Barriers to the Woody Biomass Energy Industry in British Columbia

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EXECUTIVE SUMMARY

Biomass from harvest residues or “woody biomass” has enormous potential to contribute to British Columbia’s renewable energy goals. Each year, non-saleable portions of the tree are left over from logging operations. Comprising up to 53 percent of total logged fibre, these residues can be converted to energy. British Columbia, home to 4 percent of the world’s forests, generates enough harvest residues to meet 24 percent of the province’s energy needs. Unfortunately, due to a fledgling industry, British Columbia meets only 1 percent of its annual energy demand with this resource.

Method

This report will look at the woody biomass industry in British Columbia and collate the various issues preventing proliferation of this fuel source. There are several reasons why this industry has not been successful despite an enormous comparative advantage in residue production. Through a comprehensive literature review, this report will organize the broad cross-section of information available on the subject. The source methodology was extracted from ‘Supply chain management: a structured literature review and implications for future research’ (Burgess et al., 2006) based on its ability to classify literature across different functional dimensions. The methodology allowed barriers to be grouped by theme and enabled categorization of these issues along the entire woody biomass supply chain. The outcome was a holistic portrait of the industry and an understanding of the linkages between each theme. The comprehensive literature review also facilitated the categorization of solutions in successful woody biomass markets along the same thematic dimensions. Information gained from these markets was used to put forward recommendations for the industry in British Columbia. The central research question of the report is therefore, ‘What are the barriers to a successful woody biomass energy industry in British Columbia along the supply chain? How can practices in successful markets inform solutions to these issues?’

The issues were put into four groupings; Harvest Residue Acquisition; Harvest Residue Processing; Energy Production Infrastructure and Market. The ‘Harvest Residues Acquisition’ grouping pertains to issues with procuring the physical residue from the forest floor. The ‘Harvest Residue Processing’ grouping refers to issues with processing the residues and ensuring they arrive at the power facility. The ‘Energy Production Infrastructure’ grouping discusses problems related to the power production process. Finally, ‘Market’ refers to the demand side of the woody biomass market and the policies that influence it. Each of the issues is outlined below. Biomass markets in Sweden and Finland provided the bulk of insight into solutions within each theme.
Analysis

The classification process of the comprehensive literature review revealed four groupings and thirteen themes. Information from a broad cross-section of data sources was categorized into these dimensions. Some articles took a different position or discussed different aspects of each theme. The methodology chosen allowed for this flexibility and delivered a set of recommendations based on the broad interpretation of each issue.

Grouping: Harvest Residue Acquisition
The first grouping of barriers identified in the comprehensive review pertained to acquiring harvest residues.

Theme: Securing Harvest Residues
The ability to secure harvest residues, or obtain an agreement for a long term fixed supply of wood fibre is often difficult. Forestry companies in British Columbia are hesitant to sign long term contracts for residues due to fluctuations in annual economic conditions and fear of an increase in price for their own fuel needs.

Theme: Variability in Harvest Residue Yield
Moisture content, tree species, ash content, physical and chemical characteristics can lead to large variations in total energy potential of forest management units (FMU). Small profit margins in the woody biomass industry mean accurate forecasting of energy potential is necessary.

Theme: Seasonal Fluctuations from Annual Allowable Cut
The Annual Allowable Cut (AAC) limits the amount of lumber a forestry company can log each year. The AAC forces forestry companies to distribute their logging unevenly throughout the year. This leads to minimal production of residues during the summer months and a cyclical supply of energy inputs.

Grouping: Harvest Residue Processing
The second grouping uncovered two different themes in the literature pertaining to harvesting, processing and transportation.

Theme: On-Site Storage
Residues need to be stored on site for several months and must maintain energy content. Current methods of storage in British Columbia can lead to a significant loss in energy content.

Theme: On-Site Processing
The logistics of transporting and processing residues is very complicated. The primary issue is deciding which system to use given a variety of factors. Choosing the wrong system can lead to overrun
transportation, machinery or time costs. No one system has been widely accepted and costly analysis and high variability dissuades energy producers from entering the market.

**Grouping: Energy Production Infrastructure**

The third grouping includes barriers pertaining to infrastructure used for power production.

**Theme: Power Plant Size**

Decisions over size and location of woody biomass plants are crucial components of the supply chain. The large role of transportation costs in providing harvest residues means the larger a catchment area becomes, the more expensive the residues are. The typical economies of scale enjoyed by building larger and larger power plants are not realized.

**Theme: District Heating Installment Cost**

A district energy system is comprised of a central plant connected to numerous buildings through a network of pipes, in order to provide heating or cooling. One of the main deterrents to biomass power generation through district heating is the initial high capital cost.

**Theme: Wood Pellet Export**

British Columbia has a large wood pellet industry, where harvest residues are turned into easily combustible pellets for district heating or home furnaces. The province exports 90 percent of its wood pellets to Europe, incurring climate and human health costs.

**Grouping: Market**

Finally, the fourth grouping includes barriers from the last stage of the supply chain including market demand and energy delivery.

**Theme: Electricity Prices**

On account of abundant hydro-electricity generation, BC Hydro offers one of the lowest electricity rates in the world at 6 cents/kwh. Low electricity prices stifle investment in renewable energy such as woody biomass.

**Theme: Natural Gas Prices**

British Columbia also has very low natural gas prices at approximately 4 cents/kwh. Low natural gas prices make it financially unattractive to switch to woody biomass technologies.

**Theme: Land Use Planning**

District energy requires compact, high density communities. As there are pipes that must connect to each building, low density suburban areas which make up the bulk of BC’s communities are not feasible for district energy. Decisions over energy systems and land use planning are not being made in tandem.
**Theme: Competition**

Harvest residues can be converted into various forms of energy. Two major forms of fuel converted from harvest residues are wood pellets and cellulosic ethanol. The competition between different forms of a fuel will prevent a critical mass in either industry from being reached and may drive up prices.

**Theme: Air Quality and Public Perception**

There is public concern regarding the air quality from harvest residue combustion and gasification. To meet air quality standards, large woody biomass facilities in urban areas need expensive filters. In addition, public resistance has blocked several district energy projects.

**Recommendations**

The comprehensive literature review facilitated an important understanding of the woody biomass industry. The recommendations that came out of the classification process can act as a guide for policy makers and stakeholders to move towards a more successful woody biomass sector in British Columbia. However, the overarching message of this report is to illuminate the scope of the issues and understand the linkages between different industry silos. Attention must be paid to providing solutions that address problems across the four groupings. Integration between the forestry industry and energy producers emerged as a solution to several of the issues uncovered in the report. The unique supply chain of woody biomass and the large portion of fixed costs already covered by the forestry industry mean sharing resources is one way to make this fuel source economical. Emphasis on the importance of coordinating land use and energy planning was also a predominant message. The report recognizes that the provincial government should set the economic parameters and provide informational resources, but must give the tools and authority over energy delivery to those that are responsible for land use planning. The following set of recommendations will provide the initial steps towards this goal and a sustainable energy future for the province of British Columbia.

- Creation of a “Wood Fibre Act” that guarantees enough residues for the internal needs of the forestry industry.
- Engage in an inter-provincial exchange of forestry data to more accurately capitalize on residues. Create a provincial body tasked with making an inventory of biomass potential across the province based on mapping, remote sensing and detailed industry information.
- Wrap residues with special paper to prevent moisture uptake.
- Improve integration between forestry companies and biomass industry to cut down on logistics costs.
- Introduce smaller scale power plants and embrace the development of powder technology.
- Make district heating cost competitive through taxation and subsidy to enhance demand for wood pellets and prevent export to European markets.
• Increase hydro-electricity and natural gas rates.
• Download jurisdiction regarding energy systems to municipalities and regional districts in order to ensure decisions are based on more than just cost considerations, and include political and social factors. This will also allow greater coordination between land use planning and energy planning.
• Focus on combustion technology until cellulosic technology is proven to provide positive returns. Continue investment in R&D.
• Using municipal government, roll out a marketing strategy creating awareness for benefits of woody biomass energy.
INTRODUCTION

As a carbon-neutral clean energy, biomass presents an excellent opportunity to improve the sustainability of British Columbia’s energy portfolio. Biomass is any form of energy that is derived from organic sources and includes trees, agricultural crops, food waste, municipal solid waste and manure. As British Columbia is home to 4.14 percent of the world’s forests and just 0.0006 percent of the world’s population, there exists an enormous comparative advantage in biomass energy production from wood (FP Innovations, 2010). When used for energy, biomass is considered clean or carbon neutral, releasing no more carbon into the atmosphere than it absorbed during its lifetime. When used to replace non-renewable sources of energy, woody biomass reduces the amount of greenhouse gases released into the atmosphere (CVRD Energy Plan, 2011).

For every tree that is logged in the forest, approximately 11 percent-55 percent of the total mass, including branches, bark and needles, is unsalable lumber and can be converted to energy (MacDonald, 2006). In British Columbia, however, if this waste is not used for the internal power needs of the forestry industry, it is often burned at the logging site or exported to Europe in the form of wood pellets. The province produces 17.1 million tonnes of logging residues each year, or enough to potentially meet 23.9 percent of the province’s energy needs. Unfortunately, the resource currently contributes just 1 percent to total energy production (BC Energy Primer, 2008).

Diminishing reserves of fossil fuels, combined with the threat of climate change, has led to increasing interest in the utilization of woody biomass as a potential energy source. British Columbia has pledged to meet all marginal energy needs with zero net increases in carbon emissions increases after 2012. Unused harvest residues represent a way for the province to achieve this goal. While several countries in Europe have been able to successfully capitalize on this energy source, including Finland, Germany, Sweden and Denmark, several fundamental issues in British Columbia have stalled the industry. The central research question of this paper, ‘What are the barriers to a successful woody biomass energy industry in British Columbia along the supply chain? How can practices in successful markets inform solutions to these issues?’ aims to uncover these issues and provide useful recommendations to move the industry forward.

As this report is intended to be a primer for environmental planners and policymakers, it will provide a comprehensive account of the various issues and problems facing the industry in BC, from feedstock to furnace. The supply chain for woody biomass contains multiple stages with different stakeholders acting at each stage. It is a complex process that requires coordination between numerous industries, land use
planning and infrastructure decisions. Each issue is interdependent and a solution requires a holistic analysis of the numerous problems in each of the four groupings. Studies typically analyze one or two of the stages outlined in figure 1. However, this report recognizes the mutually inter-dependent nature of all four and therefore attempts to outline recommendations for long term solutions.

**Figure 1: Supply Chain Categories**

Chapter 2 will provide a primer on woody biomass including more information on the various forms of energy output, the existing market in British Columbia, and the policy environment of the province.

Chapter 3 will look at the methodology chosen to undertake this report. A comprehensive literature review was identified based on its ability to amalgamate a wide body of literature across multiple disciplines. The methodology was extracted from ‘Supply chain management: a structured literature review and implications for future research’ (Burgess et al., 2006). This research attempts to collate methodological and conceptual issues found in the supply chain management literature via a structured framework. A similar structured framework will be employed to uncover barriers along the multi-disciplinary supply chain of woody biomass.

Chapter 4 will provide details regarding the results of the comprehensive literature review. The first grouping, pertaining to harvest residues acquisition, will discuss issues facing energy producers in procuring a reliable stream of energy inputs. The second grouping, harvest residue processing, will look at issues in transferring residues from the forest to the power production infrastructure. Diseconomies pertaining to power production infrastructure will be reviewed in the third grouping. Finally, the problems in generating market demand will be presented in the market grouping. After issues in each theme have been reviewed, practices in successful markets pertaining to the same theme will be presented. It is the hope of this study that lessons provided from these countries can provide a useful blueprint for interested stakeholders in British Columbia.

Finally, Chapter 5 will provide a set of recommendations based on the outcomes of the review. It will provide a set of next steps that can be taken by the policy maker or municipal stakeholder.
Research Scope

The study will not look at the technology behind the production of woody biomass fuels, nor will it examine improving efficiencies in the technology.

The report will not discuss issues related to the pine beetle epidemic. Although the epidemic will lead to a 10-20 year increase in biomass production, this report aims to address longer term structural problems within the industry.
Context

Biomass from woody residue has numerous potential benefits, including a reduction in greenhouse gas emissions, diversion of landfill waste, improvement in air quality, job creation and improving the cost competitiveness of fuel. The GLOBE Foundation’s 2007 “Endless Energy Project” report assessed British Columbia’s biomass resources to represent 47 percent of the province’s total remaining renewable energy potential (ENVIT, 2008).

Figure 2: World Energy Consumption by Type

Despite a small market in British Columbia, biomass is a predominant energy source throughout much of the world. Over 10 percent of global energy consumption is from wood combustion, as seen in Figure 2 (IEA, 2008).

Currently, Canada has 93,000MW of installed renewable energy capacity, with biomass production capacity comprising 6 percent of the total at 5,580MW (Figure 3) (Stennes & MacBeth, 2006). British Columbia leads the country with a biomass production capacity of 670MW (Nyboer et al., 2004).
While BC is home to approximately 4 percent of the world’s forests, biomass energy production meets less than 1 percent of its electricity needs (Figure 4).

The quantity of residues available in British Columbia, combined with biomass generated from silviculture plantations, has the potential to generate 273 PJ of energy annually (Figure 5). Given the province of British Columbia used 1,142 PJ of energy in 2000, biomass from forestry products represents the potential to provide 23.9 percent of the provinces energy needs (BC Biomass Energy Primer, 2008).
Biomass: An Introduction

Biomass is any form of energy that is derived from organic sources and includes trees, agricultural crops, food waste/municipal solid waste and manure (Figure 6).

Figure 6: Forms of Bioenergy

<table>
<thead>
<tr>
<th>Municipal Solid Waste</th>
<th>Sustainable Forestry</th>
<th>Mountain Pine Beetle Damaged Timber</th>
<th>Sustainable Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfills contain biomass that can captured as fuel through landfill gas collection of direct combustion</td>
<td>Includes forest residues from logging. Site preparation, early tree removal and tree stand establishment could increase forest residues</td>
<td>Pine timber that has been killed by the mountain pine beetle, resulting in 13,000,000 acres of non-recoverable wood.</td>
<td>Crop residues including stalks, husks and other fibres not used can be converted to ethanol/biodiesel. Manure can also be used.</td>
</tr>
</tbody>
</table>

Depending on the inputs and the type of processing, biomass can be used to generate heat, fuel, electricity, or both heat and electricity (co-generation).

**Types of Biomass Energy and Infrastructure**
To understand the market for biofuels, it is first important to understand the various forms which the fuel can take. Each form requires specific infrastructure with a unique supply chain.

**Solid Fuel Pellets:** Pellet Stoves, Combustion in Dedicated Biomass Power Plant
Solid fuel pellets are made from sawmill residues by compacting shavings into an easily transportable and high efficiency form. Moisture content is a problem for residues, adding weight and volume to fuel-wood and increasing transportation costs. In order to improve efficiency of the residues, the wood is typically dried and compacted into briquettes or pellets. Pellets are burned in stoves or dedicated biomass power plants (Pa et. al, 2011).

**Electricity/Heat:** Cogeneration, Gasification Plant
Cogeneration infrastructure uses wood or shavings to create steam which is converted to electricity and heat energy. The predominant use of wood biomass in cogeneration is found in mill operations where heat energy and electricity are generated simultaneously to dry wood.

**Liquid Fuels:** Ethanol/Bio-Oil/Methanol/Biodiesel: Automotive Sector
Liquid fuel from woody biomass is known as second generation biofuel. Ethanol, biodiesel, methanol or bio-oil is produced from non-edible plant materials such as stems, pits, and branches and a process is required to separate the lignosin from the plant materials to produce liquid fuel.

**Synthetic Natural Gas or SynGas:** Cogeneration, Heaters, Engines
Second generation processing also includes gasification of forest residues. Output is normally syngas which can be used in heat production or for electrical power generation in combustion motors. For example, Sparwood, BC is using gasification to convert harvest residues to energy (BC Energy Primer, 2008).

**Current Policy**
The Province of British Columbia has made a commitment to meet 100 percent of all additional electricity demand from renewable energy sources (ENVIT, 2008). Due to the large role of hydroelectricity in the province, 90 percent of the existing energy portfolio is already renewable. New electricity generation plants will have zero net greenhouse gas emissions (BC Clean Energy Plan, 2008).
The province aims to achieve 50 percent of renewable fuel goals by 2020 through the development of biofuel options. While biofuel encapsulates all forms of biomass, not just from woody residues, the policy aims to provide strong support for the woody biomass market. Benefits of the market outlined by the provincial government include:

- Enhancing British Columbia’s ability to become electricity self-sufficient.
- Fostering the development of a sustainable bioenergy sector.
- Creating new jobs.
- Supporting improvements in air quality.
- Promoting opportunities to create power from mountain pine beetle-impacted timber.
- Positioning British Columbia for world leadership in the development and commercial adoption of wood energy technology.
- Advancing innovative solutions to agricultural and other waste management challenges.
- Encouraging diversification in the forestry and agriculture industries.
- Producing liquid biofuels to meet Renewable Fuel Standards and displace conventional fossil fuels (BC Clean Energy Plan, 2008).

Provincial Bill 27 allows local governments to develop renewable energy projects under certain conditions and provides them with funding for projects with a longer payoff term. However all projects must be processed and approved by BC Hydro.

BC forest ownership is approximately 1 percent federal, 3 percent private and 96 percent provincial (Climate Change Solutions, 2007). Independent Power Producers (IPP)’s currently have two options for provincially owned land. They can either obtain a long term forest license to collect biomass from Crown land or can form partnerships with licensed holders. Forestry plots are divided into “Forestry Management Units” or FMU’s, and licenses are given out based on these administrative lines.

**Figure 7: BC Hydro IPP Forestry Partnerships**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Status</th>
<th>Location</th>
<th>GWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGP Bio Energy</td>
<td>Operating</td>
<td>Prince George</td>
<td>85</td>
</tr>
<tr>
<td>NEW Williams Lake WW</td>
<td>Operating</td>
<td>Williams Lake</td>
<td>545</td>
</tr>
<tr>
<td>Skookimchuck Power Project</td>
<td>Operating</td>
<td>Kimberly</td>
<td>206</td>
</tr>
<tr>
<td>Armstrong Woodwaste Co-Gen</td>
<td>Operating</td>
<td>Armstrong</td>
<td>163</td>
</tr>
<tr>
<td>Celgar Green Energy</td>
<td>Operating</td>
<td>Castlegar</td>
<td>242</td>
</tr>
<tr>
<td>Kamloops Green Energy</td>
<td>Operating</td>
<td>Kamloops</td>
<td>288</td>
</tr>
<tr>
<td>LP Golden Biomass</td>
<td>Operating</td>
<td>Golden</td>
<td>4</td>
</tr>
<tr>
<td>Howe Sound Green Energy</td>
<td>Operating</td>
<td>Squamish</td>
<td>400</td>
</tr>
<tr>
<td>Total Operating GWh/year</td>
<td></td>
<td></td>
<td>1933</td>
</tr>
<tr>
<td><strong>Capacity MW</strong></td>
<td></td>
<td></td>
<td><strong>221</strong></td>
</tr>
<tr>
<td>Project Name</td>
<td>Status</td>
<td>Location</td>
<td>GWh/year</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>----------</td>
</tr>
<tr>
<td>Fraser Lake Sawmill Biomass</td>
<td>In Development</td>
<td>Fraser Lake</td>
<td>88</td>
</tr>
<tr>
<td>Fort St. James Green Energy</td>
<td>In Development</td>
<td>Fort St. James</td>
<td>289</td>
</tr>
<tr>
<td>Chetwynd Forest Industries</td>
<td>In Development</td>
<td>Chetwynd</td>
<td>88</td>
</tr>
<tr>
<td>Merritt Green Energy</td>
<td>In Development</td>
<td>Merritt</td>
<td>289</td>
</tr>
<tr>
<td>PGWE</td>
<td>In Development</td>
<td>Prince George</td>
<td>70</td>
</tr>
<tr>
<td>Conifex Green Energy</td>
<td>In Development</td>
<td>Mackenzie</td>
<td>209</td>
</tr>
<tr>
<td>Cariboo Pulp &amp; Paper</td>
<td>In Development</td>
<td>Quesnel</td>
<td>172</td>
</tr>
<tr>
<td>Catalyst Paper</td>
<td>In Development</td>
<td>Powell River</td>
<td>151</td>
</tr>
<tr>
<td>Total in Development GWh/year</td>
<td></td>
<td></td>
<td>1356</td>
</tr>
<tr>
<td><strong>Capacity MW</strong></td>
<td></td>
<td></td>
<td><strong>155</strong></td>
</tr>
<tr>
<td>Total Additional Capacity MW</td>
<td></td>
<td></td>
<td><strong>375</strong></td>
</tr>
</tbody>
</table>

*Source: BC Hydro, 2011*

BC Hydro, the electric utility company owned by the province of British Columbia, has also created policy that will allow the province to capitalize on harvest residues. The public company can now buy electricity generated from Independent Power Producers (IPPs) through energy purchase contracts at special rates. The program has led to partnerships with the 16 mills outlined in figure 7. These mills use sawmill residues and logging debris to generate electricity on-site in large heaters and sell it back to the public utility. The capacity of operating cogeneration facilities is 221MW, representing 1/3 of biomass production capacity in British Columbia. BC Hydro plans to add an additional 155MW of capacity which will increase biomass production capacity within the province by 23 percent (BCHydro Press Release, 2011).
Biomass in British Columbia

Figure 8: Bioenergy in British Columbia


Figure 8 reveals areas within BC where energy is being converted from harvest residues. Areas with brown circles indicate communities that have developed infrastructure to produce wood pellets. The blue circles represent areas where harvest residues are being used to generate power in cogeneration facilities for the lumber industry.

In total, there are 8 wood pellet plants in British Columbia in Houston, Vanderhoof, Prince George, Quesnel, Williams Lake, Armstrong, Kelowna and Princeton. There are two developments and three communities in British Columbia that are using woody biomass for district heating.
METHODOLOGY

Introduction

Based on an enormous comparative advantage in residue production within British Columbia, woody biomass has the potential to be a significant renewable energy industry. However, given the current size of the industry, it is evident that large portions of residues are not being used. Academic research on the subject has attempted to uncover the reasons for this. However, this research typically focuses on problems within one industry or area, including the forestry industry, energy producers, land use planning or public policy. There is little attempt to approach the subject from a holistic supply chain perspective. In order to successfully produce and utilise energy from woody biomass, coordination is needed across multiple sectors and public and private stakeholders.

Due to the number of technical documents on the subject and a fragmented approach, a consistent research methodology has not been developed in the woody biomass arena. There is also no commonly accepted definition of the supply chain in the literature. An inability to understand the interdependent components of the supply chain makes devising comprehensive solutions difficult. Accordingly, a comprehensive literature review was seen as needed to fully understand the barriers to industry development.

The comprehensive literature review aims to answer the research question; ‘What are the barriers to a successful woody biomass industry in British Columbia along the supply chain? How can practices in successful markets inform solutions to these issues?’

An applicable research methodology was extracted from ‘Supply chain management: a structured literature review and implications for future research’ (Burgess et al., 2006). This research attempts to provide a common theoretical definition and methodology for supply chain management across disciplines. It also aims to collate methodological and conceptual issues found in the supply chain management literature via a structured framework.

Similarly, none of the available literature found on the woody biomass industry follows a thematic analysis of the supply chain. The (Burgess et al., 2006) methodology groups issues along four conceptual dimensions and this study will use a similar grouping system to collate themes along the supply chain. The structured framework provided by the source methodology will also facilitate the categorization of content within groupings of issues.
Another methodology that provided insight into supply chain research was found in ‘The Nature of Supply Chain Management and Research: Insights from a Content Analysis of International Supply Chain Management Literature from 1990 to 2006’ (Wolf, 2008). Although this report used content analysis, the research question paralleled that of this report; “How can the process of knowledge creation in Supply Chain Management be characterized and how did they evolve over time?” The report questioned the nature of supply chain research and thus aimed to codify the existing body of literature into large paradigmatic ideas. While the two research questions addressed different topics, the overarching goal of collating and distilling a large body of literature to answer new questions was similar. By using a standardized procedure for drawing out themes and recurring ideas, the (Wolf, 2008) methodology allowed broad inferences to be made from the body of literature on the subject. The aim of the study was to produce an objective, systematic and reliable study of qualitative data.

The comprehensive literature review methodology employed in this report set out to accomplish a similar goal, but instead used a more detailed classification system. The system for coding and grouping the data used in the (Burgess et al., 2006) study allowed for better organization and chronicling of available literature. This was necessary to come up with holistic recommendations and understand interdependent components.

A summary of methodological steps will now be provided.

Selection of Articles
The first step in the methodological process was determining which type of literature would be analysed for the purposes of the comprehensive review. Various databases were used including Google Scholar, and the Queen’s University Library. It was the intention of the initial searches to uncover a broad cross-section of literature types. The keyword searches “Issues with Woody Biomass Industry in British Columbia” and “Harvest Residues in British Columbia” were used. The term “Supply Chain Woody Biomass Issues” was also used but did not yield many results.

The initial search yielded a mix of government documents, peer reviewed academic journals and industry reports. Since the first portion of the research question has a relatively narrow scope, “Issues facing the industry in British Columbia”, a search result yielded a limited number of pertinent articles. Consequently any literature that referenced issues within the BC market was automatically reviewed.

The second portion of the research question sought literature pertaining to successful biomass markets. Thus keyword searches “Successful Woody Biomass Industry” yielded results from a variety of European markets. These studies also included government documents, peer reviewed academic journals and
industry reports. Those countries with woody biomass comprising at least 10 percent of total energy production were considered successful and reviewed for the purposes of the study. This figure was used as an indicator as it points the fact that the country has a large supply of forest resources in concert with a critical mass of production able to materially contribute to the energy needs of the country.

**Review Process and Inter-Reliability**

There were thirteen issues or themes pertaining to the supply chain of woody biomass that were identified through a scan of the literature produced by the first search. A classification of the themes pertaining to the woody biomass market literature from British Columbia produced the following dimensions.

- Securing Harvest Residues
- Variability in Yield
- Seasonal Fluctuations from Annual Allowable Cut
- On-site Storage
- On-site Processing
- Power Plant Size
- District Heating
- Wood Pellet Infrastructure
- Electricity Prices
- Natural Gas Prices
- Land Use Planning
- Competition for Feedstocks
- Air Quality and Public Perception

In order to ensure inter-reliability, two articles from different types of sources that discussed the same theme were cross-checked. For example, an industry report from (Envirochem, 2012) which discussed wood pellet infrastructure, was cross checked with information in a peer reviewed journal article by (Akom et al., 2010). Any discordant information would be checked with a third source. Information from the same type of source that referenced the same theme but was published at different dates was also cross-checked to ensure reliability. Information that appeared to have changed over time was cross-checked with another more recent piece of literature. This ensured the consistency of facts within the report.

A preliminary scan of the literature revealed that articles pertaining to harvest residues in British Columbia typically discussed more than one issue. While the research question would usually focus on one section of the supply chain, a discussion of other problems could be undertaken. Therefore articles could fall into two categories and appear at different points in the report. In addition, because this study
was analyzing academic articles, trade journals and government documents, some outlets provided a more comprehensive analysis of the bioenergy market. Some documents discussed several categories.

**Classification Framework**

The thirteen themes or subjects uncovered in the literature were arranged in sequential order based on what stage they temporally appeared in the energy delivery process. Securing harvest residues was seen as the first stage in energy delivery and issues with air quality and public perception as a result of combustion were seen as the last stage. Within these themes, four distinct groupings naturally emerged. These were ‘Harvest Residue Acquisition’, ‘Harvest Residue Processing’, ‘Energy Production Infrastructure’ and ‘Market’. The first three themes pertained to acquiring the raw materials inputs and ensuring a continual stable supply throughout the year. These were grouped under ‘Harvest Residue Acquisition’. The second two themes related to the process of moving the raw material from the acquisition point to the power plant and were labeled ‘Harvest Residue Processing’. The next three dimensions pertained to the actual power production process and fell under the ‘Energy Production Infrastructure’ grouping. Finally, the last five themes related to energy delivery or market demand were grouped into ‘Market’.

**Figure 9: Classification Framework**

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Theme</th>
<th>Issue</th>
<th>Solution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest Residue Acquisition</td>
<td>Securing Harvest Residues</td>
<td>xx</td>
<td>xx</td>
<td>Xx</td>
</tr>
<tr>
<td></td>
<td>Variability in Yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seasonal Fluctuations from AAC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest Residue Processing</td>
<td>On-site Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>On-site Processing</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Energy Production Infrastructure</td>
<td>Power Plant Size</td>
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<td></td>
<td>District Heating</td>
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<td></td>
<td>Wood Pellet Infrastructure</td>
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<tr>
<td>Market</td>
<td>Electricity Prices</td>
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<td></td>
<td>Natural Gas Prices</td>
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<td></td>
<td>Land Use Planning</td>
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<td></td>
<td>Competition for Feedstocks</td>
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<tr>
<td></td>
<td>Air Quality and Public Perception</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Burgess et al., 2006*
Literature was grouped along the dimensions seen in Figure 9. Articles from the “Issues with Woody Biomass in British Columbia” key search were grouped into the first column under “Issue”. Once an initial comprehensive review yielded the 13 themes, more detailed research on each issue was undertaken.

Information from the search “Successful Woody Biomass Markets” specific to each theme was grouped into the second column “Solution”. This allowed the collection of pertinent responses to the issues encountered in British Columbia. Solutions were not found in every theme as some issues were unique to British Columbia.

The themes and groupings are meant to provide a comprehensive portrait of the issues facing the woody biomass industry in British Columbia. While the solutions will focus on one theme, it is the hope of this comprehensive review that overlap and interdependence will provide a more broad-view approach to the problem. In this vein, there are solutions presented that may involve science, forestry, and economics. The supply chain covers a broad range of industries and solutions in successful markets will follow a similar diversity. Solutions presented by successful markets will not be in-depth, but will offer broad directions to take in order to move the industry forward. Financial analysis or modeling will not be undertaken, but taxes, subsidies and grants are recommended in the same broad strategic sense they were encountered in the literature.

Literature regarding Finnish and Swedish markets contained the majority of successful practices related to the four themes. Where British Columbia derives less than 1 percent of annual energy needs from woody biomass, Finland and Sweden derive 20.9 percent and 16.1 percent of energy from the resource, thus meeting the test for a successful market (10 percent) (Ericsson et al., 2004). These two countries also share geographic, climate and economic similarities with British Columbia. All three locations are home to significant forest resources and consequently large forestry industries. British Columbia’s forested regions account for 60 percent of total land mass (Ministry of Forest, Mines and Lands, 2010) with Finland and Sweden’s forests comprising 52 percent and 66 percent respectively (Ericsson et al., 2004). Per capita electricity consumption is high in all three countries due to cold climates and developed economies; Finland at 16,635 kwh/annum, Sweden at 14,893 kwh/annum and British Columbia at 16,055kwh per capita per annum (CIA Factbook, 2012).
Outlining the methodology enabled the next stage of the study; analysis. The following chapter will highlight issues uncovered in the literature along the supply chain. It will also delve into further detail regarding successful practices along similar themes.
ANALYSIS

The overall aim of the analysis section is to break down the issues facing British Columbia’s woody biomass industry into four grouping along the supply chain outlined in figure 10; ‘Harvest Residue Acquisition’, ‘Harvest Residue Processing’, ‘Energy Production Infrastructure’ and ‘Market’. Each issue will be explained in greater detail in order to gain a more holistic understanding of the industry. Once a more in-depth awareness is achieved for each theme, information from successful markets will follow.

Figure 10: Supply Chain Issues

Harvest Residues Acquisition
Harvest residues, also known as ‘fibre flows’ are the by-product of logging trees to obtain cylindrical saleable lumber. Approximately 47 percent of the tree is typically available to be used as lumber. The remaining bark, slabs, woodchips, shavings and sawdust can be used as wood bioenergy. Considering this material comprises over half the tree, it is important this fibre is not wasted. However, several issues prevent the procurement of a steady supply of harvest residues. The following section will deal with themes related to this grouping (Figure 11).

Figure 11: Harvest Residue Acquisition

Securing Harvest Residues
Forestry companies in British Columbia currently have no obligation to sell harvest residues. They are required to leave a certain amount on the forest floor for eco-system health and restoration, and are required to dispose of the remainder through burning in bee-hive burners or energy utilization (Mariscenu, 2011).

The cyclical nature of the forestry industry leads to highly variable lumber production from year to year. Changing economic conditions influence the demand for housing and other wood based industries and thus, the price of lumber. For example, in 2008, the price of lumber fell dramatically on account of the
economic crisis (BC Hydro, 2010). Prices fell below the cost of production and many forestry companies responded by curtailing production. This led to a large reduction in the availability of residues, driving up prices significantly.

The fluctuating nature of lumber demand means forestry companies are hesitant to commit to contracts that require a set annual cut. This could potentially drive up prices for feedstock used internally for forestry operations. Since biomass systems require a secure, long-term supply of fuel, there has thus been hesitation to invest in district energy systems, or wood processing infrastructure. While biomass energy systems have the potential to generate positive returns or be financially self-sustaining, the time horizons are typically longer and require certainty in supply (ENVIROCHEM, 2012).

Approximately 675 million m$^3$ of lumber (FP Innovations, 2010) has been destroyed by the mountain pine beetle, or over half the merchantable stock from BC’s interior. The vast supply of dead pine, which must be used within a time horizon of 20 years, however, has led to the introduction of several policies to turn the dead wood into energy. Contracts between forestry companies and energy producers for long term supply of residues have been made to utilize the wood before it is decomposes. This has enabled investment in infrastructure due to secure fibre flow agreements in certain areas of BC. Studies show, however, that the increased fibre flow associated with the recent epidemic will be short term in nature and could decrease in the next decade (Stennes and McBeth, 2006).

Before the installation of a biomass heating plant, feasibility studies assessing the quality, quantity and price of the biomass resource that is available, the reliability of the suppliers, the fuel handling requirements imposed by the characteristics of the available biomass fuel, and possible changes in the future demand for the targeted biomass resource must be made (ENVIROCHEM, 2012). As with any energy project, producers need to determine fuel availability and cost over several years before investment will take place. This has proven more difficult to organize for biomass than with other energy inputs when no contracts for residues will be made by forestry companies, leading to uncertainty in price. At present, an inability to make long term contracts for fibre flows outside of the pine beetle infestation region has limited investment in infrastructure.

**Securing Harvest Residues: Sweden**
Initially, the Swedish forestry industry also shared a reluctance to enter the biofuel market. Apprehension about competition for feedstocks and eager to ensure low electricity prices for its own operations, Swedish forestry companies bargained for the creation of the Wood Fibre Act in 1987 (Ericsson et al., 2004). The Wood Fibre Act restricted the amount of fibre that could be used annually for
biofuel and guaranteed primary access to forestry companies. A total of 200,000 m³ would be reserved for the forestry industry in order to ensure sufficient fibre would be available for their internal energy needs at low prices (Hilring, 1997). However, the fear of a fibre shortage went unfounded and in 1993 the Act was discarded. This removed any apprehension towards biofuels and helped the forestry industry develop a positive attitude towards the production of woody bioenergy. The creation of the Wood Fibre Act also helped to build collaboration between the two industries. Today, a significant portion of the woody biofuel market is operated in Sweden by subsidiaries of the forestry industry. This allows these companies to share infrastructure, reducing operating costs and leveraging skill and knowledge of the industry. In addition, subsidies and grants to the forestry industry ensure priority is given to generating significant residues for the external energy market.

**Yield Variability**

The second theme in the ‘Harvest Residues’ grouping is yield variability. Yield variability poses a barrier to the bioenergy market due to the wide range in energy content of wood on a given plot of land. Aspects such as moisture content, ash content, tree species, tree size and physical and chemical characteristics can lead to large variations in total energy potential, making energy forecasting difficult.

High moisture content is one of the most important factors influencing yield and therefore energy content. Moisture content is affected by temperature, humidity, precipitation, tree species and tree size (Mahmoudi, 2009). High moisture content reduces energy derived from trees on two fronts. Heat is needed to boil the water out of the wood and there is less mass within the tree for heating. Due to low moisture content, foliage brings up the calometric value of biomass on a volume basis.

The wide variability in yield not only makes predicting energy content difficult, but the equipment needed to harvest and process residues are dependent on terrain conditions, species mix, and the stand and size of the operation (Mahmoudi, 2009). Difficultly in forecasting the various conditions affecting yield, especially in the case of small margins, increases risk to producers and acts as a disincentive for investment in the industry.

**Yield Variability: Finland**

As outlined, there are numerous factors that must be considered when harvesting residues for conversion to energy. Moisture content, species composition, harvest plot size, tree density and foliage quantity, all must be considered, creating a complicated formula that would require detailed feasibility analysis for each project.
In Finland, (Tanta, 2004) has come up with a system that uses GIS availability analysis and remote sensing to evaluate energy availability. In Finland, as in British Columbia, there is large regional variation in residue potential. In order to determine quantity of the resource, a nation-wide supply analysis and demand model was created using Vertical Mapper and MapInfo.

The exercise used stand data from forestry companies and remote sensing to make detailed regional availability maps. Lumber output from three forestry companies was taken and placed in a database, which represented 75 percent of total forestry area in Finland. Differences in stand composition were recorded by region, which was used to compute residue recovery rates. The amount of logging residues was estimated using stem volume to residue ratios for the various tree species including pine, spruce and birch. Seasonal fluctuations in moisture content were also integrated into the model. Forest management stands used by the forestry industry were regrouped and aggregated along natural lines (Figure 12). The goal was to create polygons where residue was distributed more uniformly.

**Figure 12: Regional Potential of Logging Residues**

![Regional Potential of Logging Residues](source: Tanta, 2004)

This method allowed policy makers to account for variations in yield geographically. Instead of traditional FMU governing residue extraction, a more natural dispersion of uniform regions will reduce variability of energy output. In the case that FMU’s cannot be reoriented, this method can more accurately predict energy potential of each stand. The geographic visualization allows much better forecasting and reporting.
Annual Allowable Cut (AAC)

As part of a lease on crown land, forestry companies are restricted to a set quantity of lumber to harvest each year. This is called the Annual Allowable Cut (AAC) and applies to companies operating on government owned land (97 percent of British Columbia’s forests). The AAC pertains to one forest management unit (FMU) from which a forestry company will obtain tenure for five year periods (Murray Hill Consulting, 2011).

Figure 13: Monthly Delivered Tonnes of Fuelwood in Quesnel

The Annual Allowable Cut restrictions placed on forestry companies has been cited as limiting the potential of residues as fuelwood (Mahmoudi, 2009). Seasonal fluctuations in road conditions and market demand means forestry companies are forced to distribute AAC differently throughout the year to remain economical. Figure 13 shows the potential weight in dry tonnes of fuelwood delivered to a biomass plant in Quesnel on a month-to-month basis. The chart shows that May and April have the lowest amounts of delivered fuelwood.

The data derived for the power plant supply simulation in Quesnel, BC means there are fluctuations in supply to the power plant year round. For the months of April and May, alternative supplies of fuelwood would be needed. This would require importing of woodchips from other regions, or a switch to more conventional fuel for the plant. This adds significant costs to operations and reduces financial feasibility of biomass plants.

Changes to the Annual Allowable Cut also occur every 5 years based on biological, economic, environmental and social decisions made by the Provincial Chief Forester (Murray Hill Consulting, 2011).
Because of the long amortization horizons of wood biomass infrastructure projects, a fibre contract should be made for 15-20 years. The fluctuation in AAC means it is impossible to predict how much fuelwood will be available in the future in each timber supply area.

**Harvest Residue Acquisition Issue Framework**

The classification framework outlined by (Burgess *et al.*, 2006) allowed the distillation of literature on harvest residues down to the following three categories. The overarching message gleaned from this stage of the supply chain is that greater coordination between the forestry industry and the biomass industry is needed along with more detailed forestry data (Figure 14).

**Figure 14: Harvest Residue Acquisition Issue Framework**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Issue</th>
<th>Solution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Securing Harvest Residues</td>
<td>Securing an agreement for harvest residues or “fibre flows” for a long term contract at a fixed price.</td>
<td>Forestry companies in BC are hesitant to sign long term contracts for residues due to fluctuations in annual economic conditions and fear of an increase in price for their own fuel needs.</td>
<td>Sweden</td>
<td>Marisecenu, 2011</td>
</tr>
<tr>
<td>Yield Variability</td>
<td>Moisture content, tree species, ash content, physical and chemical characteristics can lead to large variations in total energy potential of forest management units (FMU).</td>
<td>Small profit margins in woody biomass industry mean accurate forecasting of energy potential of an FMU is necessary. Individual forecasts for each energy producer is too costly.</td>
<td>Finland</td>
<td>Mahmoudi, 2009</td>
</tr>
<tr>
<td>Seasonal Fluctuations from Annual Allowable Cut</td>
<td>The annual allowable cut (AAC) limits the amount of lumber a forestry company can log each year.</td>
<td>Changes to the AAC are made every five years preventing long term forecasts for bioenergy potential to be made.</td>
<td>n/a</td>
<td>Mahmoudi, 2009</td>
</tr>
</tbody>
</table>

**Harvest Residue Processing**

Once residues are secured, the process of gathering, processing and transporting them to the energy generation facility is the next stage along the supply chain. Just as there are many challenges in acquiring a stable flow of residues, there are numerous logistical issues in processing and transporting the fibre. The large bulk and low-energy density of the residues combined with large catchment areas
mean transportation costs can fluctuate widely. The following section will detail themes related to handling, processing and transportation harvest residues (Figure 15).

**Figure 15: Harvest Residue Processing**

On-Site Storage
In British Columbia, harvest residues or “slash” is logged and brought to the road and put in piles. Due to a history of burning roadside residues, current storage methods are not conducive to the biomass industry (Kumar et al., 2004). Under Section 7 of the Wildfire Act, this waste material can be stored for up to 6 to 12 months before it must be burned. Storage methods therefore require careful consideration (Murray Hall Consulting, 2011).

The piles or “windrows” must be oriented to maintain certain conditions or the slash will become unusable. For example, piles should be defoliated to allow drying and to prevent water take up. Leaving the piles with needles and leaves still on will increase the moisture content of the wood and will reduce energy capacity. Piles should also be approximately 4m high and 20-30m across and it is more efficient to bundle the piles to prevent additional moisture take up from the ground (Andersson et al., 2006). This process requires machinery called dangle head operators which will defoliate the residues, stack them in windrows and put them in bundles for transport. However, piles can still lose energy when stored over a long period of time. A better system for storing residues is required in British Columbia.

**On-Site Storage: Finland**
Research and development in Finland has led to the development of an innovative and cost-effective way to store piles and retain energy content (Sorensen, 2011). The Finnish Forest Research Institute has found that covering piles with a special paper reduces moisture by 15 percent. They compared four piles, one covered and one not covered, of two different species. At the end of a winter-long storage period, they found both species to have significantly less moisture.

The paper is placed on top of roadside piles using a wide dispenser and loose residues are laid on top to prevent the cover from blowing off. While this does add costs to the enterprise, small reductions in moisture content can have huge impacts on returns. A reduction in moisture of just 5 percent is enough
to generate positive net returns, where a reduction of 15 percent can see returns of over 200 percent, depending on the price paid for delivered energy.

**On-Site Processing**

There are numerous logistical decisions that must be made when deciding how to process on site slash in preparation for transportation. The high volume and low weight of the product, combined with wide distribution, mean transportation costs are typically the largest expenditure. Processing the slash on site is one way in which to reduce the transportation costs. However, this typically increases equipment costs as more machinery must be brought on site.

Several studies (Andersson *et al.*, 2004, Nilsson, 2009) have attempted to create a model dictating which type of machinery to use at different distances to processing plants. However, the wide variability in moisture content, yield, bulk density, and gas prices make a standardized formula difficult to create.

There are typically three methods of on-site processing and transportation and the most feasible option depends on the distance between the forested area and the biomass plant or energy facility. They are:

1) **Slash system:** In this system, unprocessed slash is transported in trucks to the plant. This means the piles of harvest residues are loaded onto the truck as is. While this requires the least amount of equipment on site, the residues are very bulky with a low density and can lead to very high transportation costs (Nilsson, 2009).

2) **Hog fuel system:** In this case, the unprocessed slash is piled at roadside and a grinder is brought on site. The grinder processes the slash or “communities” the residues and loads them into a truck where they are transported as “hog fuel” or wood shavings to the plant. This is the most expensive of the processing systems as the grinder and mobile chippers are very costly on an hourly basis.

3) **Bundle System:** Unprocessed piles of slash at roadside are bundled by a feller buncher and loaded into trucks. This increases the bulk density of the slash, however, not to the extent of the hog fuel system.

The three systems need to be analysed with respect to cost and emissions. Considering the different aspects of these three systems against the two factors creates a complicated matrix.

An analysis by (Mahmoudi, 2009) reveals that moving, chipping and transportation contribute almost 4 percent, 40 percent and 56 percent of the supply cost, respectively. The high proportion of
transportation cost generally means the slash system (slash transported unprocessed) is not feasible due to the low bulk density. However, if the transportation distances are small, the reduction in equipment costs can make this system viable.

For each load, the slash system can transport 79 percent of the hog fuel system, so the larger the plot area, the more economical to use the hog fuel system. This means comminuting a large enough plot to overcome high fixed costs. One advantage of the hog fuel system is that it reduces storage requirements on the receiving end and could be useful for plants with limited storage space. As land values get more expensive and storage costs rise, this could be the most competitive in the long run.

The bundle system has the lowest CO2 emissions of the three systems due to machinery that uses hydro-electricity. It can also be cheaper than the hog fuel system at shorter distances.

The primary issue with on-site processing is determining what system to use given a variety of factors. Choosing the wrong system can lead to overrun transportation, machinery or time costs. No one system has been widely accepted in British Columbia, and costly analysis and high variability dissuades energy producers from entering the market (Murray Hill Consulting, 2011).

**On-Site Processing: Finland and Sweden**

As outlined in the yield section, researchers in Finland have devised a system to accurately predict energy content through remote sensing, country wide mapping and forestry data. The country was spatially divided into management units that represented a specific concentration of residues.

However, the model also enabled accurate prediction of on-site processing methods, integrating logistical decisions such as technical collecting methods and transport costs. The residue volume and therefore efficiency, is dependent on harvest methods, machinery used, harvesting season. The mapping systems allowed modeling of other cost constraints including types of roads and distance to power plants. While the first stage integrated FMU composition based on species, volume, and moisture content, the second stage involved modeling the location of energy demand, distance to power plants and logistics models (Tanta, 2004). Location-allocation modeling was then undertaken to ascertain the ideal location for biomass facilities around the country. By looking at the country as a whole instead of isolated projects, processing costs could be minimized and higher efficiencies and utilization of resources achieved.
As outlined in the *yield* section, the forestry industry in Sweden also works much more closely with the biomass industry than in British Columbia. The same is the case in Finland, and the integration of supply chains in the lumber and biomass industry allows producers to divide costs of machines and forest roads between users (Roos *et al.*, 1999). Good transportation infrastructure in the country overall also leads to reduced costs through the establishment of better access roads and domestic manufacture of forestry equipment.

**Harvest Residue Processing Issue Framework**

Two themes were uncovered under the harvest residue processing grouping (Burgess *et al.*, 2006). Information from successful markets indicates more R&D spending and research is needed, along with greater integration of forestry and woody biomass supply chains (Figure 16).

**Figure 16: Harvest Residue Processing Issue Framework**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Issue</th>
<th>Solution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Site Storage</td>
<td>Residues need to be stored on site for several months and must maintain energy content.</td>
<td>Current methods of storage on site in British Columbia lead to loss in energy content or require costly machinery.</td>
<td>Finland</td>
<td>Kumar <em>et al.</em>, 2004, Andersson <em>et al.</em>, 2006</td>
</tr>
<tr>
<td>On-Site Processing</td>
<td>The logistics of transporting and processing residues for energy application in power facilities.</td>
<td>The primary issue is deciding which system to use given a variety of factors. Choosing the wrong system can lead to overrun transportation costs, machinery costs or time costs. No one system has been widely accepted BC. Costly analysis and high variability dissuades energy producers from entering the market.</td>
<td>Finland and Sweden</td>
<td>Nilsson, 2009</td>
</tr>
</tbody>
</table>

**Energy Production Infrastructure**

The production of energy from wood biomass requires significant investment in infrastructure. Due to the wide range of energy forms that wood bioenergy can take, there are numerous types of infrastructure that can be used. Each type, however, brings its own set of challenges. Direct combustion, gasification, district heating and wood pellet infrastructure and the issues associated with implementation will be discussed in the following grouping (Figure 17).
Power Plant Size
While power plants typically become more efficient as they become larger due to economies of scale, this is not the case with a biomass facility. On account of increasing transportation costs as the catchment area of a plant gets larger, costs for the fuelwood go up accordingly (Kumar et al., 2004). As outlined in the previous section, moving, chipping and transportation contribute almost 4 percent, 40 percent and 56 percent of the supply cost, respectively. This demonstrates the large role of transportation costs in the total cost of delivered fuelwood. As a result, the optimum size of a power plant is a delicate trade-off between plant capacity and catchment area.

Figure 18: Power Size vs. Power Price

Figure 18 shows how, unlike whole forest and straw residue plants, a direct combustion harvest residue facility has a small optimum size. Depending on the yield of the forest management unit and the location of biomass sources, the optimum size can fluctuate substantially. Based on a study undertaken in Northern Alberta by (Kumar et al., 2004) a power plant size of 137MW is optimal with a catchment area of 764,000ha and a forest density of 0.247 dry tonnes per hectare, using direct combustion technology.
Based on an inability to capitalize on economies of scale, biomass plants are less financially attractive than other energy plants. A small plant size means the delivered power cost of harvest residues is high compared to other types of biomass. The relative cost of power from whole forests, forest residues and agricultural residues is $71.68, $95.76 and 76.46/mwh respectively. This means biomass from forest residues at $96/mwh is close to $20 more per megawatt hour than agricultural residues, at $76/mwh.

Gasification plants, an alternative to direct combustion, have a higher capital cost but higher efficiency. This means that the additional cost is justified by the high production cost of the fuel. It has proven feasible for harvest residues, reducing the overall price per mwh by 7 percent (Kumar et. al, 2004). It has also been proven to be an efficient technology for wood pellets. With controlled gasification, external costs and GHG emission can be reduced by 35 percent and 82 percent respectively.

**Power Plant Size: Sweden**
The ability to build small to medium sized plants has enabled Sweden to achieve the economies that have not yet been seen in British Columbia. The development of bio-energy plants with an energy capacity between 0.3 and 25 MW is increasingly common in Swedish communities. Continuing R&D in this sector has brought down the costs of these facilities and has allowed localized, stable energy supply. The facilities have been introduced as district heating plants or individual systems for larger buildings (SWANTEC, 2011).

The introduction of powder technology has also enabled smaller biomass facility technology including:

- Burners which burn untreated pellets without pre-treatment
- Powder burners which burn pellets that have been ground to powder
- Powder burners that can also burn oil, gas or bio-oils

There is an abundance of pellet factories within the country supplying small to medium size plants within municipalities and townships. In total there are 94 pellet factories in Sweden supplying 2 million metric tonnes of pellets servicing detached housing, multi-dwelling housing and larger buildings.

**District Heating Cost**
A district energy system is comprised of a central plant connected to numerous buildings through a network of pipes, in order to provide heating or cooling. This approach replaces the need for individual, building-based boilers, furnaces, and cooling systems. Harvest residues are a common energy source for district heating as they allow for direct combustion and conversion to heat (BC Climate Action Toolkit, 2012). District heating is ideal for woody biomass on account of its flexibility in possible fuel inputs.
Combined with this fuel flexibility, district energy systems also have high energy efficiency and virtually no emissions.

One of the main deterrents to biomass power generation through district heating is the initial high capital cost. For district energy systems, an energy conversion facility and associated pipe network is necessary and must be built underground and connected to all buildings in the system. Retrofitting an existing building network is extremely expensive as opposed to inputting a system during the initial build.

**Wood Pellets Cost**
The wood pellet production process is the most common form of fuelwood energy production in British Columbia. Each year, the wood pellet industry ships 750,000 to 1,100,000 tonnes of wood pellets overseas (ENVIROCHEM, 2012). While direct combustion power plants and gasification plants have not gained traction within the province, the high prices paid by the European market for wood pellets make the industry profitable for BC manufacturers. In order to compete with EU prices, approximately $120/tonne or 2.4 cents/kwh is needed. For every tonne of BC pellets exported, 295 kg CO2 equivalent greenhouse gases is released.

**District Energy and Wood Pellet Infrastructure: Sweden**
A carbon tax on fuel in Sweden has incentivized the investment in district energy systems across the country. Figure 19 outlines how the carbon tax has had an impact on the price of district heating for each of the fuel sources.

**Figure 19: Relative Heat Production Costs-Sweden**

![Bar Graph showing relative heat production costs for different energy sources in Sweden](source)

*Source: Hilring, 1999*
Biomass-fired district heating has thus undergone massive proliferation in Sweden, where now 270 to 290 urban communities have district heating systems that use biomass as a principal energy source (Canadian Biomass Magazine, Mcallum, March 2010).

**Energy Production Infrastructure Issue Framework**

Figure 20 outlines the results from the literature review related to power production infrastructure. Three themes linked to power plant size, district heating installation and wood pellet infrastructure comprise this portion of the supply chain. Lessons from successful markets indicate smaller plant sizes and carbon taxes should be leveraged to compensate for the lack of economies of scale generated by the fuel.

**Figure 20: Energy Production Infrastructure Issue Framework**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Issue</th>
<th>Solution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Plant Size</td>
<td>The decision of where to locate a woody biomass plant and how large to make it is a fundamental step in the supply chain.</td>
<td>Due to the large role of transportation costs in providing harvest residues, the larger a catchment area becomes, the more expensive the residues are. The typical economies of scale enjoyed by building larger and larger power plants are not realized. Determining the size and location of a power plant is a crucial step towards realizing positive economic returns.</td>
<td>Finland, Sweden</td>
<td>Kumar et al., 2004</td>
</tr>
<tr>
<td>District Heating</td>
<td>A district energy system is comprised of a central plant connected to numerous buildings through a network of pipes, in order to provide heating or cooling.</td>
<td>One of the main deterrents to biomass power generation through district heating is the initial high capital cost.</td>
<td>Sweden</td>
<td>BC Climate Action Toolkit, 2012</td>
</tr>
<tr>
<td>Wood Pellets Infrastructure</td>
<td>British Columbia has a large wood pellet industry, where harvest residues are turned into easily combustible pellets for district heating or home furnaces.</td>
<td>The province exports 90 percent of its wood pellets to Europe, incurring greenhouse gas and human health costs.</td>
<td>Sweden</td>
<td>ENVIROCHEM, 2012</td>
</tr>
</tbody>
</table>
Market
While issues related to biomass infrastructure touch on the demand side of the market, the following grouping will delve further into themes regarding public demand for woody biomass as a fuel. British Columbia is blessed with abundant hydro electricity which can, while ensuring inexpensive energy for its residents, stifle development of other forms of renewable energy. Other themes related to public perception, land use planning and policy competition for feedstocks will be explored (Figure 21).

Figure 21: Market

Electricity Prices
Electricity prices in British Columbia represent one of the largest deterrents to biomass proliferation. On account of abundant hydro-electricity generation, BC Hydro offers one of the lowest electricity rates in the world (Figure 22). Given that hydro-electricity is also a renewable, clean energy source, there is limited incentive to switch to another clean energy source. There are no carbon credits that can be leveraged to replace hydro with biomass. BC Hydro is planning rate increases that will see electricity costs rise to 12 cents/kwh by 2014. However, additional incentives will still be needed to make woody biomass competitive.

Figure 22: Electricity Prices per Kwh in Select Cities 2008

Source: BC Climate Action Toolkit

BC Hydro offers electricity contracts for small scale biomass energy projects at 10 cents/kwh. In the absence of a feed-in tariff scheme, BC Hydro can be selective about IPP (Independent Power Producer)
projects. At this rate, new facilities, or “greenfield” projects are not financially feasible (BC Hydro, 2012). The 16 bioenergy projects sponsored by BC Hydro, or “brownfield” projects, build on existing operations underway at forestry companies. Greenfield biomass cogeneration projects require rates of 14 cents/kwh from BC Hydro to provide adequate return on investment. This translates into limited private investment in electricity cogeneration outside BC Hydro-mill partnerships.

**Natural Gas Prices**

In order to be competitive with natural gas and electricity, woody biomass must be less costly than natural gas. This fuel source is very inexpensive and readily available throughout British Columbia, costing on average 4 cents/kwh. Inflation of natural gas is also anticipated to be low at 2.4 percent per annum, resulting in a 2021 cost of 5 cents/kwh. Biomass must be significantly cheaper than natural gas due to increased storage, handling and investment costs. At 14 cents/kwh, the price of biomass is not low enough to incentivize use in the private sector and uptake is anticipated to grow slowly unless policies are introduced (ENVIROCHEM, 2012).

**Energy Prices: Sweden**

The promotion of renewable energy across Sweden is aided by the high prevailing price of electricity. Cost per/kwh in Sweden is three times the rate in British Columbia on account of taxes and production costs (Figure 23).

**Figure 23: Swedish Relative Costs of Energy**

![Figure 23: Swedish Relative Costs of Energy](image)

Source: SWANTEC, 2011

Primarily on account of a lack of oil reserves, the Swedish government has been promoting biomass supply chains since the 1970’s. The oil crisis of this era spawned the introduction of R&D programs, and subsidies were available for district heating systems and combined heat and power plants. A carbon tax
was introduced in the early 1990’s on nitrous oxide which dramatically increased the competitiveness of biomass fuels (Climate Change Solutions, 2007).

In 1996, the Swedish government allowed new producers to enter the market to promote competition and drive down prices. They allowed thermal station operators to generate electricity in a variety of renewable forms and sell it back to the grid. Electric certificates required end users to buy a certain quantity of electricity from renewable sources. The price for certificates was based on market demand and regulated by the government. This ensured continued demand for biomass, and reduced the risk for producers entering the market.

**Land Use Planning**

District energy requires compact, high density communities. Pipes must connect to each building, meaning low density suburban areas are not feasible for district energy. While British Columbia has a few notable district energy systems running on woody biomass, they are generally much smaller in scope than in Nordic countries. While Revelstoke has a district energy system, the connection supplies only a limited number of facilities. Revelstoke Community Energy Corporation (RCEC) burns wood waste for major municipal, institutional, and commercial buildings including a secondary school, community centre, aquatic centre, motels, stores, and a church (RCEC, 2007).

The district heating system run by the Lonsdale Energy Corporation provides energy to six buildings where much greater efficiencies can be made than in Revelstoke. The commercial and residential buildings have a combined floor area of 600,000 square feet serviced by the system (LDEC, 2011). While this system uses natural gas, it represents an ideal example of a high density community leveraging the efficiencies gained from district energy systems. Integrated land use and energy planning is needed in order to stimulate demand in the biomass energy sector.

**Land Use Planning: Sweden**

Decisions regarding energy systems are much more decentralized in Sweden. Municipalities typically own the local energy authority and are responsible for which fuel systems are used to power the community. This downloading of responsibility increases the autonomy of the community and ownership over environmental goals. It also means decisions about energy are based on more than just cost considerations, and can be for political or social goals (Nilsson et al., 2004). This allows municipalities to coordinate land use planning and energy decisions. Coordination of a high density footprint is essential when planning for district energy. Sweden’s higher density communities are ideally poised to integrate woody biomass combustion into their energy portfolio.
The few successful cases in British Columbia have followed this model including Lonsdale Energy Corporation and Revelstoke Community Energy Corporation, where the municipality forms a corporation to oversee energy systems. However, with the exception of LEC, these bodies typically only provide energy for municipal buildings while Sweden’s systems provide energy for the entire community.

**Competition for Feedstocks**

An additional problem facing the woody biomass industry is the increasing competition for different fuel inputs. As outlined, harvest residues can be converted into various forms of energy (Accion, Mabee & Saddler, 2010). Two forms of fuel converted from harvest residues are wood pellets and cellulosic ethanol.

The Federal Government of Canada’s bill C-33 has mandated that 5 percent of existing fossil fuel production must come from bioethanol by 2010 and 2 percent from biodiesel by 2012 (Advanced Biofuels, September 2009, Canadian Biomass). Canada consumes about 40 billion litres per year of gasoline, meaning five percent translates to two billion litres. Canada currently produces about 1.3 billion litres of ethanol, leaving the country 700 million litres short. However, given the quantity of woody feedstock available for the production of cellulosic ethanol, Canada currently has a capacity to produce 16 percent of 700 million litres using harvest residues.

Policy encouraging competition between these two industries means that a critical mass cannot be reached in either, stifling chances to attain widespread adoption. Not only can a critical mass not be reached in either industry, but competition for feedstocks and the potential for further price increases also deters potential investment. Large scale adoption of one or the other is needed to fully capture economies of scale.

**Competition for Feedstocks: Sweden**

While Sweden invests significantly into biofuel R&D each year (approximately 7.1 -10.1 million CAD) the funding has not led to significant advances in the prevailing technology. The majority of the biomass industry uses proven and conventional technologies such as combustion or combined heat and power (CHP) (Nilsson et al., 2004). The production of ethanol from lignocellulosic biomass or biomass integrated gasification combined cycle technology has not yet resulted in wide scale commercial applications. This suggests British Columbia should also continue to employ conventional technologies until further advances can be made through R&D.
Air Quality and Public Perception
There is considerable concern surrounding wood biomass combustion with respect to air quality. Part of this is due to mixed messaging from residential wood burning programs, which aim to replace inefficient wood stoves with safer stoves that reduce particulate matter. Citizens can confuse the air issues with wood stoves with the problems of woody biomass district energy and assume all wood burning is harmful.

Public perception is even more crucial in urban areas where strict emission standards and high density can lead to significant NIMBYism. In fact, the City of Vancouver saw two wood based energy plants shelved in the face of public outcry (ENVIROCHEM, 2012).

Public Perception: Florida, USA
A survey of residents in Florida revealed a lack of knowledge of the climate change benefits of wood residues over natural gas. The survey also revealed citizens were concerned about cutting down trees. However, when they were informed of the fact that the biomass facility would be making use of excess residues, they were in strong support of the program. A strong marketing campaign is necessary to promote woody biomass as a fuel source (Monroe & Oxarat, 2009).

Market Issue Framework
The last classification framework contains issues not usually associated with the woody biomass supply chain (Burgess et al. 2006). Evidence in the literature from successful markets indicates it is important to ensure prices of biomass are competitive with other energy sources and coordination between land use and energy planning is undertaken (Figure 24).
<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Issue</th>
<th>Solution</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Prices</td>
<td>On account of abundant hydro-electricity generation, BC Hydro offers one of the lowest electricity rates in the world at 6 cents/kwh.</td>
<td>Low electricity prices stifle investment in renewable energy such as woody biomass</td>
<td>Sweden</td>
<td>BC Hydro, 2012</td>
</tr>
<tr>
<td>Natural Gas Prices</td>
<td>British Columbia also has very low natural gas prices at approximately 4 cents/kwh.</td>
<td>Low natural gas prices make it financially unattractive to switch to woody biomass technologies.</td>
<td>Sweden</td>
<td>ENVIROCHEM, 2012</td>
</tr>
<tr>
<td>Land Use Planning</td>
<td>Planning for energy systems and land use decisions must be made in tandem to capitalize on renewable technology.</td>
<td>District energy requires compact, high density communities. As there are pipes that must connect to each building, low density suburban areas are not feasible for district energy, which unfortunately is the predominant land use form within BC’s communities.</td>
<td>Sweden</td>
<td>BC Climate Action Tool Kit, 2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nilsson et al., 2004</td>
</tr>
<tr>
<td>Competition for Feedstocks</td>
<td>Harvest residues can be converted into various forms of energy. Two major forms of fuel converted from harvest residues are wood pellets and cellulosic ethanol.</td>
<td>The competition between different forms of a fuel will prevent critical mass in either industry and may drive up prices.</td>
<td>Sweden</td>
<td>Ackom, Mabee &amp; Saddler, 2010, Nilsson et al., 2004</td>
</tr>
<tr>
<td>Air Quality and Public Perception</td>
<td>There is concern whether air quality will be compromised with direct combustion and gasification of harvest residues, from both a public perception perspective and human health perspective.</td>
<td>Public resistance has blocked several district energy projects.</td>
<td>Florida</td>
<td>ENVIROCHEM, 2012, Mahapatra &amp; Gustavson, 2009</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND RECOMMENDATIONS

The comprehensive literature review facilitated an important understanding of the barriers to the woody biomass energy industry. The recommendations that came out of the classification process can act as a guide for policy makers and stakeholders to move towards a more successful woody biomass sector in British Columbia. However, the overarching message of this report is to illuminate the scope of the issues and understand the linkages between different industry silos. Attention must be paid to providing solutions that address problems across the four groupings. For example, procuring a long term contract for harvest residues will not be possible if policies are not employed to incentivize demand and raise the price of energy.

Integration between the forestry industry and energy producers emerged as a solution to several of the issues uncovered in the report. The unique supply chain of woody biomass and the large portion of fixed costs already covered by the forestry industry mean sharing resources is one way to make this fuel source economical. Even when integration takes place, additional provincial policy will be needed to level the playing field with other inexpensive fuel sources, such as hydro and natural gas.

An important message underpinning many of the recommendations of this report is the downloading of responsibility over energy delivery to the local level. Woody biomass needs small scale energy facilities to generate positive returns and this can best be employed by municipal government. The report recognizes that the provincial government must set the economic parameters and provide informational resources, but must give the tools and authority to those that are responsible for land use planning. Land use planning decisions and energy system development must be coordinated. The current separation of duties will continue to lead to missed opportunities and negative externalities. If land use planning and energy planning can be better coordinated through the political, social and economic recommendations in this report, renewable energies such as biomass stand a greater chance of being integrated into society.

Recommendations

While numerous problems facing the woody biomass industry have been presented, solutions identified in the literature scan provide insight into possible next steps. The recommendations for policy makers and stakeholders take into account the interaction between the various themes uncovered in the literature and are therefore general in nature.
Creation of a “Wood Fibre Act” that guarantees enough residues for the internal needs of the forestry industry

The forestry industry in British Columbia has showcased a hesitation to enter the woody biomass market. Uncertainty over the future price of residues and potential increases in their own energy costs make them unlikely to make long term agreements for fibre flows. Due to uncertainty over future production of residues, forestry companies continue to burn biomass to avoid the risk of committing to contracts.

However, lessons uncovered in Sweden present a possible way to counter this reluctance and ensure the forestry industry can meet its internal energy needs. The Wood Fibre Act presents a useful template for the provincial government of British Columbia to assuage fears of residue shortages in the forestry industry. The Swedish government reduced risk to forestry companies by guaranteeing them first access to a set quantity of residues that would meet their internal power needs. In Sweden this was 200,000 m$^3$ per annum, however this could be adjusted based on the annual energy consumption needs of BC lumber companies. The Wood Fibre Act was no longer needed after six years in the Swedish market, once the forestry industry was on board. However, a similar act in BC could act as a useful bridge by reducing risk and improving relations between the forestry companies and energy providers.

Couple the introduction of a “Wood Fibre Act” with subsidies and grants

In Sweden, the introduction of the Wood Fibre Act was coupled with subsidies and grants to forestry companies willing to engage in the biomass industry. In addition, residues provided to the biomass industry on behalf of the forestry industry exempted them from an array of carbon and energy taxes. For example, industries in Sweden must purchase green certificates that prove they derive a portion of their energy from renewables. Industries that produce renewable energy can issue certificates and sell them. The forestry industry can both sell green certificates when engaging in the biomass industry and is not required to purchase them. While this program would require a much broader provincial commitment, it demonstrates one way of rewarding the forestry industry for internalizing negative environmental externalities.
Engage in an inter-provincial exchange of forestry data to more accurately capitalize on residues. Create a provincial body tasked with making an inventory of biomass potential across the province based on mapping, remote sensing and detailed industry information

An inability to accurately predict the energy content of a forest management unit and a wide range of factors make it difficult to properly forecast fuelwood potential. FMU boundaries were not created along natural borders and have a wide variation of natural features within them.

Lessons learned in Finland can be applied in a British Columbian context. While individual mapping projects have taken place across the province, there is no holistic database that looks beyond administrative lines. Researchers in Finland, however, have created a nation-wide supply analysis of biomass potential by grouping the country into regions based on similar features. This method allows policy makers to account for variation in yield geographically. Instead of traditional FMU governing residue extraction, a more natural dispersion of uniform regions will reduce variability of energy output. In the case that FMU’s cannot be reoriented, this method can more accurately predict energy potential of each stand. The geographic visualization allows for better forecasting and reporting, reducing risk for energy producers.

Increase Research and Development in the Woody Biomass Industry

In Finland and Sweden, R&D in the bioenergy sector is approximately $7.1-$10.1 million dollars per year. The spending goes towards developing new cost efficient technologies in the industry. One recent outcome of this spending was the development of an innovative and cost effective way to store harvest residues over the winter. Residues are wrapped in paper covers and are protected from absorbing moisture from the elements. Covering the residues with paper and therefore maintaining energy content can increase returns to energy producers by 200 percent. This is just one innovation that can come from improved research. While British Columbia can piggyback off the research of other countries, investment in R&D is an important industry incubator.

Improve integration between forestry companies and biomass industry to cut down on logistics costs

Processing and transporting harvest residues is the most expensive portion of the woody biomass supply chain. In order to complicate matters, the three systems for processing; slash, hog-fuel and bundle, each come with their own unique set of fuel, machine and time costs. The correct system for each site must be chosen based not only on cost, but also on total emissions from transportation to ensure the fuel source remains ‘renewable’. Choosing the correct system is very important, as small cost overruns can erase profit margins for energy producers.
In Sweden, however, the introduction of the *Wood Fibre Act* made forestry companies much more compliant with the biomass industry. Instead of having two separate supply chains, where the forestry companies leave residues at roadside and the energy producers process and transport the goods, the Swedish model has integrated the production stages of the supply chain. In fact, most biomass companies are now owned by the forestry companies, allowing the two industries to share transportation infrastructure and machinery. The industries are now so integrated that several industrial sawmills in Sweden have purchased wood pellet machinery to process the residues into refined fuel. Integrating the two industries in British Columbia would dramatically reduce supply costs and improve the financial returns for the biomass industry. In addition, capitalizing on the knowledge base of forestry companies would improve the ability to forecast energy potential. Supply costs of harvest residues represent 45 percent of total fuel cost, and sharing the costs of machines, roads and operations would go a long way towards making biomass more financially attractive (Kumar *et al.*, 2004).

**Introduce smaller scale power plants and embrace the development powder technology**

While integrating supply chains will cut down on supply costs, the available biomass technology continues to deliver optimal returns at small scales. Wood pellet fuel or powder must be transported by truck and therefore should not travel large distances. The ability to build small to medium sized plants has enabled Sweden to achieve economies not yet seen in British Columbia. There has been development of bio-energy plants with an energy capacity between 0.3 and 25 MW across the country. Continuing R&D in this sector has brought down the costs of these facilities and has allowed a localized, stable energy supply. The facilities have been introduced as district heating plants or individual systems for larger buildings. The example set by the Lonsdale Energy Corporation provides a useful template for small scale energy systems in British Columbia and should be replicated across the province.

**Increase hydro-electricity energy and natural gas rates**

The cost of hydroelectricity in the province of British Columbia is 6 cents/kwh, (BC Hydro, 2012) while the cost of natural gas is 4 cents/kwh (Envirochem, 2012). The cost of biomass generated from existing pulp and paper mill operations is 12 cents/kwh, while new facilities deliver biomass at 14 cents/kwh. BC Hydro plans to increase rates on electricity to 12 cents/kwh by 2014, but should consider rate parity or higher with woody biomass. The same should be done for natural gas rates. This will allow BC Hydro to pay Independent Power Producers the required rates to cover the cost of generating energy from biomass.
Download jurisdiction regarding energy systems to municipalities and regional districts in order to ensure decisions are based on more than just cost considerations, and include political and social factors

Decisions regarding energy production in British Columbian municipalities are governed by the provincial government. With the exception of the City of Vancouver, municipalities must receive approval from BC Hydro and the province before engaging in Independent Power Producer projects (IPPs). This can dissuade local governments from attempting to engage in renewable production in the face of bureaucratic and time consuming approvals. Increasing legislative power over energy decisions in the Local Community Charter will give capacity to those who care most about the sustainability of their community. It will also ensure the delivery of energy will not be based solely on cost, but will include political and social considerations central to municipal government.

Roll out a marketing strategy creating awareness for woody biomass

There is a lack of knowledge in the market regarding the environmental benefits of woody biomass as an energy source. A marketing strategy outlining the potential contribution of harvest residues to the environment and the economy will go a long way in generating community engagement on the issue. Concerns about air quality or forest health must be dispelled and information about the benefits of this resource should be highlighted in a public forum. If greater jurisdiction over energy systems is downloaded to local government, this would be an ideal place for such a marketing strategy to be generated.

Further research surrounding the supply chain of woody biomass is needed. As this was the first time the classification framework used in this report was applied to woody biomass research in British Columbia, additional reviews could begin to develop a more consistent methodological approach. Renewable energy is becoming increasingly important and as more countries switch to woody biomass, more comprehensive solution systems could be analyzed.

The recommendations provided in this report will hopefully move this energy source onto the main stage as British Columbia moves towards a more renewable energy future.
Bibliography


Energy End-Use Data and Analysis Centre (CIEEDAC), Simon Fraser University, Burnaby, B.C.

Andrea Renney 2012

Barriers to the Woody Biomass Energy Industry in BC


RCEC, 2007


Stennes, B. & Mcbeath, A. (2008). *Bioenergy options for woody feedstock: are trees killed by mountain pine beetle in British Columbia a viable bioenergy resource?* Natural Resources Canada, Canadian Forest Service, Victoria, BC.

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