UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Biomass Sourcing For Gasifier at UBC Point Grey Campus

Synthesis Report

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APSC 364

April 11, 2011

BIOMASS SOURCING FOR GASIFIER AT UBC POINT GREY CAMPUS

Synthesis Report

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April 11, 2011

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The UBC Bioenergy Research and Demonstration Project is a sustainability initiative on the UBC campus designed to help meet the University's sustainability goals. The project is planned to offset 5% electricity use and 12% steam use through a biomass power plant whereby wood-based fuel inputs will be converted into clean energy[1]. The ultimate goal of the project is to eliminate up to 4,500 tonnes of greenhouse gas emissions per year[2].

The scope of this engagement is to conduct comparative analysis across four different fuel sources - hog fuel, B.C. pine beetle, municipal trimmings, and construction & demolition fuel - and select a commercial vendor to ultimately supply fuel for 80% of the plant's operating capacity.

Fuel types were analyzed across economic, environmental, and social categories. Within these categories, each of the eight vendor candidates were evaluated across 13 criteria and 16 indicators.

Ultimately, it was found that construction and demolition wood ranked as the best fuel source. As such, Urban Woodwaste Recyclers is the recommended vendor for UBC's biomass power plant.

[1] Giffin, 2010
[2] Ibid.

INTRODUCTION

UBC Context and Sustainability Goals

UBC is a leader in combining environmental sustainability with teaching and research. It is the University's goal to ensure long-term sustainability and to reach a 100% reduction of 1990 Greenhouse Gas (GHG) emissions by 2050[3]. UBC has partnered with Nexterra Energy and General Electric (GE) to install a combined heat and power plant (CHP). It is UBC's goal to offset a portion of the current amount of natural gas consumed at the central steam plant and electricity purchased from BC Hydro.

UBC predominantly uses two types of energy: natural gas and electricity. Natural gas is used to power UBC's steam network while electricity is used to power campus electrical systems. The steam generated from the burning of gas is then distributed throughout UBC's District Energy System. UBC currently sources its natural gas from Terasen Gas and purchases this gas at spot market prices[4]. Given the increasing trend of natural gas prices as seen in Figure 1, natural gas offsetting strategies such as the biomass plant can help UBC sustainably power the campus for the long term. In terms of electricity, UBC has two main lines which run throughout the campus to power the University's buildings. A breakdown of the electricity use can be seen in Figure 2[5]. UBC's commitment to the creation of a biomass gasification plant will make a small reduction in UBC's energy outputs, but will act as a significant step toward future sustainability goals.

Figure 1: Natural Gas Prices (1989-2009)

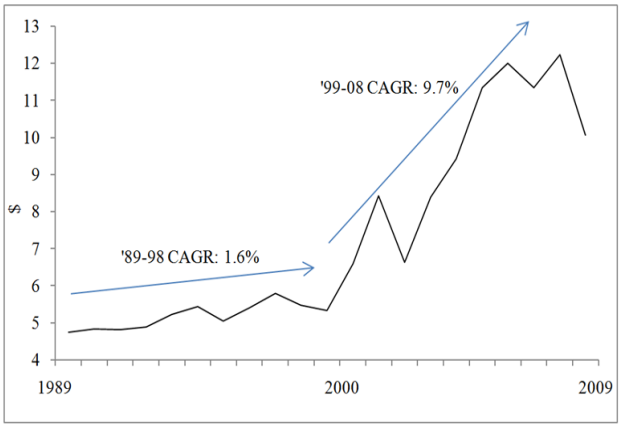
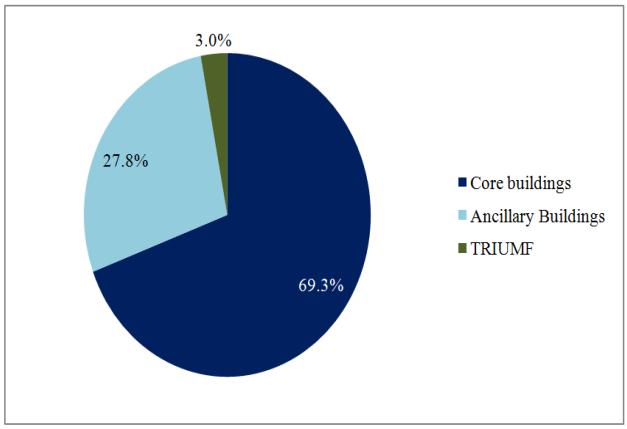


Figure 2: Breakdown of electricity use at UBC



Project Scope

The purpose of this report has been to develop a set of criteria with which to analyze the eight proposed wood fuel sources. While there are many aspects of the research and demonstration project that can be examined, the scope of this project remains on evaluating the potential impact of the fuel sources across the different vendor candidates. This evaluation was conducted with

[3] UBC Place and Promise, 2011
[4] Giffin, 2010
[5] Alternative Energy Feasibility Report – Phase Two, 2010

the three pillars of sustainability in mind – economic, environmental and social - which formed the overarching structure of the assessment tool that was developed.

A key source of information for this analysis has been Jeff Giffin's *UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Supply Options*, which not only outlined the project but also supplied key figures on moisture content, tonnage, and environmental impact of the harvesting, chipping, trucking and UBC stages. Further information regarding each vendor's operation and staff size, location, and community size was researched online. A complete list of citations can be found at the end of this report.

FUEL SOURCE OPTIONS

The eight vendor candidates under examination fall under four general fuel source categories:

- **Hog Fuel:** Consists of pulverized bark, shavings, sawdust, low-grade lumber and lumber rejects from the operation of pulp mills, saw mills and plywood plants[6].
- **Construction and Demolition (CC+D)**: Wood waste from construction and demolition sites[7].
- **Municipal trimming**s: Wood material collected from cities in maintenance of trees in parks and residential areas[8].
- **BC pine beetle**: Wood collected from forests infected by the mountain pine beetle[9].

A summary of each vendor can be found below:

Figure 3: Vendor & Fuel Source Summary

	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	Urban Woodwaste Recyclers	Davey Tree	City of Vancouver	Int'l Bio Fuels	Trace Resources
Fuel Type	Hog Fuel	Hog Fuel	Hog Fuel	CC+D	Municipal Trimmings	Municipal Trimmings	BC Pine Beetle	BC Pine Beetle
Moisture content	45%	45%	45%	25%	55%	50%	20%	25%
Tonnes required	24000	24000	24000	16500	28095	26000	14600	16500
Cost/tonne	$42.50	$40.00	$42.50	$50.00	-	-	$77.00	$70.00
Cost (total)	$1.4M	$1.3M	$1.4M	$1.0M	$0.36M	$0.36M	$1.4M	$1.4M
Vendor Location	New West	Mission	Langley	Vancouver/ New West	Vancouver	Vancouver	Merritt	Merritt
Location Population	57,549	34,505	93,726	578,041/ 57,549	587,041	587,041	6998	6998
Vendor staff	22	-	35	90	7000 (North America)	-	-	-

[6] BC Government News Release, 2008
[7] Giffin, 2010
[8] Ibid.
[9] Ibid.

Basran (Hog Fuel): Basran is one of the closest suppliers to UBC and thus has the potential to save on costs and transportation emissions based solely on the limited distance between Basran and the University campus. However, the 45% moisture content would increase energy requirements for drying before the fuel can be processed.

Chips Ahoy Fibre Supply LTD (Hog Fuel): Located in Mission BC, this fuel source would require almost 80 km of trucking each way, significantly increasing CO_2, SO_2 and ORG emissions. Furthermore, the moisture content is also 45%, increasing the energy use for drying.

Cloverdale Fuel Co. LTD (Hog Fuel): Similar to Basran, Cloverdale is also located in close proximity to UBC, requiring less trucking relative to other vendors. At the same time, as the fuel source is hog fuel, the moisture content is quite high at 45%.

Urban Woodwaste Recyclers (Construction and Demolition): Urban Woodwaste Recyclers collects wood waste from demolition crews and resells it for profit. The moisture content is within the desired range (25%) and will not require the use of UBC's dryer. The company is located in New Westminster - just under 40km away. The potential downside to this fuel source is the possibility of trace chemicals from the demolition material. However, the impacts of this on the combined heat and power plant are still unknown.

Davey Tree (Municipal Trimmings): Davey Tree is a privately-owned tree care company that services both residential and commercial properties in the GVRD and would be supplying their trimmings free of charge as they are a waste product for this vendor. Located in Richmond, this source offers the least distance travelled at only 22 km, but at the same time, has the highest moisture content of 55% which would require the most energy when drying the fuel.

City of Vancouver (Municipal Trimmings): The City of Vancouver has entered a Memorandum of Understanding (MOU) with UBC and will donate municipal trimmings from its parks located in various areas around Vancouver. As with Davey Tree, City of Vancouver trimmings are also very high in moisture content at 50%, and are also located very close to UBC.

International Biofuels (B.C. Pine Beetle): With a 20% moisture content, fuel from this vendor would not require any drying. However, this firm is located in Merritt which is over 280 km away, thereby increasing the environmental impact of this source due to the increased trucking phase. Furthermore, B.C. Pine Beetle fuel has the highest potential for acid rain and smog formation due to the harvesting with diesel equipment.

Trace Resources (BC Pine Beetle): Trace Resources offers one of the lowest moisture contents at 25%, which would not require the use of a dryer. However, this vendor is located in Merrit 280 km away which would again increase the emissions due to the increased trucking. It should also be noted that Trace Resources is already in cooperation with Domtar pulp mill in Kamloops to produce electricity[10], which might serve as direct competition for UBC and could increase the price of biomass fuel in the future.

[10] BC Ministry of Forests and Range Press Release, 2008

OVERVIEW OF THE ASSESSMENT TOOL

Purpose

An evaluation matrix was used to assess the different source options. The vendors described above were ranked against a set of 13 different criteria. Each criteria was placed into one of three different categories: economic, environmental or social. These 3 pillars of sustainability were selected to guide the analysis in order to encapsulate the many facets involved with successful sustainability evaluation.

While UBC's most prominent sustainability goal is to achieve 100% GHG elimination by 2050, there are many other factors beyond carbon emissions that should be considered when evaluating a fuel source's sustainability potential. Economic criteria help to ensure that the fuel source is financially feasible in both the short and long term, making the source attractive from an operational standpoint. Environmental criteria not only include traditional measures such as GHG emissions, but also attempt to capture other factors that could have environmental ramifications on UBC and the surrounding area. Finally, social criteria support UBC sustainability goals by investigating social impacts not only within UBC, but also impacted stakeholders external to the University. It is through these three categories that an ultimate fuel source was identified as the optimal sustainable fuel source.

When developing this assessment tool, there was particular emphasis placed on building a matrix that considers an exhaustive set of sustainable factors across the fuel source's lifecycle. In doing so, the aim was that no fuel source would be ultimately recommended without its negative sustainability attributes exposed. Overall, this assessment tool was designed to assess the fuel source options for the biomass power plant at a level that maintains UBC's high quality standard.

Approach

The development of an effective evaluation tool relies on the creation of a strong criteria set. The aim when choosing the criteria was to push UBC to adopt a comprehensive evaluation methodology that extends beyond traditional, easily quantifiable metrics such as greenhouse gas emissions and annual cost. As such, criteria development began with establishing an exhaustive list of criteria that may hold relevance for fuel source evaluation. This list of criteria was then narrowed down until a final criteria set was established. The table on the following page provides a summary of this elimination process:

Figure 4: Establishing an Appropriate Criteria Set

	Criteria List	Traditional Influence	Desired Influence	Outcome	Justification
Economic	Fuel cost			Include	Standard economic measure
	Price sustainability			Include	As important as spot price
	Minimizing operational risk			Include	Links economic to environmental
	Operating cost of drying fuel			Include	Standard economic measure
Environmental	GHG emissions			Include	Standard environmental measure
	Acid rain potential			Include	Standard environmental measure
	Smog formation potential			Include	Standard environmental measure
	Energy consumption during drying phase			Include	Important environmental factors
	Post-gasification environmental risk			Include	Acknowledges a new phase
Social	Transportation noise externality			Include	Accounts for UBC stakeholder
	Relative benefit to source community			Include	Community impact (individuals)
	Alternative use of fuel source			Include	Considers 'what-ifs'
	Relative benefit to vendor			Include	Impact small B.C. businesses
	UBC community perception			Not include	Plant focused, not fuel focused
	UBC research & education			Not include	More pertinent to other projects
	Campus odour externality			Not include	Total odour is already negligible

LEGEND:
Not Include
Include

The traditional influence column in the above table asks "to what degree might UBC typically include a certain criteria when undergoing sustainability project assessment on campus?" In contrast, the desired influence column reflects which criteria this engagement team felt should be included in order to develop a comprehensive sustainability criteria set. Ultimately, the top 13 criteria shown in Figure 4 were selected for inclusion in this evaluation study.

Criteria Weighting

In the base-case evaluation, the economic, environmental and social categories were weighted equally. A sensitivity analysis was conducted to determine how a reconfiguration of these weightings might impact the final recommendation. This can be found later in the report.

Within each of the three high-level categories, weightings were assigned to each criteria. These weightings remained unchanged throughout the course of the evaluation study. The final criteria set along with the respective weightings can be seen below:

Figure 5: Final Criteria Set and Weighting

Final criteria set

33% Economic		33% Environmental		33% Social	
45%	Fuel cost (materials, transport, taxes)	45%	GHG emissions	10%	Transportation noise externality
20%	Price sustainability	15%	Acid rain potential	25%	Job creation for source community
10%	Minimizing operational risk	15%	Smog formation potential	40%	Alternative use of fuel source
25%	Operating cost (drying fuel)	15%	Energy consumption (drying phase)	25%	Relative benefit to vendor
		10%	Post-gasification environmental risk		

Overall, the criteria weightings were assigned based on the perceived overall impact a specific criteria might have on the project. For instance, 'total fuel cost', 'operating cost', and 'price sustainability' together encompassed a majority of the economic category because these are the primary drivers that will likely determine financial viability from a management perspective. In contrast, criteria such as 'post-gasification environmental risk' comprised only 10% of the environmental category because the degree of its environmental impact is relatively unknown. Given that this report represents an early evaluation stage, weighting 'post-gasification environmental risk' too heavily could eliminate a vendor candidate prematurely. Within the social category, a criteria such as 'transportation noise externality' was assigned a low weighting because there are multiple strategies that can be employed to mitigate this issue such as evening or weekend truck trips. This ease of mitigation ultimately led to lower social impacts when compared to other criteria such as source community job creation of alternative fuel source uses.

EVALUATION MATRIX

Evaluation Methodology

With a final set of criteria developed, indicators were created in order to measure each selected criteria. A majority of quantitative criteria had data available that could be used directly as an indicator. For instance, 'material cost', 'transportation cost', and 'tax data' were available to measure the annual cost criteria and CO_2 emissions data could be used as an indicator to directly measure the greenhouse gas emission criteria. Conversely, other criteria required assumptions to act as a proxy for measurement. For instance, long-run price data could not be collected. Instead, demand and supply assumptions for each fuel source were used as a substitute to assign price sustainability scores. A further discussion of the evaluation methodology can be found below:

Figure 6: Evaluation Methodology

Criteria	Indicator	Type	Discussion
Economic			
Fuel	Total annual cost ($/yr) ▪ Material cost ▪ Non-rebateable HST ▪ Distribution cost ▪ Carbon tax	Quantitative	Total annual cost was aggregated from four different cost figures: material cost, distribution cost, non-rebateable HST, and transportation carbon tax. Operating cost at the UBC power plant itself was not included in this section. Because post-drying costs are the same across all fuel sources, the only UBC point gray cost that was relevant was the drying cost. Drying cost was reflected in its own criteria.
Price Sustainability	Demand ▪ Low (3 pt) ▪ Med (2 pt) ▪ High (1 pt) Supply ▪ Low (1 pt) ▪ Med (2 pt) ▪ High (3 pt)	Qualitative	Since fuel price data could not be collected directly, assumptions were made regarding the demand and the supply of a fuel source. A fuel anticipated to have a low demand and high supply would rank the best in terms of price sustainability.
Minimizing Operational Risk	Trace chemical risk ▪ Yes (0 pt) ▪ No (1 pt) Decomposition risk ▪ Yes (0 pt) ▪ No (1 pt)	Qualitative	Presence of trace chemicals or decomposed matter violates Nexterra's specifications for wood fuel that can be gasified. Fuel sources that are at risk of containing trace chemicals or decomposed matter could have negative consequences on plant machinery, thereby potentially increasing maintenance costs or forcing UBC

			to order high batch sizes in order to fill the plant's capacity with viable wood.
Operating Cost of Drying Fuel	Total energy usage during drying (GJ/yr)	Quantitative	Since specific cost data was not available regarding only the drying phase, energy usage during drying was used as a proxy. It is assumed that since cost per GJ is likely fixed, the energy usage will be directly correlated to the cost of drying.
Environmental			
GHG Emissions	Tonnes CO2-e/year	Quantitative	Total tonnes of CO2-e/year were aggregated across the harvesting, chipping, transportation, and point gray phases of the lifecycle.
Acid Rain Potential	Tonnes SO2-e/year	Quantitative	Total tonnes of SO2-e/year were aggregated across the harvesting, chipping, transportation, and point gray phases of the lifecycle.
Smog Formation Potential	Tonnes ORG/year	Quantitative	Total tonnes of ORG/year were aggregated across the harvesting, chipping, transportation, and point gray phases of the lifecycle.
Energy Consumption During Drying Phase	Total energy usage during drying (GJ/year)	Quantitative	Only fuels that contain a moisture content above 25% were considered to consume energy in order to dry the wood fuel to the ideal level.
Post-gasification Environmental Risk	Trace chemical risk: ▪ Yes (0 pt) ▪ No (1 pt)	Qualitative	It is important to consider environmental effects that occur after gasification has occurred as well. It is assumed that a fuel source containing trace chemicals before being gasified is also at risk of creating an ash by-product that contains harmful chemicals as well.
Social			
Transportation Noise Externality	# of truck trips/year	Quantitative	Truck trips used to transport fuel to the UBC campus may create noise disruptions on campus. It is assumed that a greater number of annual truck trips will lead to a higher likelihood that noise externalities occur.
Relative Benefit to Source Community	# of jobs created ▪ Low (1 pt) ▪ Med (2 pt) ▪ High (3 pt) Size of community ▪ Large (1 pt) ▪ Med (2 pt) ▪ Small (3 pt)	Qualitative	A benefit to the source community was defined with respect to job creation. Both the number of jobs created and the size of the impacted community were considered within this analysis. Ultimately, there would be a higher relative social impact if UBC contracted a vendor in a small community wherein a high number of jobs are created.
Alternative Use of Fuel Source	Fuel would otherwise be harmful or unproductive ▪ No (0 pt) ▪ Yes (1 pt)	Qualitative	This criteria considers how a fuel source would be used or disposed of if it was not chosen as a fuel input for UBC's power plant. UBC should be more inclined to choose a fuel that would otherwise be harmful or unproductive because the use of it as a fuel source diverts these alternate repercussions. In effect, UBC creates a social impact by supporting a market for diverting the disposal of harmful materials.
Relative Benefit to Vendor	Firm size ▪ Large (1 pt) ▪ Medium (2 pt) ▪ Small (3 pt)	Qualitative	This criteria captures the social benefit of supporting small British Columbia businesses. Providing that these small firms are able to effectively supply wood fuel for the long term (captured in the price sustainability criteria), a smaller firm would be a more highly favoured vendor.

Score Allocation

Assumptions were made when conducting the analysis of many of the quantitative and qualitative criteria. However, two criteria in particular – price sustainability and relative benefit to the source community – require more in-depth explanation regarding the allocation of points throughout the analysis. This discussion can be found below:

Price Sustainability: In projecting the supply and demand for each fuel source, generalized conclusions were made about the different fuel types and their location. Due to a lack of in-depth information regarding each vendor, assumptions were made regarding the fuel types as a whole. It is understood that these assumptions are subject to error. This analysis merely serves as a baseline with which further analysis may be conducted. Below is a summary of demand and supply assumptions:

Figure 7: Demand and Supply Assumptions

Fuel Type	Demand Assumptions	Supply Assumptions
Hog Fuel	▪ Neutral	▪ Low supply – the B.C. forestry industry has been in decline over the last few years[11]; this will decrease the availability of this fuel source.
BC Pine Beetle	▪ High demand – both B.C. Pine Beetle vendors have signed agreements to provide fuel to similar projects in B.C. (Trace Resources – Kamloops Domtar Mill[12], Int'l Biofuels – Spectrum Energy[13]) .	▪ High supply – B.C. pine beetle infestation is predicted to continue in the future with drier, hotter summers[14].
Municipal Trimmings	▪ High demand – as this source of fuel is free, the assumption is that there will be a high demand from similar projects in the future.	▪ High supply – for City of Vancouver, the supply of parks where the trimmings comes from is assumed to be constant; for Davey Tree it is a neutral supply.
Construction and Demolition	▪ Low demand – while Urban Woodwaste Recyclers is the largest in the lower mainland, their business is structured on taking construction waste and recycling it for primarily composting and mulching[15].	▪ High supply – there over 350,000 tonnes of woodwaste in landfills currently[16].

[11] Giffin, 2010
[12] BC Government News Release, 2008
[13] International Biofuels News Release, 2009
[14] Natural Resources Canada, 2011.
[15] Urban Woodwaste Recyclers Website, 2011
[16] Ibid.

Relative benefit to source community: For this criteria, assumptions were made regarding the size of the community and the size of the vendor. For the former, data was collected regarding the population of each vendor's city; small communities were assumed to be under 40,000 while large communities had populations over 60,000. For the vendor size, information was gathered regarding each firm's employee size, revenue and how long it had been in operation. This collected data was then used to rank the firms as either small, medium, or large. Because UBC's order size is relatively fixed, it was assumed that smaller communities would see a larger relative increase in the number of jobs created in order to increase processing capacity and meet the University's demand.

RESULTS

Ranking

Figure 8 shows the final rankings across each of the 13 different criteria. Please refer to the appendix for a full break-down of the rankings within each criteria.

Figure 8: Ranking of vendors against each criteria 1-8, 1 being the highest

Criteria	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	Urban Woodwaste Recyclers	Davey Tree	City of Vancouver	International Bio Fuels	Trace Resources
Annual Fuel Cost	6	4	6	3	1	1	5	8
Price Sustainability	4	4	4	1	2	3	4	4
Minimizing Operational Risk	3	3	3	3	1	1	3	3
Operating Cost of Drying Fuel	4	4	4	1	7	7	1	1
GHG Potential	8	8	8	1	5	5	3	3
Acid Rain Potential	6	6	6	1	3	3	8	8
Smog Formation Potential	6	6	6	1	3	3	8	8
Drying Phase Energy Use	4	4	4	1	7	7	1	1
Post-Gasification Environmental Risk	1	1	1	8	1	1	1	1
Transportation Noise Externality	4	4	4	1	7	7	1	1
Relative Benefit to Source Community	4	1	4	6	7	7	1	1
Alternative Use of Fuel Source	2	2	2	1	2	2	2	2
Relative Benefits to Vendor	1	1	1	6	7	7	1	1

Key Drivers

Below is a brief description regarding the key drivers that allowed a fuel source to rank first place within a given criteria:

- **Annual fuel cost (1st Place: municipal trimmings):** Given that materials cost represents a large proportion of total annual fuel cost, municipal trimmings vendors were able to rank first because the fuel is provided to UBC for free.
- **Price sustainability (1st Place: construction):** supply remains high because construction wood waste is projected to remain at a high level. Demand is relatively lower than other fuels because there has traditionally been found to be less uses for construction wood waste compared to other sources.
- **Minimizing operational risk (1st Place: municipal trimmings):** municipal trimmings are at a lower risk of containing trace particulates when compared to other fuels such as construction wood. Municipal trimmings are also freshly cut, giving it a lower chance of decomposition.
- **Operating cost of drying fuel (1st Place: construction and B.C. pine beetle):** both fuel sources contain lower moisture content and therefore cost less to dry.
- **GHG emissions, acid rain potential and smog formation potential (1st Place: construction):** construction and demolition wood uses electricity instead of diesel during the chipping phase and has no associated emissions during the harvesting stage, thus allowing this fuel type to rank first across all three criteria.
- **Drying phase energy use (1st Place: construction and B.C. pine beetle):** both fuel sources meet the moisture content threshold and thus do not require any energy during the drying phase.
- **Post-gasification environmental risk (1st Place: all fuel sources except construction):** construction sites are the only source site that would likely contaminate fuels with trace chemicals.
- **Transportation noise externality (1st Place: construction and B.C. pine beetle):** both fuels are sourced from vendors that are either closer in proximity to the UBC campus thereby requiring less distance traveled, or contain a lower moisture content so that less frequent truck trips are needed.
- **Relative benefit to source community (1st Place: B.C. pine beetle):** B.C. pine beetle vendors are located in Merritt, a comparatively smaller source community in relation to other vendors.
- **Alternative use of fuel source (1st Place: construction):** construction and demolition wood was seen to be the only fuel source that could not naturally decompose without having potentially negative ramifications.
- **Relative benefit to vendor (1st Place: hog fuel and B.C. pine beetle):** both fuel types are sourced from firms that were deemed to have small operations in terms of employee base and annual order capacity.

RECOMMENDATION

Based on the above analysis, the recommended vendor for the UBC Bioenergy Research and Demonstration Project is **Urban Woodwaste Recyclers** in order to purchase construction and demolition wood fuel. Urban Woodwaste Recyclers ranked first place in 8 of the 13 criteria. This was accomplished under the base-case equal weighting for the economic, environmental and social categories.

Scenario Analysis

It is understood, however, that the end evaluator may not necessarily hold equal importance across the three sustainability categories. To further examine the sources, a scenario analysis was conducted to determine the impact of changing the weightings across the three categories. A summary of three scenarios conducted can be found below:

Figure 9: Scenario Analysis

		Rank								
		Economic	Environ.	Social	Economic	Environ.	Social	Economic	Environ.	Social
	Criteria	20%	40%	40%	40%	20%	40%	40%	40%	20%
Hog Fuel	Basran	7			7			7		
	Chips Ahoy Fibre Supply	6			6			6		
	Cloverdale Fuel Co. Ltd.	7			7			7		
B.C. Pine	International Bio Fuels	2			2			4		
	Trace Resources	3			5			5		
Municipal Trimmings	Davey Tree	4			3			2		
	City of Vancouver	4			3			2		
CC &D	Urban Woodwaste	1			1			1		

Based on Figure 9, it can be seen that Urban Woodwaste Recycles ranks first across all three scenarios. This means that, regardless of the emphasis on economic, environmental, or social criteria, it is always optimal from a sustainability standpoint to choose Urban Woodwaste Recyclers as the vendor for UBC. This scenario analysis shows that, barring further investigative analysis, UBC decision makers can use construction and demolition wood without a trade-off risk within a particular sustainability category.

However, if it is demonstrated that Urban Woodwaste Recyclers' construction and demolition wood is unusable for UBC's biomass power plant, UBC would still require a contingency fuel source option. As such, the next best available option is **International Biofuels**. This source ranks second overall across two of the three scenarios. It should be noted that International Biofuels' strength as a source option is derived from the economic and environmental categories.

LIMITATIONS

Since the analysis presented in this report contains both assumptions and value judgements, each criteria was assigned a degree of confidence. The purpose of the table below is to highlight to the next evaluator which criteria in particular should be focused on in order to improve the quality of analysis moving forward:

Figure 10: Degree of Confidence

	Criteria	Indicator	Degree of Confidence	Limitation
Economic	Fuel cost	Total annual cost ($/year)	●	
	Price sustainability	Anticipated supply & demand	◑	Long term trends are difficult to predict
	Minimizing operational risk	Presence of trace chemicals and/or decomposed material (Y/N)	○	Indicator may not directly lead to increased maintenance or larger orders
	Cost of drying fuel	Annual energy usage (GJ/year)	●	
Environmental	GHG emissions	Tonnes $CO_{2\text{-}e}$/year	●	
	Acid rain potential	Tonnes $SO_{2\text{-}e}$/year	●	
	Smog formation potential	Tonnes ORG/year	●	
	Energy use (drying phase)	Annual energy usage (GJ/year)	●	
	Post-gasification environmental risk	Presence of trace chemicals in biomass ash (Y/N)	○	Harmful chemicals in may not directly lead to harmful chemicals out
Social	Transportation noise externality	Number of truck trips/year	●	
	Relative benefit to source community	Job creation for source community (function of firm & community size)	○	Large assumption that the smaller the firm, the more jobs created
	Alternative use of fuel source	Fuel would otherwise be harmful or unproductive (Y/N)	◑	Further investigation needed in terms of exact alternative uses
	Relative benefit to vendor	Firm size	○	Assumptions made to fill gaps with respect to firm size

LEGEND: ○ Low ◑ Medium ● High

Quantitative Limitations:

As can be seen above in Figure 10, criteria that are more quantitative in nature had the highest degree of confidence. This is because these quantitative criteria were easier to collect data for and required fewer assumptions when conducting the ultimate analysis. However, a limitation found for the quantitative criteria was the lack of diversified data sources. Moving forward, it is recommended to increase the number of data sources in order to ensure that more precise data points are being inputted into the evaluation matrix.

Qualitative Limitations:

From a qualitative criteria standpoint, a greater number of both value judgements and assumptions were made in order to assign rankings for each vendor.

Some key limitations within the economic and environmental categories were found within the 'minimizing operational risk' and 'post-gasification environmental risk' criteria. Each of these criteria were determined on a yes/no basis and required a judgement of the potential that the source would come into contact with trace contaminants and/or decomposed material. Beyond

this, a judgement was made regarding the impact that would be caused on the machinery or surrounding environment if chemical particulates or decomposed matter were present.

For social criteria, it was important to evaluate the impact that UBC's gasification plant would have upon the source community and the vendor itself. Each of these indicators were measured based on the potential job creation and firm size. The failure of this approach is in the assumption that, for example, UBC's presence will be directly correlated to the creation of jobs. It will be important to research the impact that UBC has upon these communities and vendors in order to gain a deeper understanding of the social impact that UBC is actually making.

PROJECT REFLECTION

The structure of the Applied Sustainability course was beneficial in that it allowed ample time for research outside of class. The sectioned discussion groups allowed for greater interaction on a one-to-one basis with a teaching assistant. The project design itself maintained interest throughout the entire semester as each aspect of the project was broken down into phases, with each one focused on a different aspect of the project and allowed for a greater scope of research.

It would have been beneficial to have more integration of key themes from course articles to the project. As for the articles themselves, it may have been useful to assess a larger scope of broad themes and then gradually introduce articles specific to biomass related concepts. In terms of working with other students in the class, having other biomass groups workshop ideas together was a valuable resource.

Because teams were instructed not to contact firms, the available sources online were exceedingly limited and restricted the concrete research that was able to be conducted. If this project were to be repeated, it would be beneficial to have greater access to vendors as it would provide more concrete research to ground the proposals upon. It also allows the students to do much of the research leg-work that could be beneficial to UBC Utilities and UBC Sustainability. Potentially, a new data collection phase could be introduced near the beginning of the project where groups must submit questions they would ask if given an opportunity to conduct vendor interviews. The teaching assistants could consolidate the questions and then conduct the vendor interview.

Overall, the research and learning conducted both inside and outside of the classroom has been beneficial to the team's growing understanding of sustainability. The project itself allowed for the opportunity to understand the assessment process and the difficulties that arise when determining the breakdown of an evaluation of sustainability.

AUTHORSHIP STATEMENT

Our team is appreciative of our coincidentally smaller group size because it allowed us to collaborate and dedicate focused insight with each other efficiently. Furthermore, given our diverse backgrounds in faculty and areas of interest, each member brought a different perspective to the group which proved beneficial when brainstorming and analyzing issues as they arose, in particular in designing the assessment tool.

We found that the work was divided equally amongst all three members. While every assignment was collaborated on by all members of the group, at times due to other commitments the same level of effort was not assumed by all within every phase. Ultimately, this was not found to be a problem since this was compensated for in future assignments.

Overall, it was a rewarding and worthwhile experience for all three of us, and we welcome the opportunity to work together again.

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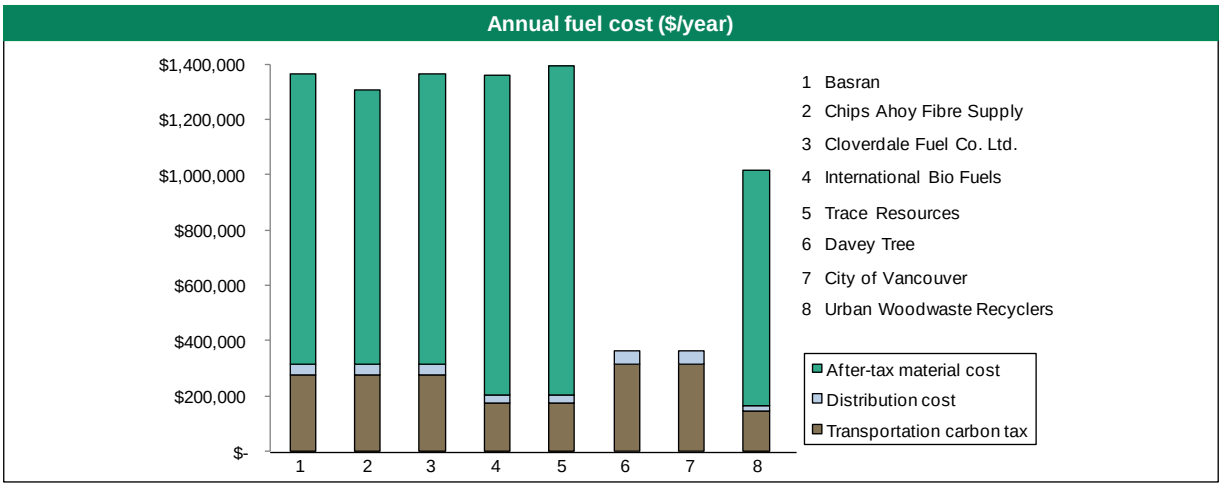
APPENDIX

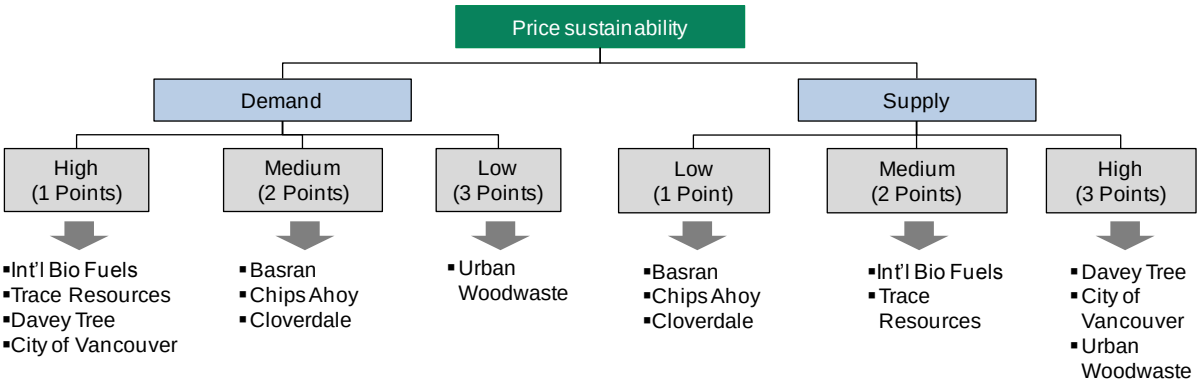
Detailed Economic Ranking

Annual Fuel Cost:



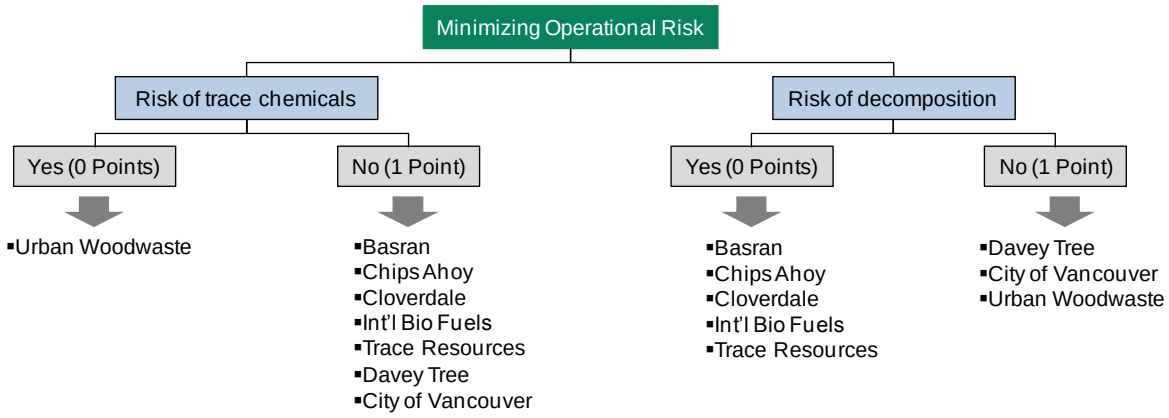
	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Total Cost	$1.37M	$1.30M	$1.37M	$1.36M	$1.39M	$0.36M	$0.36M	$1.02M
Rank	6	4	6	5	8	1	1	3

Price Sustainability:



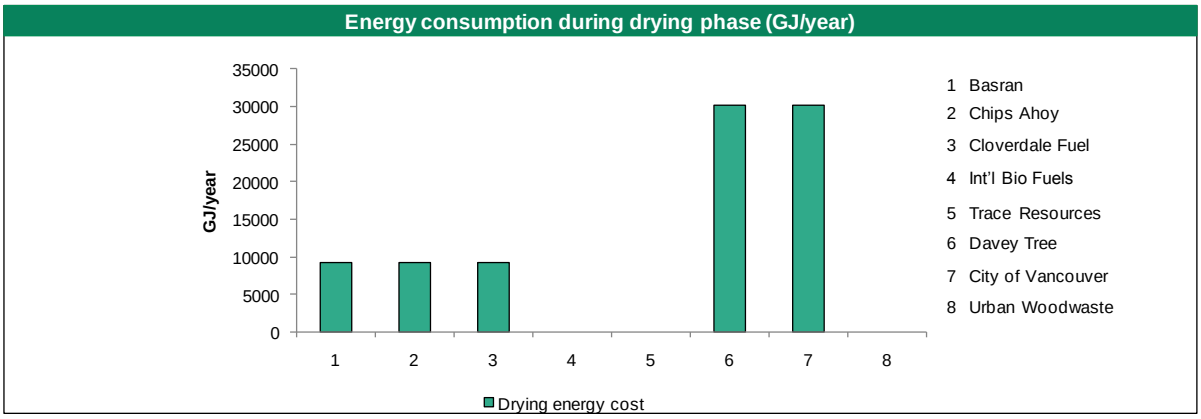
POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Demand	2	2	2	1	1	1	1	3
Supply	1	1	1	2	2	3	3	3
Total	3	3	3	3	3	4	4	6
Rank	4	4	4	4	4	2	2	1

Minimizing Operational Risk:



POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Trace Chem.	1	1	1	1	1	1	1	0
Decomp.	0	0	0	0	0	1	1	1
Total	1	1	1	1	1	2	2	1
Rank	3	3	3	3	3	1	1	3

Operating Cost of Drying Fuel:

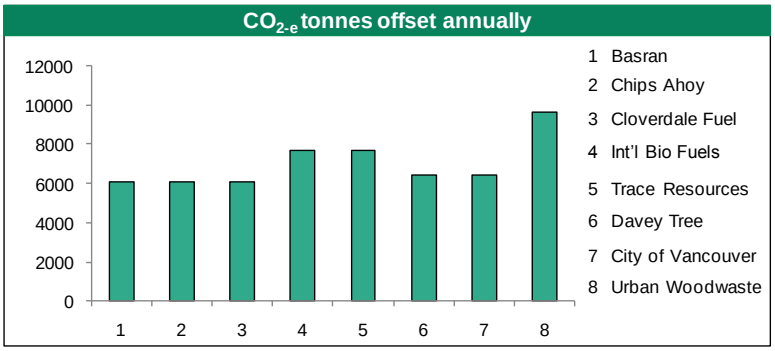


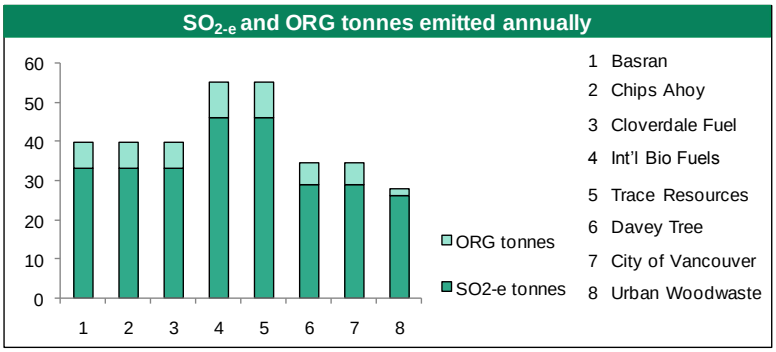
Assumption: higher drying energy consumption directly translates into higher drying costs

	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Drying GJ/year	9,320	9,320	9,320	0	0	30,120	30,120	0
Rank	4	4	4	1	1	7	7	1

Detailed Environmental Ranking

GHG, Acid Rain Potential, Smog Formation Potential:

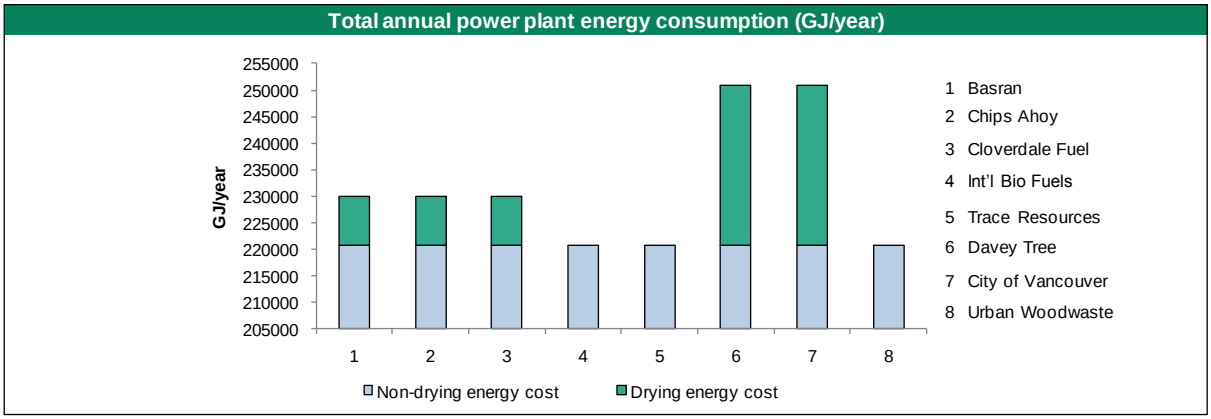




CO_{2-e}, SO_{2-e}, & ORG Rankings

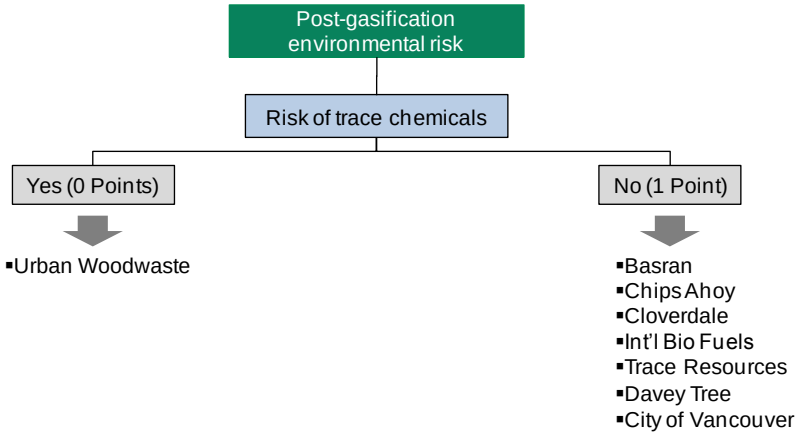
		Rank		
		CO_{2-e}	SO_{2-e}	ORG
Hog Fuel	Basran	8	6	6
	Chips Ahoy	8	6	6
	Cloverdale	8	6	6
B.C. Pine Beetle	Int'l Bio Fuels	3	8	8
	Trace Resources	3	8	8
Municipal Trimmings	Davey Tree	5	3	3
	City of Vancouver	5	3	3
CC&D	Urban Woodwaste	1	1	1

Drying Phase Energy Use:



	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Drying GJ/year	9,320	9,320	9,320	0	0	30,120	30,120	0
Rank	4	4	4	1	1	7	7	1

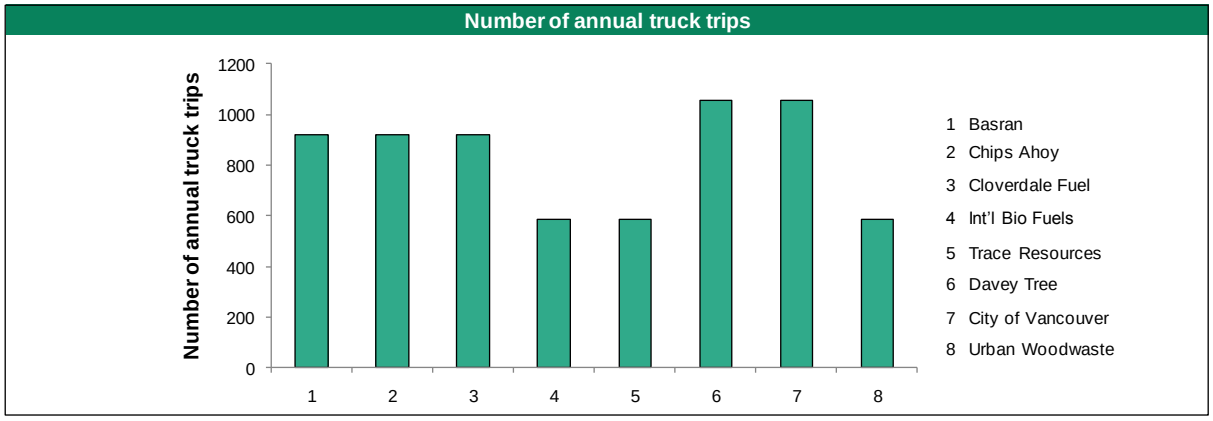
Post-Gasification Environmental Risk:



POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Trace Chem.	1	1	1	1	1	1	1	0
Rank	1	1	1	1	1	1	1	8

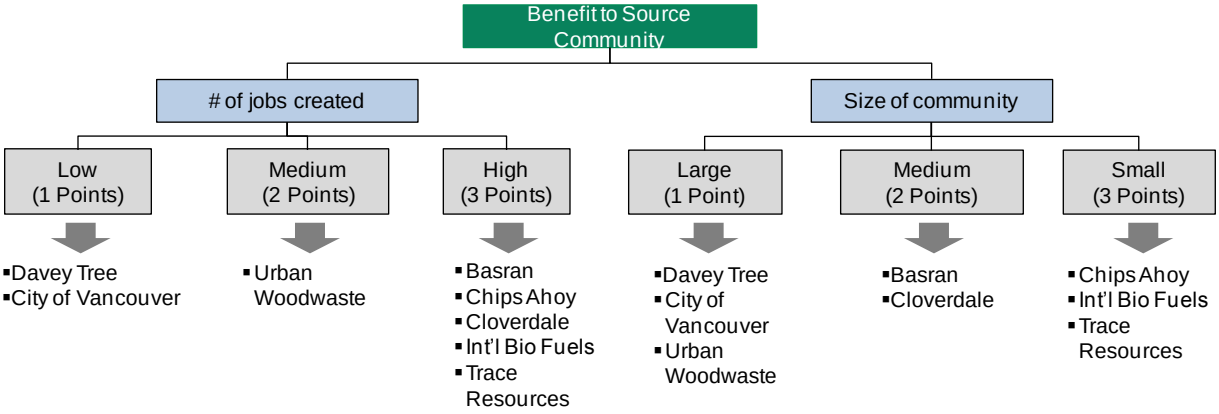
Detailed Social Ranking

Transportation Noise Externality:



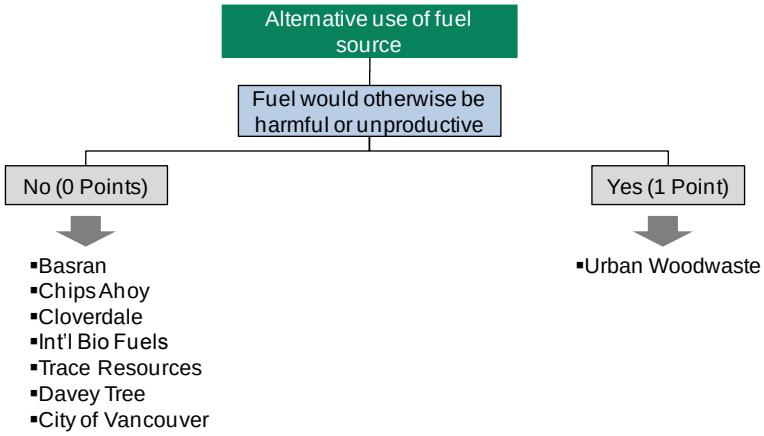
	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
# Trips /yr	920	920	920	588	588	1,055	1,055	588
Rank	4	4	4	1	1	7	7	1

Relative Benefits to Source Community:



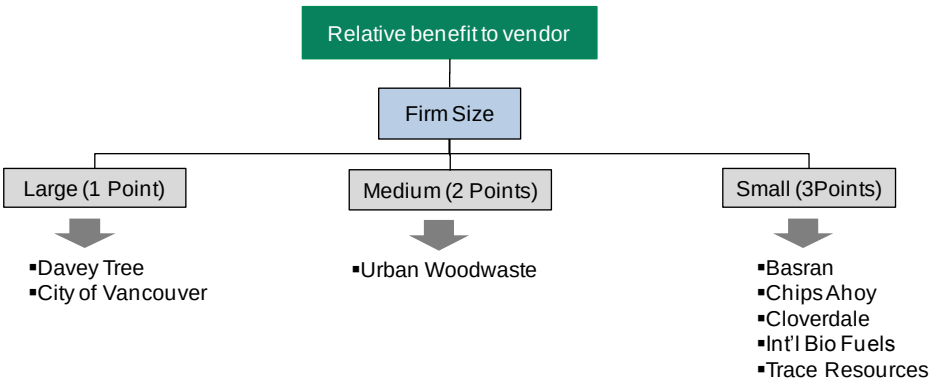
POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
# Jobs	3	3	3	3	3	1	1	2
Comm. Size	2	3	2	3	3	1	1	1
Total	5	6	5	6	6	2	2	3
Rank	4	1	4	1	1	7	7	6

Alternative Use of Fuel Source:



POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Trace Chem.	0	0	0	0	0	0	0	1
Rank	2	2	2	2	2	2	2	1

Relative Benefits to Vendor:

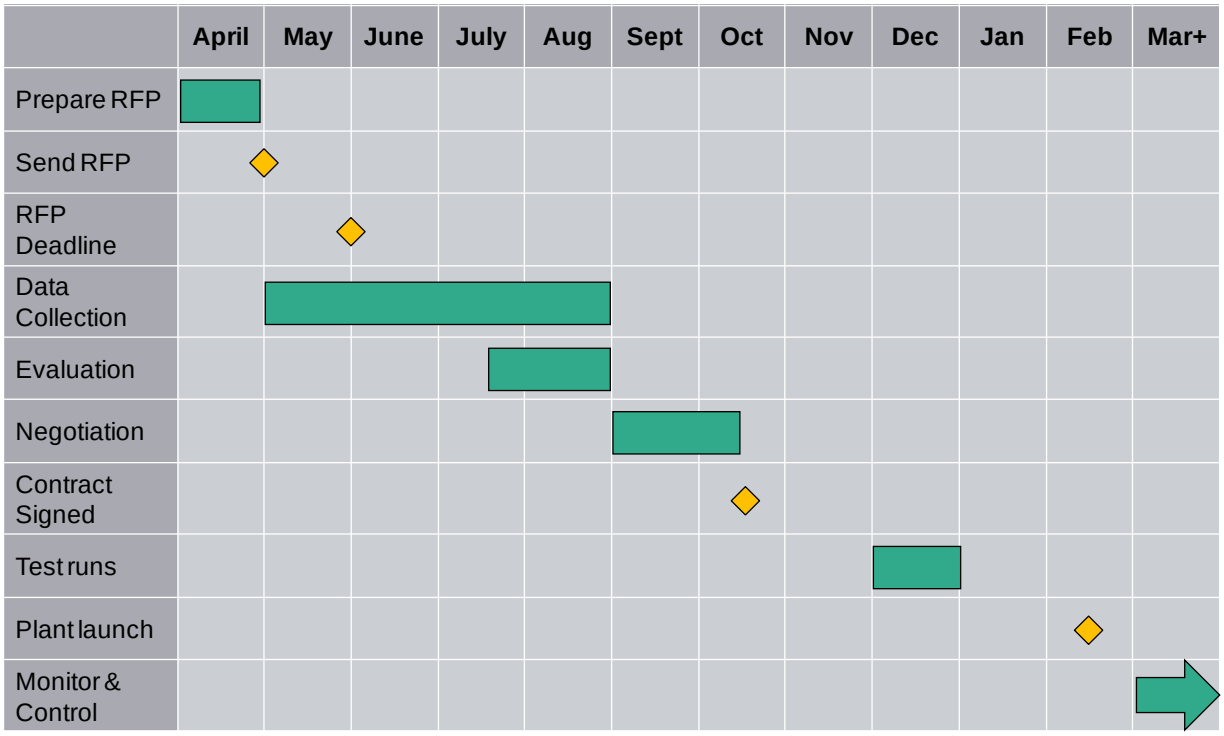


POINTS	Hog Fuel			B.C. Pine Beetle		Municipal Trimmings		CC&D
	Basran	Chips Ahoy	Cloverdale	Int'l Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste
Firm Size	3	3	3	3	3	1	1	2
Rank	1	1	1	1	1	7	7	6

Risks and Mitigations

	Risks	Mitigations
1	Contaminants harmful in Urban Woodwaste fuel	▪Monitor Nexterra's Dockside Green Facility (Victoria) to act as a case study for CC&D wood ▪Conduct proximal analysis if risk is deemed too great
2	Increase of fuel price due to unexpected demand increases	▪Leverage UBC's buyer power and lock in price at time of contract
3	UBC community backlash (transportation externalities, lack of informed public)	▪Community engagement with key groups on campus to disseminate information to respective stakeholders

Implementation – Gantt Chart



Scenario Analysis

Base Scenario:

				Hog Fuel						BC Pine Beetle				Municipal Trimmings				CC+D	
				Basran		Chips Ahoy Fibre Supply		Cloverdale Fuel Co. Ltd.		International Bio Fuels		Trace Resources		Davey Tree		City of Vancouver		Urban Woodwaste Recyclers	
		Criteria	Weight	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score
33%	Economic	Annual Cost	45%	2	0.3	5	0.75	2	0.3	4	0.6	1	0.15	7	1.05	7	1.05	6	0.9
		Minimizing Operational Risk	10%	1	0.03333	1	0.0333333	1	0.033333	1	0.033333	1	0.03333	7	0.233333	7	0.2333333	1	0.03333333
		Cost of Drying Fuel	25%	3	0.25	3	0.25	3	0.25	6	0.5	6	0.5	1	0.083333	1	0.0833333	6	0.5
		Price Sustainability	20%	1	0.06667	1	0.0666667	1	0.066667	1	0.066667	1	0.06667	6	0.4	6	0.4	8	0.53333333
33%	Environmental	Greenhouse Gas Emissions (CO_2)	45%	1	0.15	1	0.15	1	0.15	6	0.9	6	0.9	4	0.6	4	0.6	8	1.2
		Acid Rain Potential (SO_2)	15%	3	0.15	3	0.15	3	0.15	1	0.05	1	0.05	6	0.3	6	0.3	8	0.4
		Energy Use (Drying Phase)	15%	3	0.15	3	0.15	3	0.15	6	0.3	6	0.3	1	0.05	1	0.05	6	0.3
		Post-Gasification Environmental Risk	10%	1	0.03333	1	0.0333333	1	0.033333	1	0.033333	1	0.03333	7	0.233333	7	0.2333333	1	0.03333333
		Smog Formation Potential	15%	3	0.15	3	0.15	3	0.15	1	0.05	1	0.05	6	0.3	6	0.3	8	0.4
33%	Social	Transportation Externality	10%	3	0.1	3	0.1	3	0.1	6	0.2	6	0.2	1	0.033333	1	0.0333333	6	0.2
		Job Creation for Source Community	25%	4	0.33333	6	0.5	4	0.333333	6	0.5	6	0.5	1	0.083333	1	0.0833333	1	0.08333333
		Alternative Use for Fuel Source	40%	1	0.13333	1	0.1333333	1	0.133333	1	0.133333	1	0.13333	1	0.133333	1	0.1333333	8	1.06666667
		Relative Benefit to Vendor	25%	4	0.33333	4	0.3333333	4	0.333333	4	0.333333	4	0.33333	1	0.083333	1	0.0833333	3	0.25
		TOTAL SCORE:			2.18333		2.8		2.183333		3.7		3.25		3.583333		3.5833333		5.9
		RANK:**			7		6		7		2		5		3		3		1

Environmental & Social Emphasis:

				Hog Fuel						BC Pine Beetle				Municipal Trimmings				CC+D	
				Basran		Chips Ahoy Fibre Supply		Cloverdale Fuel Co. Ltd.		International Bio Fuels		Trace Resources		Davey Tree		City of Vancouver		Urban Woodwaste Recyclers	
		Criteria	Weight	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score
20%	Economic	Annual Cost	45%	2	0.18	5	0.45	2	0.18	4	0.36	1	0.09	7	0.63	7	0.63	6	0.54
		Minimizing Operational Risk	10%	1	0.02	1	0.02	1	0.02	1	0.02	1	0.02	7	0.14	7	0.14	1	0.02
		Cost of Drying Fuel	25%	3	0.15	3	0.15	3	0.15	6	0.3	6	0.3	1	0.05	1	0.05	6	0.3
		Price Sustainability	20%	1	0.04	1	0.04	1	0.04	1	0.04	1	0.04	6	0.24	6	0.24	8	0.32
40%	Environmental	Greenhouse Gas Emissions (CO_2)	45%	1	0.18	1	0.18	1	0.18	6	1.08	6	1.08	4	0.72	4	0.72	8	1.44
		Acid Rain Potential (SO_2)	15%	3	0.18	3	0.18	3	0.18	1	0.06	1	0.06	6	0.36	6	0.36	8	0.48
		Energy Use (Drying Phase)	15%	3	0.18	3	0.18	3	0.18	6	0.36	6	0.36	1	0.06	1	0.06	6	0.36
		Post-Gasification Environmental Risk	10%	1	0.04	1	0.04	1	0.04	1	0.04	1	0.04	7	0.28	7	0.28	1	0.04
		Smog Formation Potential	15%	3	0.18	3	0.18	3	0.18	1	0.06	1	0.06	6	0.36	6	0.36	8	0.48
40%	Social	Transportation Externality	10%	3	0.12	3	0.12	3	0.12	6	0.24	6	0.24	1	0.04	1	0.04	6	0.24
		Job Creation for Source Community	25%	4	0.4	6	0.6	4	0.4	6	0.6	6	0.6	1	0.1	1	0.1	1	0.1
		Alternative Use for Fuel Source	40%	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	8	1.28
		Relative Benefit to Vendor	25%	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4	1	0.1	1	0.1	3	0.3
		TOTAL SCORE:			2.23		2.7		2.23		3.72		3.45		3.24		3.24		5.9
		RANK:**			7		6		7		2		3		4		4		1

Economic & Social Emphasis:

				Hog Fuel						BC Pine Beetle				Municipal Trimmings				CC+D	
				Basran		Chips Ahoy Fibre Supply		Cloverdale Fuel Co. Ltd.		International Bio Fuels		Trace Resources		Davey Tree		City of Vancouver		Urban Woodwaste Recyclers	
		Criteria	Weight	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score
40%	Economic	Annual Cost	45%	2	0.36	5	0.9	2	0.36	4	0.72	1	0.18	7	1.26	7	1.26	6	1.08
		Minimizing Operational Risk	10%	1	0.04	1	0.04	1	0.04	1	0.04	1	0.04	7	0.28	7	0.28	1	0.04
		Cost of Drying Fuel	25%	3	0.3	3	0.3	3	0.3	6	0.6	6	0.6	1	0.1	1	0.1	6	0.6
		Price Sustainability	20%	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	6	0.48	6	0.48	8	0.64
20%	Environmental	Greenhouse Gas Emissions (CO_2)	45%	1	0.09	1	0.09	1	0.09	6	0.54	6	0.54	4	0.36	4	0.36	8	0.72
		Acid Rain Potential (SO_2)	15%	3	0.09	3	0.09	3	0.09	1	0.03	1	0.03	6	0.18	6	0.18	8	0.24
		Energy Use (Drying Phase)	15%	3	0.09	3	0.09	3	0.09	6	0.18	6	0.18	1	0.03	1	0.03	6	0.18
		Post-Gasification Environmental Risk	10%	1	0.02	1	0.02	1	0.02	1	0.02	1	0.02	7	0.14	7	0.14	1	0.02
		Smog Formation Potential	15%	3	0.09	3	0.09	3	0.09	1	0.03	1	0.03	6	0.18	6	0.18	8	0.24
40%	Social	Transportation Externality	10%	3	0.12	3	0.12	3	0.12	6	0.24	6	0.24	1	0.04	1	0.04	6	0.24
		Job Creation for Source Community	25%	4	0.4	6	0.6	4	0.4	6	0.6	6	0.6	1	0.1	1	0.1	1	0.1
		Alternative Use for Fuel Source	40%	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	1	0.16	8	1.28
		Relative Benefit to Vendor	25%	4	0.4	4	0.4	4	0.4	4	0.4	4	0.4	1	0.1	1	0.1	3	0.3
		TOTAL SCORE:			2.24		2.98		2.24		3.64		3.1		3.41		3.41		5.68
		RANK:**			7		6		7		2		5		3		3		1

Economic & Environmental Emphasis:

				Hog Fuel						BC Pine Beetle				Municipal Trimmings				CC+D	
				Basran		Chips Ahoy Fibre Supply		Cloverdale Fuel Co. Ltd.		International Bio Fuels		Trace Resources		Davey Tree		City of Vancouver		Urban Woodwaste Recyclers	
		Criteria	Weight	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score	Score (out of 8)*	Weighted Score
40%	Economic	Annual Cost	45%	2	0.36	5	0.9	2	0.36	4	0.72	1	0.18	7	1.26	7	1.26	6	1.08
		Minimizing Operational Risk	10%	1	0.04	1	0.04	1	0.04	1	0.04	1	0.04	7	0.28	7	0.28	1	0.04
		Cost of Drying Fuel	25%	3	0.3	3	0.3	3	0.3	6	0.6	6	0.6	1	0.1	1	0.1	6	0.6
		Price Sustainability	20%	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	6	0.48	6	0.48	8	0.64
40%	Environmental	Greenhouse Gas Emissions (CO_2)	45%	1	0.18	1	0.18	1	0.18	6	1.08	6	1.08	4	0.72	4	0.72	8	1.44
		Acid Rain Potential (SO_2)	15%	3	0.18	3	0.18	3	0.18	1	0.06	1	0.06	6	0.36	6	0.36	8	0.48
		Energy Use (Drying Phase)	15%	3	0.18	3	0.18	3	0.18	6	0.36	6	0.36	1	0.06	1	0.06	6	0.36
		Post-Gasification Environmental Risk	10%	1	0.04	1	0.04	1	0.04	1	0.04	1	0.04	7	0.28	7	0.28	1	0.04
		Smog Formation Potential	15%	3	0.18	3	0.18	3	0.18	1	0.06	1	0.06	6	0.36	6	0.36	8	0.48
20%	Social	Transportation Externality	10%	3	0.06	3	0.06	3	0.06	6	0.12	6	0.12	1	0.02	1	0.02	6	0.12
		Job Creation for Source Community	25%	4	0.2	6	0.3	4	0.2	6	0.3	6	0.3	1	0.05	1	0.05	1	0.05
		Alternative Use for Fuel Source	40%	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	1	0.08	8	0.64
		Relative Benefit to Vendor	25%	4	0.2	4	0.2	4	0.2	4	0.2	4	0.2	1	0.05	1	0.05	3	0.15
		TOTAL SCORE:			2.08		2.72		2.08		3.74		3.2		4.1		4.1		6.12
		RANK:**			7		6		7		4		5		2		2		1

Economic Calculations

Annual Fuel Cost:

Annual Cost

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Cost ($)/Green Tonne*	$ 42.50	$ 40.00	$ 42.50	$ 77.00	$ 70.00	$ -	$ -	$ 50.00
Tonnes Needed/Year*	24,000	24,000	24,000	14,600	16,500	28,095	26,000	16,500
Annual Materials Cost ($/Year)	$1,020,000.00	$ 960,000.00	$ 1,020,000.00	$ 1,124,200.00	$ 1,155,000.00	$ -	$ -	$ 825,000.00
Non-rebateable HST*	3.147%	3.147%	3.147%	3.147%	3.147%	3.147%	3.147%	3.147%
HST ($)	$ 32,099.40	$ 30,211.20	$ 32,099.40	$ 35,378.57	$ 36,347.85	$ -	$ -	$ 25,962.75
After-Tax Annual Materials Cost ($/Year)	$1,052,099.40	$ 990,211.20	$ 1,052,099.40	$ 1,159,578.57	$ 1,191,347.85	$ -	$ -	$ 850,962.75
Cost ($)/Litre**	$ 1.22	$ 1.22	$ 1.22	$ 1.22	$ 1.22	$ 1.22	$ 1.22	$ 1.22
Annual Litres Consumed*	33,120	33,120	33,120	21,185	21,185	38,016	38,016	17,478
Annual Distribution Cost ($/Year)	$ 40,406.40	$ 40,406.40	$ 40,406.40	$ 25,845.70	$ 25,845.70	$ 46,379.52	$ 46,379.52	$ 21,323.16
Transportation Carbon Tax ($/L) ***	$ 8.27	$ 8.27	$ 8.27	$ 8.27	$ 8.27	$ 8.27	$ 8.27	$ 8.27
Annual Transporation Carbon Tax ($)	$ 273,902.40	$ 273,902.40	$ 273,902.40	$ 175,199.95	$ 175,199.95	$ 314,392.32	$ 314,392.32	$ 144,543.06
Total Annual Cost	**$1,366,408.20**	**$ 1,304,520.00**	**$ 1,366,408.20**	**$ 1,360,624.22**	**$ 1,392,393.50**	**$ 360,771.84**	**$ 360,771.84**	**$ 1,016,828.97**
Score	2	5	2	4	1	7	7	6

*Jeff Giffen

**http://www.bcgasprices.com/index.aspx?fuel=D

***http://www.sbr.gov.bc.ca/documents_library/notices/British_Columbia_Carbon_Tax.pdf

Price Sustainability:

Price Sustainability

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Supply	1	1	1	2	2	3	3	3
Demand	2	2	2	1	1	1	1	3
Total	3	3	3	3	3	4	4	6
Points	1	1	1	1	1	6	6	8
Rank	4	4	4	4	4	2	2	1

Points

LEGEND	Low	Medium	High
Supply	1	2	3
Demand	3	2	1

	Demand assumptions	Supply assumptions
Basran	BC Forestry declining = lower supply	neutral
Chips Ahoy	BC Forestry declining = lower supply	neutral
Cloverdale	BC Forestry declining = lower supply	neutral
Int`l Bio Fuels	other competition = high demand	MPB projected to be still big problem
Trace	other competition = high demand	MPB projected to be still big problem
Davey	Free wood waste = higher demand	high (albeit constant) level of trimmings
City of Vancouver	Free wood waste = higher demand	high (albeit constant) level of trimmings
Urban Woodwaste	Few want construction waste	neutral

Minimizing Operational Risk:

Operational Risk

		Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
		Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
	Trace Chemicals	1	1	1	1	1	1	1	0
	Decomposed Materials	0	0	0	0	0	1	1	1
	Points	1	1	1	1	1	2	2	1
	Score	1	1	1	1	1	7	7	1
	Rank	3	3	3	3	3	1	1	1

	LEGEND	Yes	No
	Possible Trace Chemicals	0	1
	Possible Decomposed Materials	0	1

	Possible Trace Chemical Assumptions	Possible Decomposed Material Assumptions
Basran	none	yes
Chips Ahoy	none	yes
Cloverdale	none	yes
Int`l Bio Fuels	none	yes
Trace	none	yes
Davey	none	no - municipal trimmings fresh
City of Vancouver	none	no - municipal trimmings fresh
Urban Woodwaste	yes - not 100% free of chemicals	no - urban woodwaste not decomposed

Operating Cost of Drying Fuel:

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Moisture Content	45%	45%	45%	20%	25%	55%	50%	25%
Total Energy Cost (GJ/yr)	230000	230000	230000	220680	220680	250800	250800	220680
Energy Cost due to drying (GJ/yr)	9320	9320	9320	0	0	30120	30120	0
Points	3	3	3	6	6	1	1	6
Rank	4	4	4	1	1	2	2	1

Assumptions:

If moisture content 25% or less, 0 energy cost for drying

Environmental Calculations

GHG Emissions, Acid Rain Potential, and Smog Formation Potential:

Greenhouse Gas Emissions

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Greenhouse Gas Emissions (CO_2 tonnes/year)*	-6074	-6074	-6074	-7711	-7711	-6453	-6453	-9617
Score	1	1	1	6	6	4	4	8

*Jeff Giffin

Acid Raid Potential

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Acid Rain Potential (SO_2 tonnes/year)	33	33	33	46	46	29	29	26
Score	3	3	3	1	1	6	6	8

Smog Formation Potential

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
SFP tonnes ORG eq.*	6.8	6.8	6.8	9	9	5.4	5.4	1.9
Score	3	3	3	1	1	6	6	8

*Jeff Giffin

Drying Phase Energy Use:

Energy Use During Drying

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Moisture Content	45%	45%	45%	20%	25%	55%	50%	25%
Total Energy Cost (GJ/yr)	230000	230000	230000	220680	220680	250800	250800	220680
Energy Cost due to drying (GJ/yr)	9320	9320	9320	0	0	30120	30120	0
Points	3	3	3	6	6	1	1	6
Rank	4	4	4	1	1	2	2	1

Post-Gasification Environmental Risk:

		Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
		Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
	Trace Chemicals	1	1	1	1	1	1	1	0
	Decomposed Materials	0	0	0	0	0	1	1	1
	Total	1	1	1	1	1	2	2	1
	Score	1	1	1	1	1	7	7	1
	Rank	3	3	3	3	3	1	1	1

	LEGEND	Yes	No
	Possible Trace Chemicals	0	1
	Possible Decomposed Materials	0	1

Presence of harmful materials in biomass ash (if harmful materials before use i.e.trace contaminants/decomposed material, assume also in biomass waste)

	Possible Trace Chemical Assumptions	Possible Decomposed Material Assumptions
Basran	none	yes
Chips Ahoy	none	yes
Cloverdale	none	yes
Int`l Bio Fuels	none	yes
Trace	none	yes
Davey	none	no - municipal trimmings fresh
City of Vancouver	none	no - municipal trimmings fresh
Urban Woodwaste	yes - not 100% free of chemicals	no - urban woodwaste not decomposed

Social Calculations

Transportation Noise Externality:

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Trips per day*	2.52	2.52	2.52	1.61	1.61	2.89	2.89	1.61
Days per year	365	365	365	365	365	365	365	365
Number of annual trips	919.8	919.8	919.8	587.65	587.65	1054.85	1054.85	587.65
Score	3	3	3	6	6	1	1	6

*Jeff Giffin

Relative Benefits to Source Community:

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Location	New Westminster	Mission	Langley	Merritt	Merritt	Vancouver	Vancouver	Vancouver/New Westminster
Community population	57,549	34,505	93,726	6998	6998	578,041	578,041	578,041/57,549
Size of Community	Medium	Small	Medium	Small	Small	Large	Large	Large
Score	2	3	2	3	3	1	1	1
Employees	22	N/A	35	N/A	N/A	7000 (N.A.)	<5000	90
Quantity of jobs	Low	Low	Low	Low	Low	High	High	Medium
Score	3	3	3	3	3	1	1	2

Total	5	6	5	6	6	2	2	3
Score	4	6	4	6	6	1	1	3
Rank	4	1	4	1	1	7	7	6

Alternative Use of Fuel Source:

		Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
		Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
	Harmful/Unproductive Fuel use	0	0	0	0	0	0	0	1
	Rank	2	2	2	2	2	2	2	1

	Harmful/Unproductive Fuel use	0	0	0	0	0	0	0	1
	Score	1	1	1	1	1	1	1	8

Harmful/Unproductive Fuel use	Yes	No
Points	1	0

	Fuel Type	Alternative Fuel Use Assumpti
Basran	Hog Fuel	useful
Chips Ahoy	Hog Fuel	useful
Cloverdale	Hog Fuel	useful
Int'l Bio Fuels	BC Pine Beetle	useful
Trace	BC Pine Beetle	useful
Davey	Municipal Trimmings	useful
City of Vancouver	Municipal Trimmings	useful
Urban Woodwaste	Construction and Demolition	harmful

Relative Benefit to Vendor:

	Hog Fuel			BC Pine Beetle		Municipal Trimmings		CC+D
	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.	International Bio Fuels	Trace Resources	Davey Tree	City of Vancouver	Urban Woodwaste Recyclers
Location	New Westminster	Mission	Langley	Merritt	Merritt	Vancouver	Vancouver	Vancouver/New Westminster
Population Size of community	57,549	34,505	93,726	6998	6998	578,041	578,041	578,041/57,549
Employees	22	N/A	35	N/A	N/A	7000 (N.A.)	<5000	90
Operating Since	N/A	N/A	1945	N/A	2008	1880	1886	1993
Company Size	Small	Small	Small	Small	Small	Large	Large	Medium

Firm Size	3	3	3	3	3	1	1	2
Rank	1	1	1	1	1	7	7	6