UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Fuel Sources for the UBC-Nexterra Biomass Gasification Plant

Bethany Dobson

Bosco Ho

Grace Wong

Samuel Wu

University of British Columbia

APSC 364

April 11, 2011

APSC 364

Fuel Sources for the UBC-Nexterra Biomass Gasification Plant

April 11, 2011

Bethany Dobson
Bosco Ho
Grace Wong
Samuel Wu

Contents

1.0 Introduction

UBC consumes energy in two main forms: heat and electricity. Heat is currently distributed through UBC using a district heating system. It is projected UBC's heating needs will increase 18% by 2030. The steam plant already operates at 67MWth during peak hours, which is within 10% of the plant's capacity. UBC's electricity, on the other hand, is all purchased from BC Hydro at approximately $4.4 million/year. There is no independent power generator on campus. To reduce the load on the steam plant as well as make the campus more self-sustaining, UBC has partnered with Nexterra to create a biomass gasification pilot plant on campus.

The proposed biomass plant combines Nexterra's biomass gasification and syngas cleaning technology with a G.E. Janbacher high efficiency internal combustion engine. The combustion engine will generate 2MWe electricity. The boiler will produce 5.9 MWth alone without the engine running or 3.0 MWth with the engine running. It will be connected to the campus heating grid so that steam is distributed through the existing system. During cogeneration the plant will produce approximately 5% of the campus' electrical consumption and 12% of the steam required (Giffin, 2011).

The following paper ranks potential fuel supply sources for the UBC-Nexterra biomass gasification plant. There are four sources of biomass fuel: hog fuel, BC mountain pine beetle wood, construction and demolition materials, and municipal trimmings. Each of these sources has 1-3 different companies/organizations from which the fuel could be bought. We conducted our analysis on each company; hence we considered a total of eight different sources. However the data we were given only varied significantly by source type. As a result, the ranking in this paper is presented for the four source types first then is further ranked for each company.

The indicators used to evaluate the sources were split into four categories: technical feasibility, economic impacts, environmental impacts, and social impacts. Technical feasibility was deemed to be the most important category. If the fuel source is simply unsuitable for the gasification process there is little point in considering its other potential impacts. The economic and environmental indicators are either Yes/No options or quantifiable numbers. The social indicators, on the other hand, are all either Yes/No or were qualitatively assigned a measurement of Substantial/Moderate/None.

2.0 UBC's Energy Use

As mentioned previously, UBC consumes energy in the forms of heat and electricity. The following section gives a brief quantitative and qualitative overview of UBC's energy cycle for both these energy systems.

2.1 Heating

UBC uses a steam district heating system to heat its buildings. The district system begins with an energy plant with four boilers to produce steam. This system consumes approximately 280 GWh of energy per year, supplied by natural gas from Terasen Gas and fuel oil. These fuels are combusted and the energy stored in the form of steam by four boilers at the UBC steam plant (UBC Utilities, 2008). The steam flows from the plant and is then distributed across campus through an extensive piping distribution network. The piping ends at energy transfer stations at each building whose function is to reduce the pressure of the steam for end use.

By 2030 the steam plant energy consumption is projected to grow to approximately 330 GWh/yr, corresponding to an 18% increase. The plant's maximum capacity is 75 MWth while peak demand is 67 MWth, within 10% of the plant's capacity and occurring approximately 20% of the year during the coldest winter days. In addition, one of the boilers is nearing the end of its service life. (Stantec Consulting, 2010). According to the Alternative Energy Feasibility Report, "the projected loads have been estimated at 175 kWh/m2/yr for research facilities and 75 kWh/m2/yr for housing on campus. Mixed housing/retail and new non-UBC tenant spaces have been estimated at 100 kWh/m2/yr" (Stantec Consulting, 2010).

In 2008/09 UBC Utilities spent $9.4 million on natural gas for steam production at the energy plant (Stantec Consulting, 2010). Beginning in 2010, UBC will pay an additional $2.3 million in carbon taxes and carbon offsets for the natural gas used in the plant (Giffin, 2011).

Stantec/UBC staff estimate that 25-28% of the steam that leaves the powerhouse is lost in distribution and 4-6% of the steam is used internally for deaerating and hot stand-by. The distribution losses are generally consistent throughout the year, while the deaerator load will vary with the steam produced and the piping heat losses will vary slightly with different summer and winter temperatures. Overall system efficiency of the steam district heating system is estimated at 62% (Stantec Consulting, 2010).

Additionally, costs are incurred because the existing energy system must be operated all year long when the demand is not consistent from month to month (i.e. lower demand in the summer months versus high demand in the fall and winter academic terms).

2.2 Electricity

UBC currently does not have an independent power generator on campus but buys electricity from BC Hydro at a grandfathered discount rate. UBC is powered by two BC Hydro transmission circuits called 60L56-North and 60L57-South, operating in parallel and fed by the Sperling substation. The 60L56-North terminates at the North substation (UNY) and the 60L57-

South can terminate at either the UNY or South substation (UNS). The UNS also supplies electric power to TRIUMF. Connecting the UNY and UNS through the 60L57-South creates a transmission ring so that if either line is out of service the other circuit can theoretically carry the entire load of both substations. From the substations, electricity is distributed by means of overhead and underground 69kV and 12kV lines that terminate at transformers and switchgears at each building, which ultimately feed outlets and other electrical aspects (Babich, 2005).

For electrical load growth projections, the energy use is based on developments in research/academic, student housing, and mixed development in the North Campus. For South Campus, development is anticipated for non-UBC tenant, mixed development, and UBC support. This is specifically for electricity demand growth projections based on the timeframe to year 2030 which totals to an estimated 21.1MW peak demand of energy use capacity, corresponding to a total of 903,000 m2 of area needed.

UBC presently buys approximately $4.4 million/year of electricity from BC Hydro (UBC Utilities, 2008) and there are power losses associated with transmitting over large distances (from dams, etc).

3.0 Biomass Source Options

Four types of fuel sources are considered in this report: hog fuel, BC mountain pine beetle wood, construction and demolition waste, and municipal trimmings. Each of these, except construction waste, can be obtained through 2-3 different companies. The following section gives a brief description of each source as well as information relevant to its capability as fuel source for the biomass gasification plant.

3.1 Hog fuel

Hog fuel is unused woody byproducts collected from the forestry industry (i.e. wood chips from sawmills). Since hog fuel originated from trees that were harvested and processed, a portion of the environmental costs incurred there must be taken into account in addition to the preparation (chipping), transportation and combustion stages. The following information concerns Basran, however, Chips Ahoy and Cloverdale Fuel Co prices are included for comparison.

Cost/unit

	Basran	Chips Ahoy Fibre Supply	Cloverdale Fuel Co. Ltd.
Cost/ton (after HST tax)	$43.84	$41.26	$43.84
Tonnes required per annum	24000t	24000t	24000t
Total cost	$1,052,160.00	$990,240.00	$1,052,160.00

Source location
- Basran sources its fuel from lumber mills along the Fraser River.

Proposed means of transportation to UBC campus
- From harvesting location to Delta lumber mill: 200km by tugboat.
- Delta lumber mill to UBC round trip: 80km by 53' truck.

Environmental impacts
- Overall reduction GWP CO_2 eq emisisons per annum: 6074 t

Energy input required
- Moisture content reduction required: 20% (from 45% to 25%)
- Harvesting, Chipping and Transportation energy consumption per annum: 6458 GJ

Long term availability
- It is unlikely for hog fuel sources to run out, lest the forestry industry becomes even more efficient with minimizing waste material. The sources, however, could be diverted to supply energy generation efforts to local areas.

Costs to surrounding communities of sources of options
- Additional traffic along the fuel transport route from Delta.

Potential controversy arising from source selection / Stakeholders both on and off UBC campus impacted
- Hog fuel could be used closer to their harvesting or processing (Delta) locations to generate heat or electricity for the community or processing facility.

3.2 BC Mountain Pine Beetle (MPB)

This source is a result of approximately 30% of the BC area's trees killed by the mountain pine beetle. The pine beetles destroy a tree by manifesting itself into the bark where it lays its eggs, eventually damaging the tree enough to cut off food and nutrient flow. MPB infestations are particularly widespread in the summer months as the beetle population surges in warm weather. Since MPB wood originated from trees that were destroyed from pine beetle infestation, a portion of the environmental costs incurred there must be taken into account in addition to the preparation (chipping), transportation and combustion stages.

Cost/unit

International Bio Fuels	Trace Resources
Total cost considering HST: $1,159,579	Total cost considering HST: $1,155,000
Tonnes needed per year: 14,600 tonnes/yr	Tonnes needed per year: 16,500 tonnes/yr
Approximate revised cost: $79 / green tonne	Approximate revised cost: $72 / green tonne

Source location

MPB can come from:

- Merritt (254km away from Vancouver), the closest source to UBC with a 10 year supply
- Other areas affected by the MPB

Proposed means of transportation to UBC campus

- Harvesting and griding to Delta Consolidator: 254km by suber-B truck
- Delta Consolidator to UBC: 80km round trip by 53' truck
  (B-train truck transfer facility in Delta for distribution to the Lower Maintain)

Environmental impacts

- Creates energy from "waste"; wood waste is consider "carbon neutral"
- Overall reduction GWP CO2 eq emisisons per annum: 7711 t

Long term availability (and cost implications)

There is no foreseeable shortage as 30% of BC's area is affected by the MPB. There is currently an estimated 10 year-supply of wood wherein after that period, MPB-killed trees will have decomposed to a point of no longer reusable.

Co-benefits (or costs) to surrounding communities of sources options

- MPB woodchips have low moisture content, at 20%-25%, which translates to benefits for reduced fuel requirements and Bioenergy Plant truck trips
- Does not require a drying stage therefore eliminating the need for a belt dryer

Stakeholders both on and off UBC campus impacted

- City of Merritt
- Creating industrial/employment opportunities for processing MPB infested wood

3.3 Construction and Demolition Materials

Urban Woodwaste Recyclers collects various recyclable materials from construction and demolition projects in the Lower Mainland that otherwise would have probably ended up in landfills. This biomass fuel is already harvested, therefore the environmental costs considered are from the preparation (chipping), transportation (to the Urban Woodwaste Recyclers location and to UBC), and combustion stages.

Cost/unit
Total cost considering HST: $850,963
Tonnes needed per year: 16,500
Approximate revised cost: $52 / green tonne

Source location
Urban Woodwaste Recyclers has two locations:

- Main Street Location: 110 E 69th Ave, Vancouver
- Spruce Street Location: 4 Spruce Street, New Westminster

Proposed means of transportation to UBC campus
Truck from Urban Woodwaste Recyclers location.

- From Main Street Location to UBC: 45km
- From Spruce Street Location to UBC: 110km

Environmental impacts

- Reduces construction and demolition waste volume that goes to landfills
- Creates energy from "waste"

Long term availability (and cost implications)
Vancouver will continue both constructing and demolishing buildings for the foreseeable future, therefore this biomass fuel will be available long term. Costs of the fuel and/or transportation are not predicted to rise or fall significantly.

Co-benefits (or costs) to surrounding communities of sources options

- Reduced waste volume means less trucks driving to Vancouver Landfill (5400 72nd St, Delta)
- More trucks along Marine Drive to transport fuel from Urban Woodwaste Recyclers to UBC

Potential controversy arising from source selection

- Possibility that takes more energy to ship, sort, process, and deliver recycled wood waste than to collect it directly.

Stakeholders both on and off UBC campus impacted

- Construction Industry: recycling materials requires extra effort and money on the part of the construction industry, however the industry's attitudes need to change to consider recycling part of every job.
- City of Vancouver: less material to the Vancouver Landfill means the landfill will last longer and the City will not have to look for a new location as soon.

3.4 Municipal trimmings

There are two possible sources of fuel for municipal trimmings: the City of Vancouver and Davey Tree. The City of Vancouver has agreed to provide UBC with "trees and branches that fall in parks or on city streets, as well as other clean wood waste material" that are transported to the City's composting facility. Trimmings are derived from existing City operations, therefore the environmental costs considered are from the preparation (chipping), transportation, and combustion stages.

Davey Tree are a global private tree and lawn services provider with operations in Vancouver, BC. The firm meets the City of Vancouver's "minimum qualifications to obtain a Street Tree Worker License" (out of 18 qualified firms) and "may perform major pruning on streeet trees". As such, it may be assumed that the firm has a sizeable scale of tree pruning operations in Vancouver. However, information is scant on the total amounts of trimmings available from Davey Tree seasonally and annually. The following is a source analysis of City of Vancouver trimmings which will likely apply to Davey Tree as well, given that both have the same source origin and source region.

<u>Cost/unit</u>
Total cost of harvested fuel: nil (under Memorandum of Understanding with City of Vancouver)

Tonnes needed per year: 26,000	Revised cost: $28 per tonne (based upon uncertainties listed below)

(Purchase of "large chipping equipment" by UBC, need for fuel receiving bays for "tipping trucks" and storage facilities at UBC, and need for a "fuel broker" to "assure the quantity, quality and availability of fuel".)

<u>Source location</u>
- Composting facility at the Vancouver Landfill in 5400 72nd Street, Delta.
- Vancouver South Transfer Station (Yard Trimmings Drop-off) at 377 West Kent Avenue North, Van.
- (Possibility that a portion of municipal trimmings will be directly transported from 377 West Kent Ave. N., since composting is not required for biomass fuel.)

<u>Proposed means of transportation to UBC campus</u>
- City maintenance to composting facility in Delta: 40 km by truck.
- City composting facility to UBC: 80 km round trip by 53' truck.
- Vancouver South Transfer Station to UBC: ~30 km round trip.

<u>Environmental impacts</u>
- Reduction (chipping/transportation/combustion) of 6453 GWP tonnes CO2 eq in emissions.
- Energy consumption at chipping and transportation stages (2323 and 1470 GJ/yr, respectively)

Long term availability (and cost implications)

- It is unlikely for Vancouver parks and residents to substantially reduce gardening activities. Residential yard trimmings, which accounted for "49% of trimmings processed" by the City in 2009, has steadily increased from ~37,500 tonnes in 1999 to ~48,000 tonnes in 2009 – more than the 26,000 tonnes need for UBC's biomass plant. Total municipal yard trimmings totaled at 52,105 tonnes in 2009.
- Seasonal fluctuations in yard trimmings disposal is of concern, with trimmings (total tonnes) peaking in late autumn (November) and dropping significantly from Janurary to March.
- Its high moisture content (~50%) will require "significant drying", which could lead to either increased processing costs (energy and financial) or longer storage periods (need for more storage space).
- UBC's biomass plant also requires fuel to be free of chemicals, metal components, and rotten material, which may decrease the total tonnage of usable fuel provided by the City, depending on the usage of chemicals by City parks and residents, and the time required between harvesting and transporting to UBC.

Co-benefits (or costs) to surrounding communities of sources of options

- More large trucks along Marine Drive to transport fuel from Vancouver composting/trimmings facilities to UBC.
- Fewer traffic along the Hwy. 99 corridor between Delta, Richmond, and Vancouver.

Potential controversy arising from source selection / Stakeholders both on and off UBC campus impacted

- City of Vancouver: potential reduction in City composting expenditures (which accounted for ~89% of yard trimmings program expenditures) as trimmings are diverted to UBC's biomass plant instead.
- Current beneficiaries of free City compost (including school groups, community gardens, Keep Vancouver Spectacular event, and Delta residents)
- UBC Yard Trimmings & Compost Agricultural Use Studies: City of Vancouver and UBC co-project to "investigate the use of yard trimmings compost for local agricultural purposes".

4.0 Indicator Criteria Description

There were four major criteria chosen for this project: Technical Feasibility, Economic Impacts, Environmental Impacts and Social Impacts.

It is noteworthy that if a source does not fulfill or pass technical feasibility indicators, then this rules it out as a considerable choice altogether regardless of its ratings in the other three areas. The reasoning behind this is that if a source simply does not pass basic functional criteria for meeting the gasification plant's specifications, then it cannot be evaluated as a probable source. This is the case for the construction and demolition materials.

Criteria 1 - Technical Feasibility

Objective – To ensure source meets technical and logistical requirements of usage.

This criteria looks at the logistics of using a source. If a source were to be unable to meet the technical requirements or impose the need for more equipment, this source may not be suitable, as it simply cannot be used. The following indicators measure how feasible each fuel source is based on the technical specifications of the Nexterra biomass unit.

Indicator	Units	Justification
Moisture content	% Water	Moisture content would affect the processing required before gasification and the capital investment required to use the fuel. A fuel requiring less moisture would require less energy expenditure to reduce its moisture content to an acceptable levels and thus this indicator should be minimized.
Additional equipment necessary	Yes/No	If the above moisture content is greater than 25%, drying belt equipment is required to process the source.
Other trace chemicals	Yes/No	In order to be used for the Nexterra project the wood chips cannot have any trace chemicals present. Use of such fuels may damage the plant or release toxic chemicals during gasification. As this is a crucial consideration, any fuel source (for example, CC+D) with a high risk of containing unknown chemicals should be removed if it does not pass this indicator.

Criteria 2 - Economic Impacts

Objective – To minimize monetary costs.

The economic feasibility of the source fuel is highly dependent on price as UBC only has a limited budget. The units used are dollars per year because this takes into considering volume of fuel required as well as its unit price/transportation requirements.

Indicator	Units	Justification
Price • Fuel + HST • Carbon tax • Transportation	($/year)	All these indicators contribute to the overall monetary cost of the fuel source and together provide a comprehensive measure thereof. As UBC does
Long-term availability	Qualitative Scale: • Likely • Unknown • Unlikely	Long-term availability is required as to avoid costs associated with having to research a new source. Also, there is a "learning curve" in applying a fuel source, in which it takes time to learn to use a source effectively. Implementation of a new source would require more time, effort and money. This can be measured as likely, unlikely or unknown depending on the availability of appropriate data.

Criteria 3 - Environmental Impacts

Objective – To minimize negative environmental impacts.

One of the purposes of the Nexterra biomass project is to develop alternative sustainability energy solutions, therefore environmental impacts should be a top priority for evaluation. GHG gas emissions during gasification have already been taken into account through the carbon tax/credit indicator above.

Indicator	Units	Justification
Impact on local ecosystem	Qualitative 123	Fuel usage should not detriment the local ecosystem, as this makes the source unsustainable environmentally. This evaluation metric should be robust in the sense that
GHG emissions • Sourcing • Transportation • Processing	GHG Emissions $CO_{2\text{-}e}$ / kWh	UBC plans to reduce its GHG emissions by 100% by 2050. GHG emission is an international standard for measuring impact on global climate change, which also has significance for socio-economic issues on a national, regional and community scale.
Chemical emissions during gasification	Chemical emissions g / kWh	Chemical emissions should be considered due to possible health risks to surrounding communities involved in gasification of source fuel and the potential for acid rain formation in the surrounding area. This is measured in the Acid Rain Potential in tonnes of SO2 emitted.

Criteria 4 - Social Impacts

Objective – To minimize negative and maximize positive social impacts.

Social impacts are the hardest indicators to measure. Qualitative indicators, however, still encompass some of the most important considerations in selecting a fuel source. The sources are rated on a case-by-case basis as having substantial, moderate, or no potential with regards to the indicator.

Indicator	Units	Justification
Potential learning value to local community	(123 scale) 1. Substantial 2. Moderate 3. None	UBC is committed to community outreach programs, thus the type of wood chips used (depending on proximity of source) could provide an opportunity for the community to learn about the processing. For example, use of mountain pine beetle wood could provide an opportunity for the communities in and around UBC to learn about the pine beetle issue, as well as lifecycles.
Political controversy potential	(123 scale) 1. Substantial 2. Moderate 3. None	Ultimately the decisions to build the Nexterra plant and conduct any further research are political decisions aside from other considerations. If there is political backlash, operations may have to be halted and this would incur financial and administrative costs. As such, this indicator should be minimized.
Research potential	(123 scale) 1. Substantial 2. Moderate 3. None	Some fuel sources may have further research potential for the university, such as the usage possibilities for pine beetle wood previously considered unusable.
Partnership potential	(123 scale) 1. Substantial 2. Moderate 3. None	UBC has a commitment to increase research opportunities and partnerships. Benefits of using a particular source may include opportunities to apply knowledge to real world situations in addition to private sector funding for UBC initiatives. UBC may also be able to tap into the source's business network in future projects (such as connections in the forestry if working with hog fuel companies or the city of Vancouver's network if deriving wood waste from them).

5.0 Recommendations

The first choice of fuel source was determined to be hog fuel. The companies that could potentially supply hog fuel are ranked as follows:

- Chips Ahoy Fibre Supply
- Basran and Cloverdale Fuel (tie)

The second choice of fuel source was determined to be municipal trimmings. Municipal trimmings would be sourced from the City of Vancouver. Davey Tree was deemed unfeasible primarily due to a relative lack of information.

The third choice of fuel source was determined to be BC mountain pine beetle wood. The companies that could potentially supply pine beetle wood are ranked as follows:

- International Bio Fuels
- Trace Resources

The construction and demolition materials were found to be technically unfeasible because of the possibility of infiltration of trace chemicals.

6.0 Discussion

Hog fuel was chosen as the best option as a fuel source because it does not negatively impact its local ecosystem and has the lowest GHG emissions during both generation (harvesting and chipping) and transportation. Although it had no potential social impacts (negative or positive), its environmental impacts were significant enough to convince us it should be the fuel source for the Nexterra-UBC plant. Of the three companies that supply hog fuel, the only currently known difference between them is cost. Chips Ahoy Fibre Supply is the cheapest fuel source while both Basran and Cloverdale Fuel are the same price. (See Appendices A, B, and C for comprehensive source evaluations, sample calculations and the results of applying the developed matrix).

Municipal trimmings remains an attractive option compared to hog fuel in terms of economic costs and GHG emissions – costing approximately $100,000 extra per year, while producing ~ 10 tonnes less CO2 per year. However, political controversy could arise if significant amounts of municipal trimmings are diverted from current uses, which include a UBC pilot project for local agricultural use of compost and free use of City compost by local organizations like schools and community gardens. Yet, the negative impacts of political controversy could be outweighed by the potential for local citizens to learn about genuinely local ways of energy production, as well as the potential for academics to learn about how academic institutions like UBC can bring public and private sectors together into sustainability partnerships.

BC mountain pine beetle (MPB) wood produces significantly higher GHG emissions than hog fuel. Also its use has a negative impact on its local ecosystem because the wood does not decay naturally and replenish its surroundings with nutrients. On the other hand, it has the highest potential learning value to the community, political controversy potential, and academic research potential of all four sources. It is also the only fuel source that has potential job creation. However, the long term availability of this source is questionable considering a potential market for MPB wood. This may raise opportunity cost implications in the future as this fuel source could be in demand for structural or construction purposes. The result of this competition may be uncertainty around economic feasibility, specific to pricing of the source. Similarly to the companies supplying hog fuel, the only current known differences between the two potential pine beetle wood companies are price (according to current estimates) and moisture content.

Unfortunately there is currently no price estimate for the municipal trimmings option, therefore it was left out of the rankings. If its price was found to be comparable, however, to the other two options then it would be listed as second choice and mountain pine beetle wood would become third choice.

The construction and demolition waste was determined to be unfeasible because it is impossible to guarantee that there are no trace chemicals mixed into the fuel source. This is unfortunate because it ranked the highest on the environmental impacts with the lowest GHG emissions and a positive impact on the local ecosystem. Its cost is comparably low along with hog fuel. In addition, its social impacts are all moderate (both negative and positive).

Three criteria in the indicator matrix are currently blank for all four fuel options. The first is "price of energy generation as a function of moisture content" under the Economic Impact section. It seems likely that more water in a fuel source would mean more energy/time would have to be used to dry it and therefore it would be more expensive to use for energy generation. Unfortunately although we had moisture content information we do not know enough about the gasification process to make a reasonable estimation for additional costs.

The second blank indicator is "chemical emissions during gasification" under Environmental Impacts. It is unknown whether each fuel sources would emit significantly different chemicals during gasification, however we believe this possibility is worth investigating.

The last blank indicator is "partnership potential" under the Social Impacts sections. We did not feel we were knowledgeable enough about BC's wood/construction industry to adequately estimate the potential for partnering companies or organizations for each fuel source.

7.0 Conclusion

Overall, the current evaluations were based on very limited data available. Much of the qualitative assertions and evaluations in the Social Impacts section can be argued for many sides. It is also high possibly that many unforeseeable arguments can sway the indicators currently assigned. However, given the current information available to us and logical assumptions made along the way, we believe that hog fuel is the most ideal fuel source considering technical feasibility and a fine balance of the `triple bottom line` (i.e. social, economic, and environmental factors). If multiple sources can be used to supply the Nexterra plant, then the City of Vancouver would also provide a feasible option against the principles of the triple bottom line.

8.0 Reflections

One of the more intriguing phases of this project was when we had to construct our criteria matrix. Notwithstanding the difficult task of distinguishing between a criteria/objective/indicator, it was surprising to know that even some of the seemingly taken-for-granted criteria like 'political', 'social', or 'educational' are subject to multiple definitions. For example, there was disagreement as to whether 'political implications' could be distinguished from 'public perception'. It was valuable to know that while science students tended towards separating the two, arts students would see them as inseparable. Similar discussions were raised regarding the definition of 'educational'. Perhaps one of the benefits of having a cross-faculty course like APSC 364 is that students are exposed to different interpretations of seemingly obvious terms like 'political', which helps to bridge the gap between the arts and sciences in general.

The distinction between performance-based criteria and evaluation-based criteria was certainly an important lesson from this course, since both criteria sets require data to be gathered and presented in different ways. Ultimately, these two criteria sets serve distinct purposes, but this was not apparent to us until later in this course.

Logistically, it was difficult to gather any additional data regarding fuel sources that was not already available to UBC mainly due to time constraints. However, this seems to be part of the process of learning about how sustainability is much more easily discussed than done in practice.

Seminar class sizes were small enough that made it comfortable for students to participate in discussions.

Specifically for the biomass project, a group of 4 was perfect because there were four sources to choose from. This allowed each person to specialize in each source, and made it easy to divide the work between team members. In addition, having a multi-disciplinary team added more depth to the indicator choice discussions.

References

Phase 1: Energy cycle

Stantec Consulting. *Alternative Energy Feasibility Report for UBC.* 2010.

Giffin, Jeff. *Biomass Presentation.* January 20, 2011.

Giffin, Jeff. *UBC Bioenergy Research and Demonstration Project.* 2010.

UBC Utilities. Updated Oct 20, 2008. Accessed Jan 19, 2011.
<http://www.utilities.ubc.ca/services.html>

Babich, David. *Strategic Business Analysis for UBC Utilities*. 2005

Phase 2: Options study

Giffins, Jeff (2011) Personal communication.

Giffins, Jeff (2010) UBC Bioenergy Research and Demonstration Project, CEEN 502.

Nexterra. Typical Wood Fuel Specifications. January 2009.

Additional references for CC+D

Urban Woodwaste Recyclers (2009) Web. Accessed on 2/3/2011 <http://www.uwwr.com/>

Additional references for Municipal Trimmings

City of Vancouver (2009) 2009 Vancouver Landfill Annual Report. Web. Accessed on 2/4/2011 <http://vancouver.ca/engsvcs/solidwaste/landfill/documents/09OCReport-revised.pdf>

City of Vancouver (2010) 2004-2009 Solid Waste Division Report. Web. Accessed on 2/4/2011 <http://vancouver.ca/engsvcs/solidwaste/documents/SWSummaryRpt04-09.pdf>

City of Vancouver: Engineering Services – Solid Waste (2011). "Composting at Vancouver Landfill" Web. Accessed on 2/4/2011 <http://vancouver.ca/engsvcs/solidwaste/landfill/compost.htm>

City of Vancouver: Engineering Services – Solid Waste (2011). "Vancouver South Transfer Station, Recycling Depot & Yard Trimmings Drop-off" Web. Accessed on 2/4/2011 <http://vancouver.ca/engsvcs/solidwaste/transfer/index.htm >

City of Vancouver: Engineering Services – Solid Waste (2011). "Vancouver Landfill" Web. Accessed on 2/4/2011 <http://vancouver.ca/engsvcs/solidwaste/landfill/index.htm >

City of Vancouver (2011) Urban Forestry Division: Street Tree Worker License 2011. Web. Accessed on 2/6/2011

<http://www.cityofvancouver.us/parks-recreation/parks_trails/urban_forestry/pdf/STWL_web_list.pdf>

The Davey Tree Expert Company (2011) “Davey corporate information” Web. Accessed on 2/6/2011 <http://www.davey.com/about/corporate-information.aspx>

University of British Columbia. “Partnership to reach Greenest City Goals” Web. Accessed on 2/4/2011 <http://www.sustain.ubc.ca/ubc-sustainability/partnership-reach-greenest-city-goals?quicktabs_1=0>

Phase 3: Criteria matrix

N/A

Phase 4: Recommendations

Coosa-Alabama River Improvement Association. “Barges and Tugboats.” Accessed March 20, 2011. <http://www.caria.org/barges_tugboats.html>

Giffin, Jeff. (2010). *UBC Bioenergy Research and Demonstration Project: Multi-criteria decision analysis of fuel source options*. UBC CEEN 502.

Maritime Reporter and MarineNews. “U.S. Waterways: Greenhouse Gas Emissions Study.” June 16, 2009. Accessed March 20, 2011. <http://marinelink.com/news/article/330909.aspx>

UBC Utilities. (2010). *Wood Fuel Source Options*.

Westerman, Harold. (2011). “Port Planning” presentation to CIVL 445 class on Feb 21, 2011.

Appendix A: Source Evaluations.

Hog Fuel – Basran, Chips Ahoy Fibre Supply, Cloverdale Fuel

Technical Feasibility
Moisture content: 45%
Additional equipment requirement (Yes): Equipment required to dry wood chips from 45% moisture content to <25%.
Other trace chemicals (No): Waste materials come from processing of wood harvested from forests, so unless there are chemical fertilizers used in the growth of the trees, little or minimal trace chemicals should be present,

Economic Impacts
Long-term availability (Likely): The forestry industry is likely to function in the near and foreseeable future.

Environmental Impacts
Impact on local ecosystem (None): This source is wood that was already harvested. Using this source would have no impact on the fuel's ecosystem. Should this not be used as a fuel the material would end up in a landfill.

Social Impacts
Potential learning value to local community (None): The fuel comes from industry and as such, has no social community ties.

Political controversy potential (None): The waste wood is sourced from the by-products of the forestry industry and as such, there should not be many stakeholders, nor any who would have a keen interest in this waste.

Academic research potential (None): There are no foreseeable research possibilities for the waste by-products of wood processing.

BC Mountain Pine Beetle - International Bio Fuels and Trace Resources

Technical Feasibility
Moisture content: 20% (International Bio Fuels) and 25% (Trace Resources)
Additional equipment requirement (No): No foreseeable need to further process MPB woodchips.
Other trace chemicals (No): None to minimal, contingent on source and if local area utilised chemicals or pesticides to mitigate mountain pine beetles.

Economic Impacts
Long-term availability (Unknown): An estimated 10 year supply of wood (wherein after that period, MPB-killed trees will have decomposed to a point of no longer reusable) due to 30% of BC`s land infested by the beetle. *However*, the true availability of this source is unknown due to the potential of MPB wood having economic value for other uses (and therefore competing factors of availability as an input for the Nexterra plant).

Environmental Impacts
Impact on local ecosystem (Negative): As MPB wood decays in its original habitat, the decomposing wood would`ve served as a fertilizer to the local ecosystem. Thus, extracting the wood may have negative effects on its local ecosystem due to its missing composting functionality.

Social Impacts
Potential learning value to local community (Substantial): This source may have substantial learning potential due to association with the Mountain Pine Beetle infestation. The local community would be able to learn about the processing of this wood source and how it came to be (i.e. deriving value from an otherwise wasted product, the affects of beetle species, etc).

Political controversy potential (Substantial): There may be substantial political controversy for two main reasons – (1) the dead wood may have other structural or construction uses and therefore the Nexterra project would have opportunity cost implications and (2) the decaying wood may have ecosystem value as a fertiliser to the local habitat.

Academic research potential (Substantial): There is much to study with this source on many levels of its lifecycle including the origins stage (affects of MPB infestations, an interest for biological studies), the processing stage (interest for forestry research) and the usage stage (its economic valuation or study for a waste product).

Partnership potential (Substantial): Considering 30% of BC`s land being affected by the MPB, they are numerous communities in which the source would be available. That being said, many communities would equal a large network of potential partnerships of interest for the university on many levels such as community education (community service learning projects) and rural or developmental programs associated with UBC.

Construction and Demolition Materials – Urban Woodwaste Recyclers

Technical Feasibility
Moisture content: 25%
Additional equipment requirement (No): No foreseeable need to further process MPB woodchips.
Other trace chemicals (Yes): Waste materials from construction and demolition sites are usually all mixed together during to construction/demolition process. The possibility of trace chemicals infiltrating the wood waste may make this option unfeasible.

Economic Impacts
Long-term availability (Likely): Both construction of new buildings and demolition of old buildings will likely continue in Vancouver for the foreseeable future.

Environmental Impacts
Impact on local ecosystem (Positive): This wood source would have ended up in a landfill should it not be used as a fuel source and as the wood was harvested elsewhere, there is no impact on the ecosystem from which it was originally sourced.

Social Impacts
Potential learning value to local community (Moderate): This source may have moderate learning potential because it shows how recycling can be expanded to a larger scope beyond the household.

Political controversy potential (Moderate): There may be objections to using construction and demolition waste because if it could potentially be used for other purposes. For instance it makes more sense to reuse a recycled beam for structural purposes in a new building than chip it up for biomass fuel.

Academic research potential (Substantial): This source may have substantial research potential because it provides further information for life-cycle assessments (LCA) of buildings. Also it would be prove the Nexterra gasification process can work despite trace chemicals.

Municipal Trimmings – City of Vancouver, Davey Tree

Technical Feasibility
Moisture content: 50% (City of Vancouver), 55% (Davey Tree)
Additional equipment requirement (Yes): Equipment required to dry wood chips from 45% moisture content to <25%.
Other trace chemicals (None): Minimal risk, depending on the City and residents' gardening practices.

Economic Impacts
Long-term availability (likely): Annual residential yard trimmings processed by the City has steadily increased in recent years, and is well above the Nexterra plant's requirment of 26,000 tonnes p.a.. However, a seasonal drop in supply from January to March might pose supply issues if proposed biomass plants in and around Metro Vancouver find municipal trimmings an attractive source.

Environmental Impacts
Impact on local ecosystems (none): Municipal trimmings derived from either private gardens or pre-existing City park operations, thus no new 'ecosystems' will be exploited or protected.

Social Impacts
Potential learning value to local community (moderate): Demonstrates to Metro Vancouver municipal governments and citizens the potential for truly locally-based energy production from end-to end (fuel source to energy production).

Political controversy potential (moderate): Fuel source might conflict with current beneficiaries of free City compost. On the other hand, the City's composting expenditures could be reduced if trimmings are diverted to the Nexterra plant instead.

Academic research potential (moderate): Successful or not, an attempted tripatite partnership between government, academia, and private sector would help researchers improve upon their own regions' partnership models based on UBC's model. Davey Trees would be less likely than the city of Vancouver to provide a comprehensive case-study for researchers.

Partnership potential (moderate): This is a difficult indicator to measure, but potentially significant. Theoretically, the City has many local, regional, and international contacts in both public and private sectors, but this is no guarantee that they will translate into meaningful partnerships for UBC. Davey Tree is less likely to provide and facilitate a wide-range of local, regional and international contacts that could form partnerships with UBC in its academic, research and administrative/utility operations.

<u>Appendix B: Sample Calculations.</u>

<u>Unit cost, moisture content, required fuel mass</u>
Numbers taken from “Wood Fuel Source Options” (2010) by UBC Utilities.

<u>Barge transportation distance, truck transporation distance, truck capacity</u>
Numbers taken from “UBC Bioenergy Research and Demonstration Project: Multi-criteria decision analysis of fuel supply options” (2010) by Jeff Giffin.

<u>Barge capacity</u>
http://www.caria.org/barges_tugboats.html
Gives average barge capacity as 1500 tonnes.

<u>Barge gas price [$/km]</u>
Harold Westerman (Port Planner and Engineer for Moffat & Nichol) stated in presentation for CIVL 445 (Spring 2011) that barges cost $0.10 per tonne mile. To determine price/km:

$$\frac{price}{km} = \frac{50.10}{tonne\ mile} * \frac{mile}{1.609km} * \frac{1500\ tonnes}{load}$$

<u>Truck gas [price/km]</u>
Harold Westerman (Port Planner and Engineer for Moffat & Nichol) stated in presentation for CIVL 445 class that trucks cost $1.00 per tonne mile.

$$\frac{price}{km} = \frac{51.00}{tonne\ mile} * \frac{mile}{1.609km} * \frac{25\ tonnes}{load}$$

<u>Barge GHG emissions/km</u>
http://marinelink.com/news/article/330909.aspx
Gives GHG emissions for barges as 51,891 ton-miles of cargo movement per ton CO_2 emitted. Differences between the U.S. ton and metric tonne were ignored. To determine the carbon emissions per km per barge:

$$\frac{tonnes\ CO2\ emitted}{km} = \frac{1\ ton\ CO2\ emitted}{51891\ ton\ miles} * \frac{mile}{1.609km} * \frac{1500\ tonnes}{load} = \frac{0.018\ t}{km}$$

Type equation here.

<u>Truck GHG emissions/km</u>
http://marinelink.com/news/article/330909.aspx
Gives GHG emissions for barges as 13,964 ton-miles of cargo movement per ton CO_2 emitted. Differences between the U.S. ton and metric tonne were ignored. To determine the carbon emissions per km per barge:

$$\frac{tonnes\ CO2\ emitted}{km} = \frac{1\ ton\ CO2\ emitted}{13964\ ton\ miles} * \frac{mile}{1.609km} * \frac{25\ tonnes}{load} = \frac{0.001\ t}{km}$$

	Units	**Hog Fuel - Basran**	**Hog Fuel - Chips Ahoy Fibre Supply**	**Hog Fuel - Cloverdale Fuel**	**BC Mountain Pine Beetle - International Bio Fuels**
Economic Costs					
Unit cost	[$/tonne]	43	40	43	77
Tonnes required	[tonnes / year]	24,000	24,000	24,000	14,600
Cost/year	[$/year]	1,020,000	960,000	1,020,000	1,124,200
HST @ 3.147%	[$/year]	32,099	30,211	32,099	35,379
Total cost/year	**[$/year]**	**1,052,099**	**990,211**	**1,052,099**	**1,159,579**
Barge transportation distance (1-way)	[km/load]	200	200	200	-
Barge capacity	[tonnes/load]	1,500	1,500	1,500	-
Barge trips/year	[loads/year]	16	16	16	-
Barge distance/year	[km/year]	3,200	3,200	3,200	-
Barge gas price/distance	[$/km]	93	93	93	-
Barge transportation cost	[$/year]	297,600	297,600	297,600	0
Truck transportation distance (1-way)	[km/load]	40	40	40	291
Truck capacity	[tonnes/load]	25	25	25	25
Truck trips/year	[loads/year]	960	960	960	584
Truck distance/year	[km/year]	38,400	38,400	38,400	169,944
Truck gas price	[$/km]	16	16	16	16
Truck Transportation Cost	[$/year]	597,120	597,120	597,120	2,642,629
Total Transportation cost	**[$/year]**	**894,720**	**894,720**	**894,720**	**2,642,629**
Price including fuel + HST, carbon tax, transportation	**[$/year]**	**1,946,819**	**1,884,931**	**1,946,819**	**3,802,208**

	Units	**BC Mountain Pine Beetle - Trace Resources**	**CC+D - Urban Woodwaste Recyclers**	**Municipal Trimmings - City of Vancouver**	**Municipal Trimmings - Davey Tree**
Economic Costs					
Unit cost	[$/tonne]	70	50	0	N/A
Tonnes required	[tonnes / year]	16,500	16,500	26,000	28,095
Cost/year	[$/year]	1,155,000	825,000	(incl. Processing) 728000	N/A
HST @ 3.147%	[$/year]	36,348	25,963	22,910	N/A
Total cost/year	**[$/year]**	**1,191,348**	**850,963**	**750,910**	N/A
Barge transportation distance (1-way)	[km/load]	-	-	-	-
Barge capacity	[tonnes/load]	-	-	-	-
Barge trips/year	[loads/year]	-	-	-	-
Barge distance/year	[km/year]	-	-	-	-
Barge gas price/distance	[$/km]	-	-	-	-
Barge transportation cost	[$/year]	0	0	0	0
Truck transportation distance (1-way)	[km/load]	291	106	80	80
Truck capacity	[tonnes/load]	25	25	25	25
Truck trips/year	[loads/year]	660	660	1,040	1,124
Truck distance/year	[km/year]	192,060	69,960	83,200	89,904
Truck gas price	[$/km]	16	16	16	16
Truck Transportation Cost	[$/year]	2,986,533	1,087,878	1,293,760	1,398,007
Total Transportation cost	**[$/year]**	**2,986,533**	**1,087,878**	**1,293,760**	**1,398,007**
Price including fuel + HST, carbon tax, transportation	**[$/year]**	**4,177,881**	**1,938,841**	**2,044,670**	**N/A**

Appendix C: Matrix Results.

Indicator	*Units*	Hog Fuel - Basran	Hog Fuel - Chips Ahoy Fibre Supply	Hog Fuel - Cloverdale Fuel	BC Mountain Pine Beetle - International Bio Fuels
Technical Feasibility					
Moisture content	[% water]	45	45	45	20
Additional equipment requirement	[Y/N]	Y	Y	Y	N
Other trace chemicals	[Y/N]	N	N	N	N
Economic Impacts					
Price including fuel + HST, carbon tax, transportation	[$/year]	1,946,819	1,884,931	1,946,819	3,802,208
Long-term availability	[Likely, Unlikely, Unknown]	Likely	Likely	Likely	Unknown
Environmental Impacts					
Impact on local ecosystem	[Positive, Negative, None]	Positive	Positive	Positive	Negative
GHG emissions	GWP tonnes CO2 eq	7,683	7,683	7,683	7,304
Chemical emissions during gasification	ARP in tonnes SO2	33	33	33	46
Social Impacts		`			
Job creation [Y/N]	[Y/N]	N	N	N	Y
Potential learning value to local community	[Substantial, Moderate, None]	None	None	None	Substantial
Political controversy potential	[Substantial, Moderate, None]	None	None	None	Substantial
Academic research potential	[Substantial, Moderate, None]	None	None	None	Substantial
Partnership potential	[Substantial, Moderate, None]	-	-	-	-

Indicator	*Units*	BC Mountain Pine Beetle - Trace Resources	Construction and Demolition Materials - Urban Woodwaste Recyclers	Municipal Trimmings - City of Vancouver	Municipal Trimmings - Davey Tree
Technical Feasibility					
Moisture content	[% water]	25	25	50	55
Additional equipment requirement	[Y/N]	N	N	Y	Y
Other trace chemicals	[Y/N]	N	Y	N	N
Economic Impacts					
Price including fuel + HST, carbon tax, transportation	[$/year]	4,177,881	1,938,841	852,800	N/A
Long-term availability	[Likely, Unlikely, Unknown]	Unknown	Likely	Likely	Unknown
Environmental Impacts					
Impact on local ecosystem	[Positive, Negative, None]	Negative	Positive	None	None
GHG emissions	GWP tonnes CO2 eq	7,304	11,776	9,871	9,871
Chemical emissions during gasification	ARP in tonnes SO2	46	26	29	29
Social Impacts					
Job creation [Y/N]	[Y/N]	Y	N	N	N
Potential learning value to local community	[Substantial, Moderate, None]	Substantial	Moderate	Moderate	Moderate
Political controversy potential	[Substantial, Moderate, None]	Substantial	Moderate	Moderate	Moderate
Academic research potential	[Substantial, Moderate, None]	Substantial	Substantial	Moderate	None
Partnership potential	[Substantial, Moderate, None]	-	-	-	-