decision
  - Recently implemented in BC – driven by high natural gas prices
  - Needs pilot scale trials & R&D
  - Needs large scale pilots and further R&D on enzymes
  - Needs R&D, large scale pilots and further R&D on catalysts to adapt current technology for coal conversion
## Attendees for BC Bioenergy Strategy Meeting with Academic Community, July 5th 2006, Vancouver

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<tr>
<th>Name</th>
<th>Title</th>
<th>Affiliation</th>
<th>e-mail</th>
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<tr>
<td>Jim Lim</td>
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