UBC Social Ecological Economic Development Studies (SEEDS) Student Report

# Biomass Source Study

## Final Report

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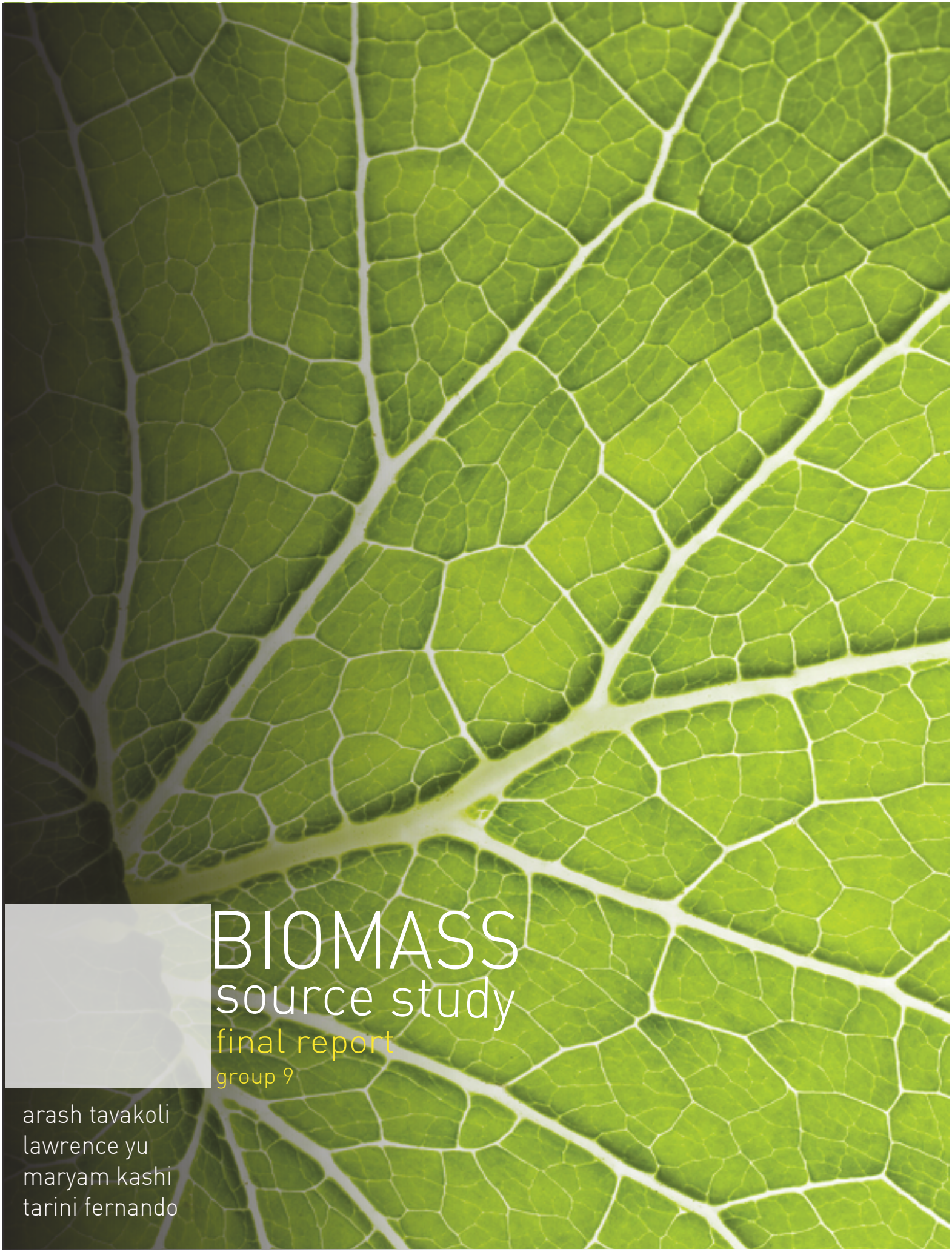

# BIOMASS
## source study
### final report
group 9

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# 1. Introduction

The University of British Columbia is a leading institution for innovation in sustainability and brings the ecological, economic, and social considerations of sustainability to the forefront of classroom learning and operational decisions. In 1998, UBC became the first university in Canada to establish a Campus Sustainability Office, affirming a commitment to address the complex issues between humans and the environment in an empowering manner.

"UBC promises a 33% GHG reduction by 2015, 67% by 2020 and the ultimate goal of 100% reduction by 2050."

Today, UBC is moving forward in sustainability leadership, and has recently pledged, through the UBC Sustainability Academic Strategy, to achieve a 33% GHG reduction by 2015, 67% by 2020 and the ultimate goal of 100% reduction by 2050[1]. While ambitious, these goals represent an opportunity for creative research and business strategy. In keeping with the vision of UBC as a "living laboratory", UBC will facilitate the unique collaboration of staff, faculty, students, and industry professionals to incubate, test, and realize new ideas that will undoubtedly allow us to achieve the set goals. One of these partnerships relates to the testing of biomass for commercial purposes – a joint venture with Nexterra and General Electric (GE) that will combine heat and power to provide clean, renewable energy in addition to a platform for bioenergy research.

The biomass project that is scheduled to start up in February of 2012 will be the first of its kind in North America to demonstrate the technical and commercial viability of combined heat and electrical power. The goal is to produce 2 MW electric and 3MW steam energy as a means of offsetting approximately 5% of electricity and 12% of steam consumed on campus[2]. While the biomass demonstration project will help advance research in clean renewable-energy production, it is important to keep in mind that the project itself has been debated by numerous stakeholders and staff at UBC and the broader community. The scope of our project however, does not extend to include an analysis of the advantages and disadvantages of the biomass project itself but rather, is intended to focus on determining which fuel source would be the most feasible and sustainable option for the biomass generator. This report will thus outline the four

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[1] Knight, Nancy., Robison, John. (2011). *The Next Generation of UBC Sustainability Initiatives.* Presented at the http://www.ires.ubc.ca/files/2010/12/USI-Presentation-APSC-364-11Jan11.pdf

[2] Griffin, Jeff. (2011). *UBC As a Living Lab: British Columbia's Hub for Sustainable Innovation. Bioenergy Research and Demonstration Project.* Presentation delivered at the University of British Columbia. Available at http://www.ires.ubc.ca/files/2011/01/Jeff-Griffin-Presentation-20.01.111.pdf

potential fuel source options, provide a comprehensive criteria matrix to assist in a holistic analysis of each source, and conclude with a ranking and recommendation for the UBC community. The purpose of this report however, is not so much to provide the right answer as it is to put forward a better set of questions and compel a broader consideration of what "sustainability" entails.

# 2. Option Study

In this section, each of the wood fuel source options provided by UBC utilities for biomass gasification research and demonstration project were analyzed and the results are reflected below. The followings sources are studied in this phase:

- Mountain Pine Beetle Wood
- Hog Fuel
- Municipal Trimming
- Urban Wood Waste

## 2.1 Mountain Pine Beetle Wood

The first source analyzed was Mountain Pine Beetle wood. This is wood that has been devastated by the MPB epidemic. Wood that has been consumed by the beetles is assumed to have zero commercial value although the latter is debated. This wood would be provided to UBC by two companies: International Bio Fuels and Trace Resources. The source of the two companies is located in the surrounding areas of Merritt and Cache Creek, British Columbia. Both companies are responsible for the extraction and processing of the MPB wood. Trace Resources recently has constructed a B-train truck transfer facility that would enable trucks to deposit unprocessed wood to the Delta Consolidator. The distance from the operation site in Merritt and the facility is 254 km. Subsequently, the MPB wood would travel an 80 KM round trip by 53' truck to UBC[3]. Due to low moisture content (20%),

Currently, there are 30% of BC forests that are inflicted with the MPB epidemic

[3] Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

only 15,000 tonnes of this fuel source is required per year. The cost of mountain pine beetle wood is estimated to have a range of 72-79 dollars per tonne.[4]

In terms of long-term availability, currently, there are 30% of BC forests that are inflicted with the MPB epidemic. Wood that has been infested by the beetle is considered to have zero commercial value. Thus, it is a viable solution to turn this liability into an asset. The current stock of MPB wood can provide up to 10 years of bio-fuels, which by then, it would be decomposed to the point where they are no longer usable for bio-energy[5]. However, the future of the forests in BC is still unknown and the epidemic is still expanding into the Northern interior of BC. The BC Ministry of Forest and Range has stated that the MPB wood will open a new industry in Canada, where more jobs can be created, especially in the area surrounding Merritt. Not only does this affirm the long term availability of MPB wood but also suggests we can move forward to meet our climate goals in a socially sustainable manner as well as help move us forward to meet our climate goals. The co-benefits that are achieved in the community are transferred to other energy-intensive sectors. SunSelect Produce Inc. in Delta, Vancouver already has greenhouses heated with electricity created by MPB bio-fuels.[6] With higher demand for cost-effective fuel sources, it is probable that MPB woods can provide a long term alternative energy to UBC and Vancouver. Ministry of Forest and Range, UBC and potential providers are stakeholders that impacted by this fuel source.

"…the future of the forests in BC is still unknown and the epidemic is still expanding into the Northern interior of BC."

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[4] UBC. (2010). UBC Utilities, Wood Fuel Source Options.

[5] Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

[6] Ministry of Forests and Range (2009). BC Company Helping Turn Beetle Wood into Power. Available at http://www2.news.gov.bc.ca/news_releases_2005-2009/2009FOR0012-000052.htm

## 2.2 Hog Fuel

The second fuel source analyzed was hog fuel. This fuel source is mainly composed of bark and is considered a waste product that many mills dispose of by burning. Half of this fuel source will be provided to UBC from UBC's Malcolm Knapp Research Forest, a sustainable forestry that is located near Maple Ridge and is managed by UBC's forestry department. The other half of it will be provided by local companies such as Basran, Chips Ahoy Fiber Supply and Cloverdale Fuel Co. Ltd. These companies source their fuel from several lumber mills located along the Frasier River. The logs are harvested near Campbell River are travel 200 Km to the Delta Lumber mill in log booms via tug boats, following which it would take an 80 Km round trip by a 53' truck to UBC[7]. The moisture content of hog fuel is 45% and accordingly 24,000 tones of this fuel source are required per year. In addition, the cost of hog fuel is estimated to be 44 dollars per tone if provided from local companies; however, it is still not clear how much would UBC be charged if the source is provided from UBC's Malcolm Knapp Research Forest.

"…the increased demand and reduced supply has caused a large increase in biofuels, contributing to the volatility of the biofuel market."

In terms of long term availability, many lumber and pulp mills that produce wood waste are being more resource-efficient and use wood waste to offset portions of electricity. This conservatism in wood waste, in addition to the new and adverse developments in the economy have led to a number of lumber mills and pulp plants across British Columbia to close down. Consequently, the increased demand and reduced supply has caused a large increase in biofuels, contributing to the volatility of the biofuel market. Moreover, the conservative trend may adversely impact the long-term availability of green wood waste both in available quantity and price. Malcolm Knapp Research Forest, UBC and provider companies are the potential stakeholders of this fuel source.

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[7] Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

## 2.3 Municipal Trimming

All open grown trees in parks and along streets require regular pruning. The municipal authority is responsible for removing deadwood, suckers, low-hanging and crossover branches to facilitate flow of air through the trees to reduce insect and disease attack, allow equipment or vehicles to maneuver, and to clear wires. These trimmed and naturally shed twigs and branches make for a potential biomass fuel source called municipal trimmings. Davey Tree, a company specializing in tree trimming, based in Kent, OH, with a branch offering service in Vancouver, and the city of Vancouver are responsible for providing this fuel source to UBC. It would be hard to estimate the amount of transportation that this fuel source would go through; however, it is estimated that the source travels 40km from Parks maintenance to consolidator in Delta, by trucks and then 80 km round-trip from Delta Consolidator to UBC by 53' trucks[8]. The high moisture content of wood (55%) from Davey Tree and their unrelated business to bioenergy have made it unnecessary to acquire costs; however, according to the Memorandum of Understanding between UBC and the City of Vancouver, the city provides some part of UBC's need with free of charge. However, the wood from City of Vancouver needs to be chipped and stored which introduce a cost of 28 dollars per tonnes with an estimated total requirement of 26,000 tonnes per year[9]. In terms of long-term availability, there will likely be few issues as trees always shed and open grow. Therefore, this source will not encounter availability issues in the future.

## 2.4 Urban Wood Waste

Another source of fuel for the biomass gasification research and demonstration project is construction and demolition waste. This waste is converted into biomass at Urban Wood Waste Recyclers. After the wood waste is dumped at the site, it is sorted at two stages and passed through "The Hammer Mill". The final product of the hammer mill is the biomass, which is sold to the market. According to Nexterra's wood fuel specifications, it is a requirement that the biomass be free of any contaminates, such as

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[8] Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

[9] UBC. (2010). UBC Utilities, Wood Fuel Source Options

glues, nails, metals, paint and plastics. This important condition is promised by Urban Wood Waste Recyclers, but not guaranteed; traces of plastics and particles are found in some instances. Urban Wood Waste Recyclers collects wood waste at two different locations: Vancouver and New Westminster/Burnaby; however, all the waste is transferred to New Westminster/Burnaby facility for the sorting and grinding process. The potential distance from the source collection site to the consolidator is about 40 km. Subsequently, the biomass would travel an 80 KM round trip by 53' truck to UBC[10]. Since the moisture content of this source is significantly low (25%), the required fuel for the project is only 16,000 tonnes per year. In addition, the cost of wood waste is estimated to be 52 dollars per tone[11].

"…traces of plastics and particles are found in some instances"

Wood is one of the most used materials in construction; however, as technology improves and sustainability thrives in building sciences, more sustainable materials such as concrete would be substituting the older materials such as wood. Therefore, the long-term availability of this source can be questionable. Despite this, there will be more incentives for construction industry to recycle waste wood. UBC, Urban Wood waste, rubbish removals and builders are potential stakeholders, which could be impacted by this fuel source.

## 3. Overview of Assessment Tools

"The conversation on sustainability cannot rest entirely on an operational level. As a result, we began to ask questions on the normative level."

In today's world, decisions are overwhelmingly made based on a cost-benefit analysis. Given the growing concerns with environmental degradation however, it is essential that decisions be made with consideration of factors above and beyond solely those that can be represented by a monetary value. To this end, it is important to account for the environmental impacts (for

[10] Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

[11] UBC. (2010). UBC Utilities, Wood Fuel Source Options

example, such things as biodiversity), as well as social impacts (for examples, community development) when making decisions. As stated in the first section, the purpose of our report is not to come up with the *right* answer, but rather, it is to shed light on the term "sustainability" in this context. In other words, the definition of sustainability in this report is directly related to how we assess it in terms of economic, environmental and social aspects. Thus, we believe that it is crucial that we are asking the *right* questions.


**Figure 1: Life-cycle assessment approach**

To start, we took on a life-cycle assessment approach, shown in Figure 1, which helped us conceptualize a framework that incorporates all three stages of the wood. The advantage to this approach is it allows us to capture the material input and environmental releases of each phase, and to evaluate the potential impacts that are associated. The conversation on sustainability cannot rest entirely on an operational level. As a result, we began to ask questions on the normative level. An example of this would be the assessment on municipal trimmings; although it requires relatively less transportation than other sources, how does it impact the source community? These kinds of questions led us to understand the trade-offs between the triple bottom line, and helped us understand the complexity of a balanced criterion.

By reporting these measurements individually, we can assess at which stage of the process is the most sustainable, or requires improvement.

## 3.1 Life Cycle Assessment Stages

Our assessment had criterions and indicators that were common in all three stages. These included:

1. To minimize energy consumption
2. To limit global warming potential
3. To minimize air pollution

These criterions are important in how we define sustainability because they cross through the three economic, environmental and social aspects. However, it is equally important that we include other criterion that might only be specific to that stage because these unique indicators may have profound impact to sustainability. By reporting these measurements individually, we can assess at which stage of the process is the most sustainable, or requires improvement. The matrix located in Appendix 1 is intended to provide a comprehensive list of considerations to assist UBC in choosing a fuel source for the biomass project that is environmentally, financially, and socially sustainable. Below is a summary of the indicators chosen at each stage.

**a. Source Community**

In the initial stage, normative questions were incorporated into our criterion, as a filter to sources that we believed was unethical. One of these criteria was to assess the value of the wood, by measuring its economic value and also its externality. Externality is the cost or benefit that is not transmitted through prices. For example, the externality of cutting wood from the Amazon forest would have a much higher externality due to the loss of biodiversity, than say, trees in British Columbia. Moreover, the energy requirement at the source stage is particularly important because some of these sources require no harvesting. Whereas mountain pine beetle wood, for example, would need to be harvested in order for it to be consumed.

**b. Consolidation**

At the consolidation stage, the criteria were mostly at the operational level. Similar to the first stage, we are concerned with the environmental releases from the input of raw

material. This concern is directly linked the location of the consolidator and the type of fuel required in the consolidation process.

**c. UBC Community**

The final stage to the life cycle is at the UBC campus. Here, our criteria for sustainability not only accounted for the three common criterions discussed above, but also for social concerns such as noise and contaminants when the wood is consumed. In addition, the matrix accounts for potential risks to UBC, such as long-term viability of the source and the reliability of the partnership.

## 3.2 Scoring System

Our group took two approaches to the scoring system. Initially, we ranked each indicator according to its importance and developed a weighing system that would result in a score for each source. The sources were then ranked according to the score. However, we realized that this scoring system was not meaningful because it depends largely on how we ranked each indicator's importance. Our second approach included both objective and subjective indicators. According to the indicator, we gave a plus, minus or neutral score to each source.

"In total there are 25 indicators in total, 13 of economics, 7 of environment, and 5 of social."

# 4. Findings and Discussions

Our initial findings using our second approach, as discussed above were then summed up according to their categories. The following table shows our first results:

| Hog Fuel | MPB | Urban | Municipal |
|---|---|---|---|
| 7 plus | 5 plus | 9 plus | 7 plus |
| 5 neutral | 2 neutral | 3 neutral | 4 neutral |
| 4 minus | 9 minus | 4 minus | 5 minus |

These initial results show us that the urban wood scores the best, following with hog fuel, municipal trimmings and lastly, mountain pine beetle wood. Although these results can be used to rank the four sources, it was not a meaningful result because it merely adds up the number of plus, minus and neutral for each source. In fact, we were more interested

in how well each source performed in terms of their economic, environmental and social aspect more so than how well it does overall. Therefore, we ranked each indicator according to their aspect towards sustainability, with some having more than one aspect. In total there are 25 indicators in total, 13 of economics, 7 of environment, and 5 of social. As a result, the following table emerged as our second results:

| | Economic | Environmental | Social |
|---|---|---|---|
| **Hog Fuel** | 1 | 7 | 1 |
| **MPB** | 3 | 4 | 3 |
| **Urban** | 1 | 9 | 1 |
| **Municipal** | 3 | 5 | 1 |

Our second results are more meaningful to this analysis because it shows how well the source performed under the triple bottom line. The following discussion will be used to explain the implications of each source to sustainability.

## 4.1 Mountain Pine Beetle Wood

The utilization of mountain pine beetle wood (MPB) has initially been thought to be an innovative alternative to the biomass generator. However, after running the source through our matrix, the source scored the least overall. The mountain pine beetle initiative is the only source that supports economic growth to forest dependent communities in BC. The decline in forest industry in recent years is due to increased technological advancement, which has led to the loss of traditional jobs. One of the criteria for sustainability, as we believe, is to sustain jobs in rural BC and to continue promoting the diversity of jobs BC has to offer. In addition, this source has a potential partnership between the provincial government, the community and the university. In terms of innovation, the MPB source scores the highest for its ability to create commercial capacity with the damaged wood that is arguably to have zero commercial value. However, to be objective, we gave a neutral score to its value, which is the sum of its commercial value and external cost, since there is potential for a new market for mountain pine beetle wood. This is supported by the composition of the wood itself;

"…it is the only source that needs to be deliberately harvested, compared to other sources, which are byproducts.

among other sources, mountain pine beetle wood has the lowest moisture content and has no artificial contaminants.

On the other hand, the mountain pine beetle source falls short in the indicators of minimizing energy use and GHG emissions. The reason is acceptable. Since the wood is harvested near Merritt, BC, the harvesting and transportation energy cost is relatively high compared to the other sources. In addition, it is the only source that needs to be deliberately harvested, compared to other sources, which are byproducts.

The decision of using mountain pine beetle wood should consider the trade-off between supporting forest dependent communities and the environmental cost of transportation and harvesting.

## 4.2 Hog Fuel

Hog fuel is a viable option for UBC. This source would come from UBC's Malcolm Knapp Research Forest, which proves a valuable research opportunity and strengthens an existing partnership between UBC and the broader community. While this is undoubtedly a positive opportunity, it does not mean new jobs are created in the source community. As a waste product that many mills dispose of, taking this wood has no detrimental impact on the source community. Moreover, in considering this source is brought to Vancouver via tug boats, there are energy savings to be made in this regard.

These energy savings are somewhat offset by the fact that hog fuel needs to be harvested – a process which also leads to higher pollution quantities as made evident by the acid rain potential in the criteria matrix. During the consolidation phase, hog fuel is chipped with electric equipment, which represents a cleaner energy and thus higher rankings. The direct result of this is lower global warming potential as quantified by acid rain potential.

Perhaps the most significant setback with using hog fuel comes by virtue of its high moisture content (45%) which makes necessary the use of the fuel source dryer - a process which results in an increase in emissions as well as an increase in the release of particulate matter and volatile organic compound. Additionally, as high moisture content is directly correlated to a higher number of trucks required to bring the source to UBC, there is a potential for increased noise.

With regards to the potential companies that would source this would such as Basran or Chips Ahoy Fibre Supply, there are limitations to our accessing company information and thus it is difficult to make a comprehensive decision on which partnership would be the most reliable and effective.

## 4.3 Municipal Trimmings

Municipal trimmings represent a fuel source that does not have any other potential commodity value. As a result it is viable to view it as a source quite apt for a sustainability-oriented project.

This source has the advantage that it does not bear harvesting costs. Furthermore, the wood is said to be provided for "free" based on a private partnership with the Vancouver City. Despite the fact that this source is to be provided free of charge by the city of Vancouver as per the "Memorandum of Understanding" between UBC and the City of Vancouver, UBC still needs to spend $28/tonne to store and further process the trimmings from Vancouver Parks. However, according to Jeff Griffin's "UBC Bioenergy Research and Demonstration Project", UBC is reluctant to establish additional facility to store and process this source. It is essential to question whether or not the figures provided in the report account for the additional transportation and GHG emissions that would come from having to subcontract another company to store the wood for UBC.

The moisture content of the wood is higher than that suitable for the plant. Therefore this source requires drying before use, which is less favorable than a source, which can be directly used due to low moisture content. This will lead to higher emissions and energy consumption. According to the same report by Jeff Griffin, the GHG emissions due to equipment use for this source are relatively high (210 GWP/yr). Considering harvesting for this source is not applicable, we speculate this high energy is consumed by equipment for chopping down the wood.

Also, municipal trimmings being in the form of branches, come in different sizes, which may not be all suitable for loading, storage and use. Thus additional chopping and processing of the wood is required which is not favorable.

This source has the advantage that it contains minimal contaminants. The toxins are limited to current air pollution, which is low in Vancouver. The log-term viability is also promising, as many parks in Vancouver whose trees will always require trimming.

## 4.4 Urban Wood

Urban wood waste performed relatively well when set against our criteria and indicators. In being wood waste, there is no alternate value for the wood and thus it does not have a high economic value or come at a great social cost (for example, our using it would not compromise biodiversity in the source community). While there are no adverse impacts on the source community, choosing to use urban wood waste will not have a significant impact on job creation in forest dependent communities for the simple reason that the source would be sorted in Burnaby.

One of the main advantages of using urban wood waste would be the potential for energy savings. As the wood waste collected would be from Vancouver, transporting the wood to the Burnaby consolidator would not contribute to significant fuel consumption or emissions because of the close proximity of the source to the consolidator and ultimately, UBC. Furthermore, urban wood waste does not need to be harvested and therefore, there are significant savings in energy and emissions at this stage. During the chipping stage, electricity is used, which is favorable as a cleaner energy comparative to diesel.

The value of urban wood waste as a potential source is further highlighted by its low moisture content (25%), which would not only eliminate the need for the fuel source dryer and thus lower total air emissions. The low moisture content would ensure the residential community along South West Marine drive is minimally disrupted via transporting wood through having to use fewer trucks.

While there are significant benefits to choosing urban wood waste, the main argument against using this source lies in the potential for some of the wood to be contaminated. It is not unlikely that the wood have traces of plastics and paints, glues, and metals. Considering there is no knowledge of how exactly burning this type of potentially contaminated wood can impact the UBC community (for example, the release of harmful toxins) it is important to exercise some caution. To this end, we can only hope that the

company (Urban Wood Waste Recyclers) is able to effectively process the wood and ensure its feasibility for use. Although a relatively new company (founded in 1993), Urban Wood Waste Recyclers represents a stable partnership with a mission and vision that corresponds to that of UBC and our broader goals for innovation in diverting waste from landfills.

## 5. Recommendations

It is now clear that Urban Wood is the top choice in terms of environmental impact, as long as the contaminants in the wood do not have adverse effects to the community. Mountain Pine Beetle Wood would be the best choice in terms of social aspect. Finally, there is a tie between Mountain Pine Beetle Wood and Municipal Trimmings in terms of the economic aspect. Through our analysis, we believe that sustainability should uphold all three aspects of the triple bottom line. As a result, our recommendation is twofold.

"…we believe that sustainability should uphold all three aspects of the triple bottom line."

First, Urban Wood should be incorporated as a source due to its high scores in terms of the environment and its competence in the other two aspects. Second, we believe that UBC should not solely purchase the source from one location, because of our belief that sustainability should include all three aspects. Thus, we recommend that Urban Wood should be complimented with either Mountain Pine Beetle, with a focus toward social sustainability in rural BC or Municipal Trimming, with a focus towards urban growth in Vancouver.

## 6. Limitations and Reflections

Although challenging, working on this project was truly enjoyable because it gave us an opportunity to engage with the broad and complex understandings of sustainability in a very practical and tangible manner. Scheduling times to meet with the group proved a little challenging but it was a worthwhile challenge as the opportunity to work collaboratively with students from various disciplines made this project a far more valuable learning experience. Additionally, the support and enthusiasm of the instructors

compelled my embracing this course as truly an investment in my learning; it was not all about the grades.

With regards to the biomass project itself, data limitations proved a significant barrier to more effective completion of the project. An opportunity to engage directly with some of the source companies and an opportunity to go on site visits (for example, to the Burnaby consolidator) would have significantly enhanced our ability to conceptualize different aspects of the life cycle we tried to assess.

Other limitations included:

- Details of livability and environmental, social, economical sensitivities in the source communities to understand how employing each source option would affect the dynamics in each respective community, particularly in the long run.
- Consolidated data about the national forest products industry regarding how wood stocks are handled and whether employed procedures are compatible with sustainable practices
- Information on the shape, size and state off each source option to properly assess – according to assumed sustainability standards – methods of preparing each source to be used in the bio-energy plant and the technical requirements/feasibility
- Time constraint – given the shortage of data and the limited time in which to complete the phases, it was challenging to clarify assumptions made throughout the process.
- Uncertainty about the relative significance of each sustainability criterion. For example, when trying to consolidate information, assigning a weight to each criterion proved challenging as these measures would have been arbitrary and thus require subjective justifications that were not based on available data.
- Uncertainty about how the provided data was compiled and what assumptions were made to reach the presented conclusions (for example, Mr. Griffin's report which served as an important resource but was nevertheless limiting).

Despite the limitations, we were able to sort and synthesize the necessary information. Undoubtedly, this project has enabled an increasing appreciation for the fact that time constraints and data limitations are a reality for operational staff and other stakeholders who ultimately have to make decisions based on imperfect knowledge.

# Appendix 1

| **SOURCE PHASE** | | | | |
|---|---|---|---|---|
| Criteria | Indicator | Measurement | Objective | Justification |
| To support forest dependent communities in BC | Job creation in source community | 1-will create jobs<br>2-may create jobs<br>3-will not create jobs | Self-evident | Forestry industry has lost 40% of its GDP over the past decade[1] and efforts should thus be made to mitigate the effects |
| To ensure the selected fuel source does not compromise economic, social, and environmental well-being of a community | Value of wood | Economic value[2] (commercial value) + external cost[3] (opportunity cost)<br><br>1- low external costs<br>2-medium external cost<br>3- high external cost | Ensure no virgin wood source is considered an option | Value of wood cannot solely be determined by quantitative calculations; social and qualitative environmental costs must be accounted for. |
| Minimize energy consumption | Fuel consumption during the harvesting phase | 0-does not require harvesting<br>1-low fuel requirement<br>2-medium fuel requirement<br>3-high fuel requirement | Preference a fuel source that does not require harvesting | Harvesting requires additional fuel consumption |

[1]Giffin, Jeff. (2010). UBC Bioenergy Research and Demonstration Project Multi-Criteria Decision Analysis of Fuel Options

[2] Economic value is the worth of the wood as determined by the market (related to price).

[3]External costs (externalities) are the costs that people other than the buyer are forced to pay as a result of the transaction. The bearers of such costs can be either particular individuals or society at large. They include things like impact on biodiversity - things that society will likely have to pay for in some way or at some time in the future, but that are not included in transaction prices.

| | | | | |
|---|---|---|---|---|
| | Energy consumed during the transportation phase | GJ/yr | To favour types of transportation that have the lowest watts/km. This would require a comparative analysis between possible types of transport (tug boat, trains, trucks) | Different types of transport have a different energy consumption |
| Limit Global Warming Potential | Transportation Requirements | GWP/yr<br>Global Warming Potential | Minimize Green House Gas (GHG)Emissions | CO2 is a GHG and thus contributes to global warming |
| | Equipment Use<br><br>Equipment required for harvesting? "No" is preferred but if "yes": ⇨ | Emissions from equipment use measured in CO2 equivalence | Minimize Green House Gas (GHG)Emissions | CO2 is a GHG and thus contributes to global warming |
| Minimize air pollution | -Particulate matter (PM)<br><br>-Nitrogen Dioxide (NO2)<br><br>-Sulphur Dioxide (SO2) | -Tonnes PM/year<br><br>ARP/yr | Ensure the chosen fuel source does not compromise air quality | PM/NO2/SO2 pollutants detract from quality of air |

| **SORTING/CONSOLIDATION PHASE** | | | | |
|---|---|---|---|---|
| Global warming potential | GHG emissions from equipment use | GWP/yr | Minimize GHG emissions that come from processing fuel source | CO2 is a GHG and thus contributes to global warming |
| | Minimize air pollution | ARP/yr | Ensure the chosen fuel source does not compromise air quality | PM/NO2/SO2 pollutants detract from quality of air |

| **UBC PHASE** | | | | |
|---|---|---|---|---|
| Minimize energy consumption | Moisture content | Rank best to worst source (1-3)<br><br>1: <25%<br>2: 25%-45%<br>3: >45% | Eliminate use of fuel source dryer | Higher moisture content requires a belt dryer to reduce moisture content to acceptable levels for the IC engine |
| Minimize risk to UBC community[4] | Contaminants in wood | Contaminant potential (Rank 1-3)<br>1-not likely to have any harmful contaminants<br>2-likely to have harmful contaminants<br>3-very likely to have harmful contaminants | Minimize social risks | Effects of burning contaminated[5] wood are unknown. It is thus important to consider the likelihood of contaminants prior to selecting a fuel source. |
| | Long-term availability of | Price volatility<br>1-low volatility | Minimize financial risk | Fluctuations in market |

[4] Community includes UBC operational staff, residents, students, and faculty
[5] Examples of potential contaminants: paint, processing chemicals, glues, sulphurous, phosphorous, chemicals

| | | | | |
|---|---|---|---|---|
| | wood | 2-medium volatility<br>3-high volatility | | supply/demand contribute to price volatility of biomass fuels, which impacts long-term availability of the chosen source |
| | Reliability of partnership with chosen company | Years in industry<br>1 – 10+ years<br>2 – 5-9 years<br>3 – 0-4 years<br><br>Innovation in Industry<br>1 – very innovative<br>2 – evident in innovation<br>3 – no innovation | Minimize financial risk | The experience of a company informs their knowledge of biomass projects and thus contributes to more efficient work. Efficiency implies a lack of mistakes – mistakes cost money |
| | Cost | $/tonne | Minimize financial risk | High cost reflects higher financial risk |
| Minimize negative impacts to UBC community | Noise pollution | Number of trucking trips/year | Minimize social disturbance | Depending on the number of truck trips required, the residential area along South West Marine Drive[6] could be disrupted |
| Minimize air pollution | -Particulate matter (PM)<br><br>-Nitrogen Dioxide (NO2)<br><br>-Sulphur Dioxide (SO2) | -Tonnes PM/year<br><br>ARP/yr | Ensure the chosen fuel source does not compromise air quality | PM/NO2/SO2 pollutants detract from quality of air |

[6] South West Marine Drive is the designated truck route

# Appendix 2

**Legend**
Social
Environmental
Economic

| Life Cycle | Indicator | | Source | | | |
|---|---|---|---|---|---|---|
| | | Hog Fuel | MPB | Urban | Municipal | |
| **Source Community** | | | | | | |
| Jobs | 1.1 | minus | plus | minus | minus | |
| Value of Wood | 1.2 | plus | neutral (unknown) | plus | plus (justify please) | |
| Fuel Consumption | 1.3 | plus | minus | plus | plus | |
| Energy Used | 1.4 | plus | minus | plus | neutral | |
| Transportation | 1.5 | plus | minus | plus | neutral | |
| Harvesting | 1.6 | neutral | minus | plus | plus | |
| Pollution - Acid Rain | 1.7 | neutral | minus | plus | plus | |
| **Consolidator** | | | | | | |
| GHG from Equipment use | 2.1 | plus | minus | plus | minus | |
| Pollution - Acid Rain | 2.2 | plus | minus | plus | minus | |
| **UBC Community** | | | | | | |
| Minimize Moisture | 3.1 | minus | plus | neutral | minus | |
| Contaminants in Wood | 3.2 | plus | plus | minus | plus | |
| Long Term Viability | 3.3 | minus | plus | neutral | plus | |
| Years in Industry | 3.4 | neutral | minus | neutral | plus | |
| Innovation | 3.5 | minus | plus | minus | neutral | |
| Cost | 3.6 | neutral | minus | neutral | plus | |
| Noise Pollution | 3.7 | minus | plus | plus | minus | |
| Pollution - Acid Rain | 3.8 | Neutral | Neutral | minus | neutral | |