Design Proposal for UNBC's Organic Waste Management System

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Executive Summary

The University of Northern British Columbia (UNBC) has been operating in partnership with the Prince George Public Interest and Research Group (PGPIRG) to divert food waste, or organic waste, produced on campus since 1995. However, the current organic waste management system has reached capacity, and a new system is required. Our objective was to design a solution that can handle the entire quantity and variety of organic food waste generated at UNBC, while maximizing criteria identified through stakeholder consultation, that can also be applicable to small Northern communities. Throughout the design process, stakeholder consultation played an important role, and helped appraise which design solution was most suitable for UNBC. Five design criteria were identified and refined, and it is recommend that the UNBC manage its organic waste with a Brome 8100 in-vessel composting (IVC) system. This system would divert 1,400 - 1,700 kg/week organic waste from the landfill, and require 30 wt% bulker, in the form of wood pellets, to produce quality compost; up to 15% compostable paper products can also be used to amend the compost. The IVC will be located in the recycling room, directly next to UNBC's kitchen, as over 60% of the organic waste on campus originates from the kitchen. The location proposed for both the curing and storage facilities is within the current composting site. Collection of organic waste from the UNBC campus would remain the same as the current system, but would also include optional participation from the student residences. The project has a capital cost of $147,100 ±5%, and annual operations cost of $9,600 ±10%. It will lead to an estimated diversion of 50 – 60 tonnes/year organic waste from the landfill, resulting in a reduction of 45-60 tonnes CO_2 e/year from the current system, further strengthening UNBC's commitment as *Canada's Green University*™.

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1. Current Organic Waste Management at UNBC

The University of Northern British Columbia (UNBC) has been operating in partnership with the Prince George Public Interest and Research Group (PGPIRG) and the Recycling and Environmental Action Planning Society (REAPS) to divert food waste, or organic waste, produced on campus since 1995 (PGPIRG, 2006). This system currently handles and annual average of 6.5 tonnes organic waste, and is run by PGPIRG volunteers (Section 5.1). However, the current organic waste management system has reached capacity, and new alternatives need to be found.

There are many challenges to the current composting system. During the winter, cold temperatures cause the decomposition process to slow down significantly (Michiel, et al., 2013). Since the system cannot control the decomposition temperature, it is limited in the variety of organic waste that it may accept. Only fruit and vegetable scraps, coffee grounds, tea bags, and eggshells are allowed in the composting bins; the system cannot accept cooked food, grains, meat, dairy, fat, oil, and grease (PGPIRG, 2006). Since it cannot accept all types of food waste, 70% of the organic waste produced at UNBC is send to the landfill (Section 5.1). Additionally, the system is styled like a backyard composting process, which is very labour intensive, requiring hand turning by few volunteers.

In addition to the above challenges faced by the current composting facility, recent changes to food services on campus have resulted in the system running at capacity. A new buffet style cafeteria was installed in 2014 that runs on an all-you-can-eat basis. Currently, all students living on campus with less than 60 credit hours are required to purchase a meal plan subscription; those who are not on the subscription may pay a fee to enter the cafeteria (UNBC, 2015). These changes have lead to a dramatic increase in the amount of organic waste generated on campus (UNBC, 2015) and a need to reevaluate how organic waste is managed at UNBC.

Our objective is to design a solution that can handle the entire quantity and variety of organic food waste generated at UNBC, while maximizing criteria identified through stakeholder consultation, that can also be applicable to small Northern communities. The following report outlines the design process used to evaluate organic waste management solutions, as well as the associated recommendations, economic analysis, and operating plans.

2. Organic Waste Management Options for UNBC

When examining the potential solutions to managing the organic waste produced at UNBC, we wanted to explore what methods were available. These options range from simple to complex, environmentally responsible to not, and alternatives that can take a few days or a few years. The following is a list of options we explored that could potentially handle the organic waste at UNBC, which could also be appropriate in small Northern communities. The applicability of these options are further discussed in Section 4.

2.1. Composting Options

2.1.1. The Science of Composting

Composting is a biological process where aerobic microorganisms break down organic matter into a stable soil amendment (FAO, 2003). When organic matter is placed in an aerated pile, it goes through two stages. The first, or active, stage is a mesophilic process where microorganisms rapidly break down the organic matter. These microorganisms grow in the 20 - 45 degrees Celsius range, and they heat up the organic matter to a point where they can no longer function. After this, thermophilic microorganisms take over and raise the temperature to 65 degrees Celsius. The curing stage follows the active stage, and in this stage the temperature slowly reduces to ambient temperature and the decomposition process stabilizes (FAO, 2003). This entire composting process produces water, carbon dioxide, methane, nitrous oxide, ammonia, heat, and a stable end product called humus. An overview of this process is depicted in Figure 1. As with most processes, there are optimal ranges or inputs to produce compost, which are further discussed in Section 5.4.

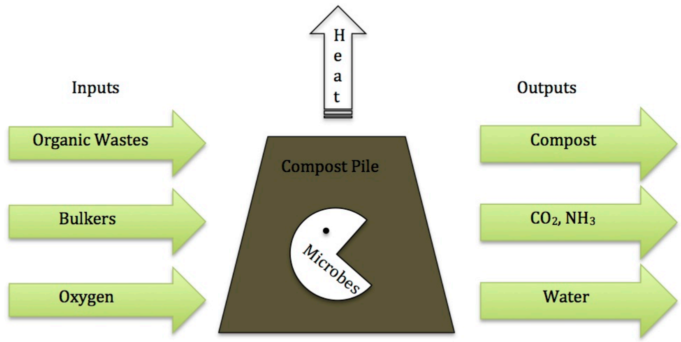

Figure 1: Composting Process

2.1.2. Status Quo

Before looking into different options, it is important to evaluate the status quo. Currently, the composting process at UNBC is primarily volunteer driven. Volunteers from PGPIRG collect bins of pre-consumer organic waste around the campus, including the kitchen, Thirsty Moose Pub, and Degrees Coffee locations, and place the contents and a small amount of sawdust into a hopper. This hopper is located in the recycling room, and is emptied about once a week. There have been many concerns and complaints regarding the odour produced by the hopper contents, as well as the associated fruit flies.

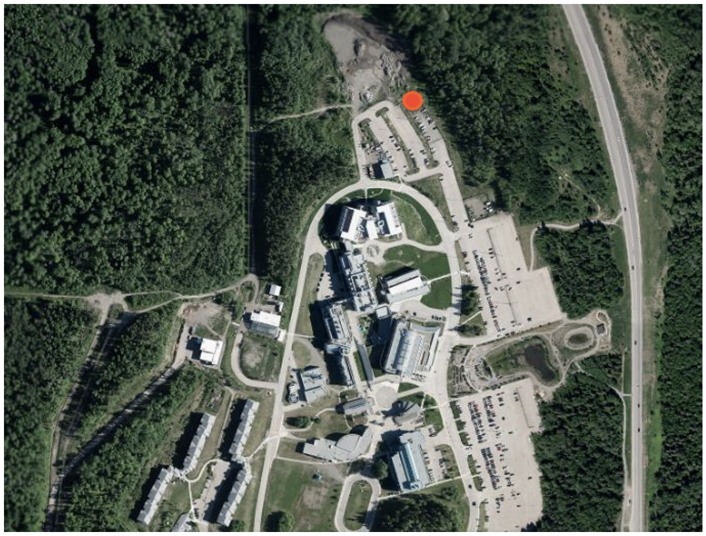

Figure 2: Current Outdoor Compost Location in Relation to UNBC Buildings

University facilities staff take the hopper and dump the contents in a secured and electric-fenced location just past Parking Lot C (Figure 2;Figure3). The organic waste is left in piles to decompose, and volunteers hand turn the piles once or twice a year to aerate them. This system is basic and simple, allows for community building and research opportunities at the university, and produces compost that has been sold despite not meeting government regulatory standards (PGPIRG, 2006).

Figure 3: Current Outdoor Compost Location

2.1.3. Pile Composting

Pile composting currently in use (Section 2.1.2) is not the only type of simple composting that UNBC could utilize. Other types of composting systems can be mixed or static, and with or without forced aeration. Large scale pile composting is often done at regional facilities, and the material is normally formed into windrows. Specialized machinery can be used to efficiently turn the windrows, or aeration can be provided through pipes underneath the windrows. These options require a relatively small capital investment, but require a large footprint in order to operate.

2.1.4. In-Vessel Composting

In-vessel composters are typically horizontal cylinders that either rotate, or have an auger inside to rotate the material. Organic waste and bulking or amending agents, such as wood pellets, are inserted at one end of the cylinder, and un-matured compost exits the other. The cylinder rotates or turns the contents to provide aeration and thorough mixing, while pushing the contents towards the exit. Residence time is dependent on the size of the vessel and the amount of organic waste processed, ranging from a few days to a few weeks. During this time, the composting process takes place (Section 2.1.1), but with the advantage of being in a controlled environment. The compost produced is not yet mature, and needs a place to cure and be brought down to ambient temperature. In-vessel composters can handle a large amount of organic waste with a relatively small footprint, and have been used at facilities that produce medium amounts of organic wastes, such as universities, hospitals, and malls (Bonhotal et al., 2011).

2.2. Non-Composting Options

2.2.1. Landfill

A simple, but not very environmentally responsible, way to handle the organic waste produced at UNBC would be to send it all to the Foothills Boulevard Regional Landfill. This option would not require any additional infrastructure or planning requirements, and organic waste would be collected, compacted, and sent with the other solid wastes produced on campus.

2.2.2. Livestock Feed

Feeding organic waste to livestock, pigs specifically, is another alternative for disposing of UNBC's organic waste. Pigs are known to eat anything and, as an added benefit, will convert the waste back into a usable food source. Prince George and the surrounding area have multiple farms that could act as potential acceptors of food waste. The organic waste would be collected in the same manor as it is currently, but instead of emptying the hopper outside, farmers could pick up the contents. This option, of course, would rely on the interest of local farmers.

2.2.3. Anaerobic Digestion

Perhaps the most technical option would be to convert the organic waste to biogas and biosolids through the process of anaerobic digestion. The production of biogas through anaerobic digestion is similar to the composting process, with a similar solids output, but an additional benefit of producing an energy supply. As the name suggests, aeration is not required, and food waste is put into a chamber under anaerobic conditions. Microbes under specific pH and temperature conditions break down the organic waste, and produce methane, carbon dioxide, and organic acids. While a similar process to the composting one, the microbes in anaerobic digestion are much more sensitive, and the process needs to be closely monitored. The methane produced can be captured and burned to produce heat or electricity, depending on which system is installed (Mihelcic & Zimmerman, 2009).

3. Stakeholder Consultation

Stakeholder consultation played an important role in the redesign of UNBC's organic waste management system; there are many people and groups who interact with the current system, and who would be affected by any changes made to it. It is important to understand what concerns and challenges each stakeholder group has with the current system, and what changes should be incorporated into a new system.

Many of these consultations were done through small group meetings with the heads of each group, which were conversational and fairly informal. In this process, stakeholders were never asked to pick between the design options we had identified (Section 2) and specific design criteria for the project was not discussed or ranked. The feedback was used to ensure that the design proposed would satisfy stakeholder concerns. We continued to check in with the stakeholders throughout the design process to receive additional information and ensure we still had a complementary vision for organic waste management at UNBC. Additionally, weekly meetings were held with our supervisors (David Claus and Amanda Drew) and sponsor (Kyrke Gaudreau); both groups are instrumental to the implementation of the system recommended.

3.1. Stakeholder Feedback

Table 1 provides a summary of key feedback received during stakeholder consultation.

Table 1: Key Stakeholder Feedback

Stakeholder	Role	Key Feedback
PGPIRG	Operators of current compost system	- UNBC needs to play a greater role in managing the current system - It is hard to get enough volunteers out to take care of the current system
SGU (Students for a Green University)	Increase awareness around environmental issues within the university	- Very open to providing assistance / potentially volunteers - Wants to see composting implemented for student residences
Facilities: Shipping and Handling	Work in mailroom and shipping receiving areas	- Smell related issues most problematic - There can be outbreaks of fruit flies - Want to see a better system in place
Facilities: Maintenance	Empty hopper when full and perform landscaping	- Hopper is filling up very rapidly since cafeteria changes - They can always use more compost for campus landscaping
Residence Life Coordinators	Oversee how the two university residence buildings are managed	- Residents want composting - They cannot provide any funds for an extra residence assistance (RA) to be devoted to bringing waste from res to the new system
Students, Faculty, and Staff	Users of compost system	- Priorities are positive environmental impact and ability to achieve 100% diversion; see results of dotmocracy below

Inputs from the general student body, faculty, and staff were collected using a dotmocracy survey; this format was selected due to its anonymousness, ease of implementation and use, and the ability to reach a consensus among the different populations. Six options related to the design criteria (Section 4.1) were polled, and each criterion could be ranked on a scale of one to five. A total of 123 students and 32 faculty and staff were polled over three hours, and the results are presented in Figure 4 and Figure 5 below.

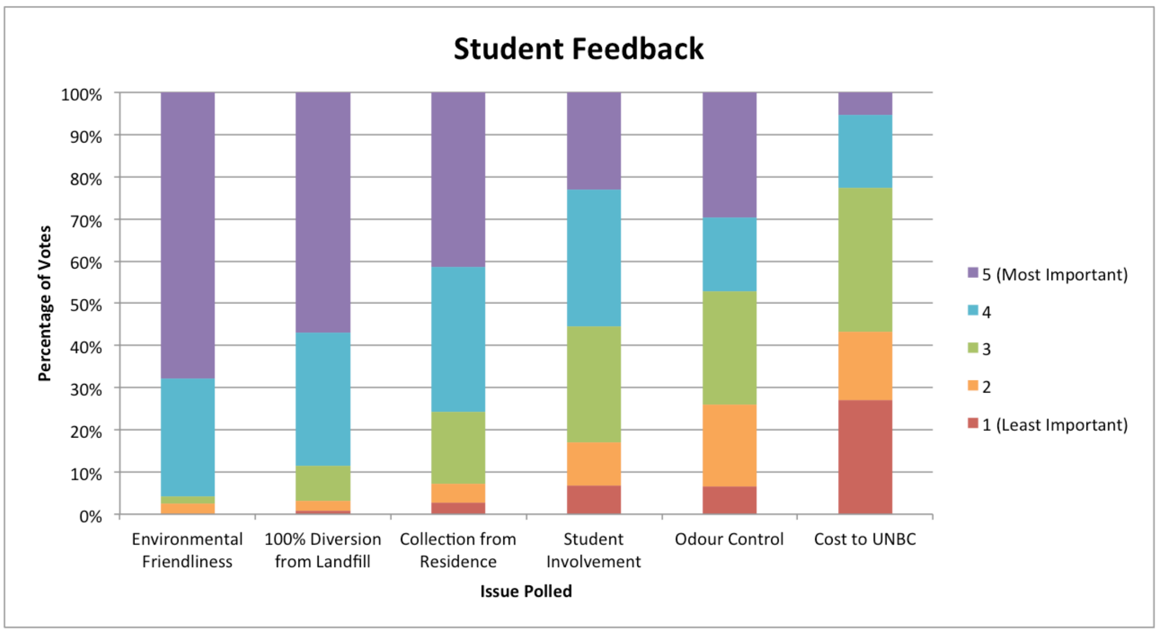

Figure 4: Dotmocracy Results from Students

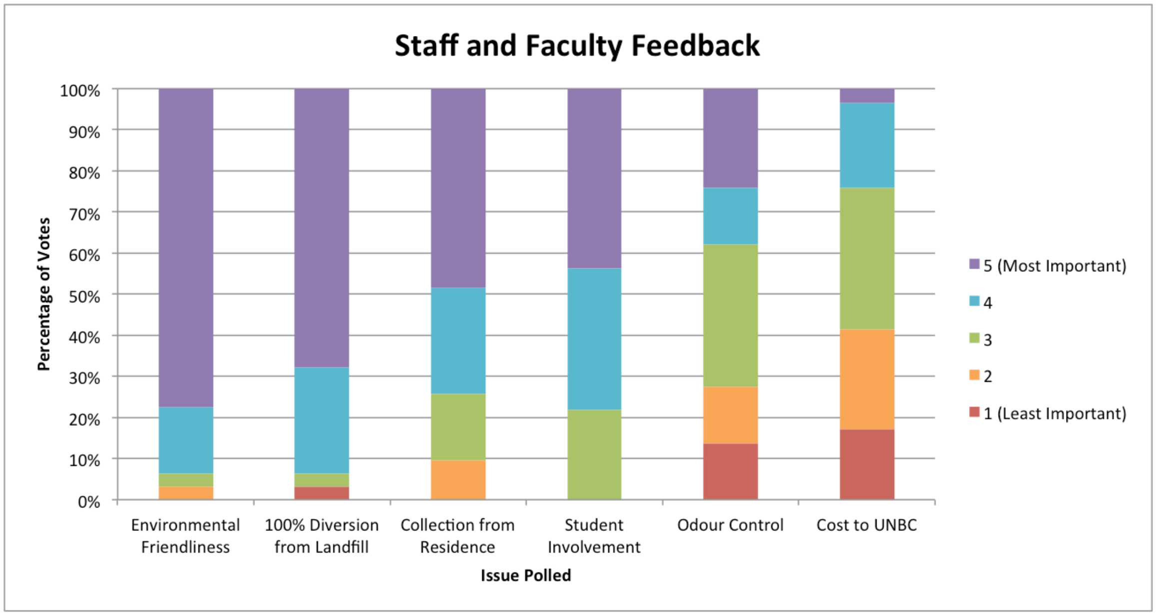

Figure 5: Dotmocracy Results from Staff and Faculty

Both stakeholder groups surveyed highly valued positive environmental impacts and 100% waste diversion, and were neutral regarding how much a new system would cost UNBC. Additionally, at least eight students were not knowledgeable on composting or its use on campus, and three participants went out of their way to say that student involvement is nice, but the system should not rely on volunteers.

3.2. Recommendations for Future Stakeholder Consultation

If another dotmocracy were to be conducted in the future, some changes should be made. Different criterion should be selected; student opinions do not carry much weight when considering how much a system should cost, and polling them is not helpful on that subject. Criterion should also be more descriptive, as "environmental friendliness" is neither descriptive, nor helpful as a category. Furthermore, the option to give all criteria the same ranking should be eliminated, as it impossible to tell which criterion is the most important when all are ranked as the "most important".

4. Design Refinement of Organic Waste Management Options for UNBC

4.1. Design Criteria

In evaluating which system would work best for UNBC, five design criteria were identified and refined. These criteria were originally assigned equal weight, with approval from the project sponsor and supervisors, and those weights were adjusted after stakeholder consultation. The criteria, and respective sub criteria, are as follows:

- Environmental Impacts
  - Image of UNBC as *Canada's Green University* ™
  - Greenhouse gas emissions
  - Ability to divert 100% of the organic waste from the landfill
- Economics
  - Includes capital and operation costs
- Adaptability
  - Automation of system
  - Minimal potential for misuse
  - Ability to accept variable feedstock composition and quantity
- Community Impacts and Involvement
  - Student participation
  - Research opportunities
- Feasibility
  - Labour requirements (additional personnel required)
  - Ease of transition

Qualitative results from the stakeholder consultation were used to adjust the design criteria. Environmental impacts were addressed as being very important by various stakeholders, as seen in the dotmocracy results, so this continued to have a significant weight. Economics also continued to carry a significant weight, even though some stakeholders were neutral on that aspect, since most projects are driven by economics or safety and the system would eventually need to be funded. Adaptability, or robustness, of the system also carried a substantial weight since that aspect factors into economics, safety, and simplicity. Community impacts and involvement was given less importance, since this was seen as an added benefit rather than a requirement. Additionally, feasibility carried less weight since it would be a temporary hurdle for the design to overcome. Overall, environmental impacts, economics, and adaptability were given equal weights of 25% each, and community impacts and involvement and feasibility were each assigned 12.5% of the total design criteria. Figure 6 shows the weighted design criteria used to evaluate potential organic waste management solutions for UNBC.

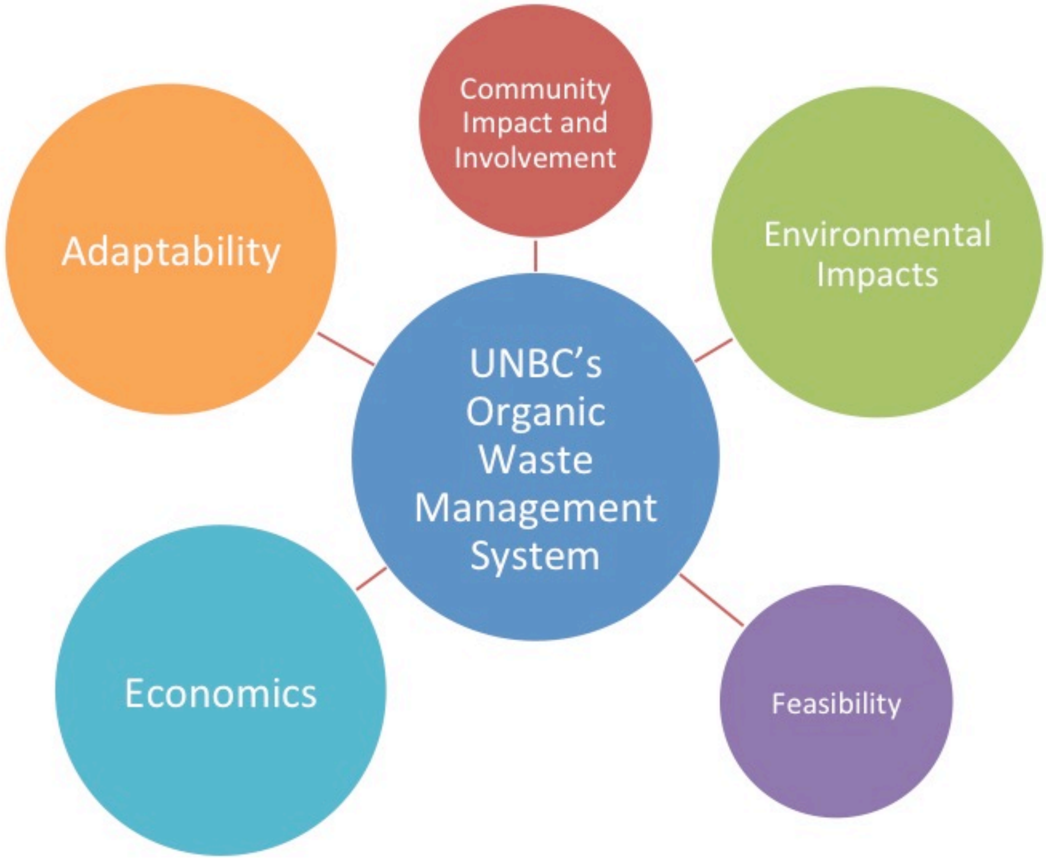

Figure 6: Weighted Design Criteria Used to Evaluate Organic Waste Management Options

4.1.1. Decision Matrix

Design criteria and their respective weights identified in Section 4.1 were used to evaluate each potential organic waste management solution by means of a decision matrix. Sub criteria were used to quantitatively evaluate each design criteria. As with the design criteria, these sub criteria were initially given equal weights, and then adjusted when necessary, following input from stakeholder consultation. The sub criteria for both environmental impacts and adaptability were not adjusted, and remained at equal weights. For community impacts and involvement, student participation was assigned 33% of the total weight, and research opportunities 66%; stakeholders identified that while student participation is beneficial, the project should not depend on the availability of volunteers. For the feasibility criteria, labour requirements, or the amount of additional personnel required, was adjusted to 80% of the importance while ease of transition was less important, holding 20%; transitioning from one system to another should only be a temporary hurdle.

Overall results from the decision matrix are present below in Figure 7. Detailed decision matrices for each design criteria and further justification for each can be found in Appendix A. As part of the objective is to design a solution that maximizes criteria identified through stakeholder consultation, we recommend that the UNBC manage its organic waste with an in-vessel composting system.

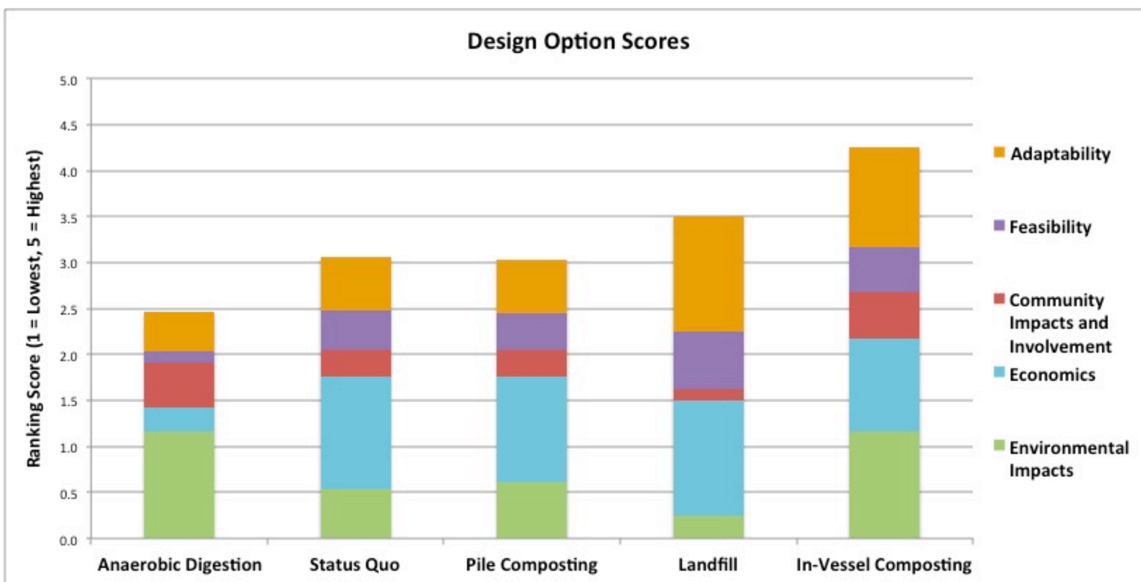

Figure 7: Potential Organic Waste Management Scores Determined Using Design Criteria

5. In-Vessel Composting Design Components

There are many components that need to be identified and considered before selecting which in-vessel composter is the most suitable for use at UNBC. A range of food waste generated at UNBC needs to be calculated in order to determine both how much bulker is necessary and what size vessel is appropriate. An estimation of volume reduction expected is required to determine how much compost will be produced. Finally, there are various characteristics of the compost chemistry that need to be identified in order to produce quality compost, and mitigate potential issues with the composting process.

5.1. Food Waste Generated at UNBC

Over the years, many waste audits have been performed at UNBC, including its cafeteria and student residences. Four of these waste audits were reviewed, and the information was used to project how much organic waste could be expected (Michiel et al., 2013; Rajan, 2015; Smyth et al., 2010; Watson and Fredeen, 2015). Table 2 below is a compilation of these audits, separated by source of organic food waste; waste generated in the summer months is not expected to change relative to the current system, as food service changes are not in effect during the summer. Calculations and assumptions for these projections can be found in Appendix B.

Table 2: Projected Organic Waste Produced at UNBC

Location	kg / day	Projected kg / week [Sept to May] (100% Diversion)	Projected kg / week [Sept to May] (80% Diversion except '*')	Projected kg / week [May to Sept]
Core Campus*	9.7	70	70	-
Kitchen	29.9	-	-	-
Thirsty Moose Pub	6.1	170	140	-
Degrees Coffee*	17.7	120	120	-
Residences	21.1	300	240	-
Cafeteria	102	1070	860	-
Total	**-**	**1700**	**1400**	**100**

Note: Kitchen waste is not projected, as it is encompassed within the cafeteria waste audit

The above projections have uncertainties related to the temporal nature of waste audits, varying precision of each audit performed, and the changes to food services at UNBC since some of the audits were conducted. Additionally, the amount of organic waste generated varies by day and season, as seen in Figure 8 below.

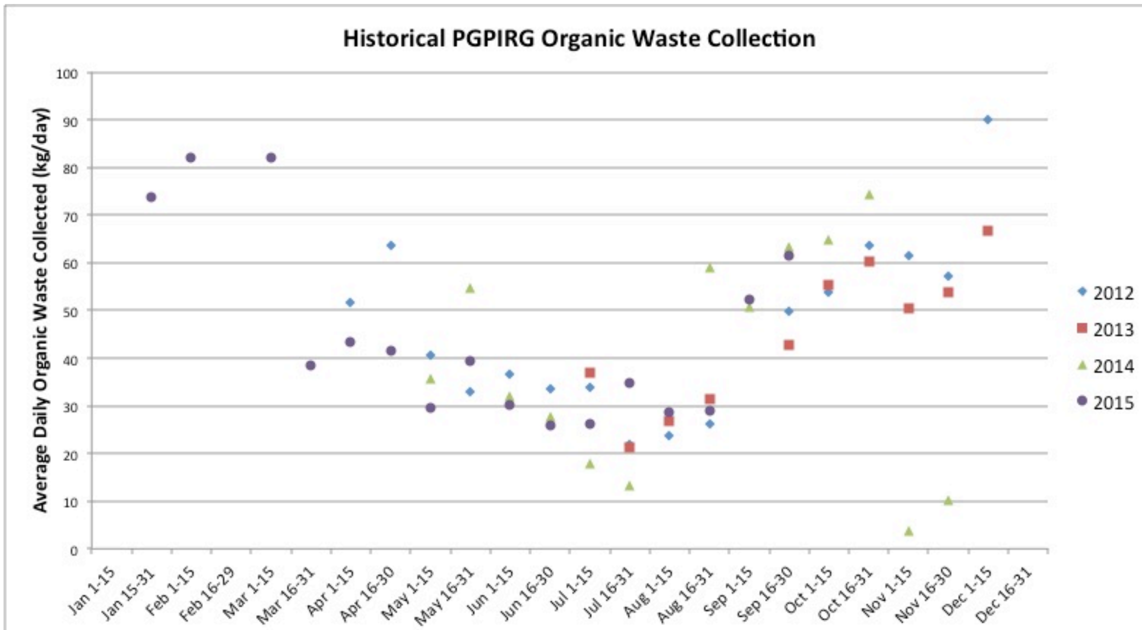

Figure 8: Historic Daily Organic Waste Collected by PGPIRG Volunteers

The current composting system handles an average of 440 kg/week, comprised of a limited variety of organic waste. Projected food waste to be collected in the new system includes all of the following: fruits, vegetables, post-consumer food waste, meat, dairy, grains, coffee grounds, teabags, and eggshells. Other compostable products, such as soiled paper plates, napkins, and compostable coffee cups, are not accounted for in the projection of organic waste generated at UNBC but are discussed in Section 5.2.2. In-vessel composters considered for managing UNBC's organic waste should be capable of handling 1,400 – 1,700 kg/week, plus bulkers and amendments.

5.2. Bulkers and Amendments

Operation of an IVC requires not only organic waste but also the addition of bulking agents and amendments, which serve to increase the carbon to nitrogen ratio, increase porosity, and absorb excess water (HotRot Organic Solutions, 2012). It is necessary to increase the carbon to nitrogen (C:N) ratio of the organic waste, since too little carbon will lead to ammonia production and undesirable odours (Vermont Waste Management Division, 2012). Organic waste from food scraps typically has a C:N ratio of less than 15:1, whereas the optimal ratio ranges from 25:1 to 40:1, depending on the carbon availability (BC Ministry of Agriculture and Food, 1996; Vermont Waste Management Division, 2012). Bulkers and amendments also serve to increases the porosity of the compost and absorbs excess water, allowing for better aeration (HotRot Organic Solutions, 2012). Wood chips are best at adding porosity to the compost, while sawdust, paper, and other easily broken down paper products are good at absorbing moisture.

The amount of bulker required varies by vessel manufacturer and academic sources investigated. Suggestions range from 10 – 90 weight percent of bulker to food waste, however we propose that 20 – 40% of bulker be used after discussing the issue with several manufacturers and users of IVCs (personal communication, Paul Larouche, Jérémie Forget, UBC AMS). This would result in 10 – 20 tonnes of bulker required per year, which could be reduced by incorporating other compostable paper products to the vessel to aid in moisture control.

5.2.1. Hog Fuel, Wood Pellets, Wood Shavings

Hog fuel, wood pellets, and wood shavings were considered for use as a bulker for UNBC's in-vessel composter. Hog fuel is readily available on campus due to its use at the BioEnergy plant. Wood pellets, while also used at UNBC, would need to be delivered by pallets to be used as a bulking agent. Wood shavings were also considered due to their high absorption properties, which could result in less being required. Table 3 below summarizes the types of bulker considered for use at UNBC, and Appendix C has information regarding where cost estimates were found.

Table 3: Summary of Bulker Options

Bulker Characteristics	Hog Fuel	Wood Shavings	Wood Pellets
$ per tonne	$65.00	$480.00	$250
Moisture Content (%)	35	<19	6
Average Particle Size (mm)	20-40	10-60	5-35
Bulk Density (kg/m^3)	130	350	675
Estimated Labour Required	16 hours/month	½ hour/month	½ hour/month

It is recommended that wood pellets be used as bulking agent for in-vessel composting at UNBC. While more expensive per tonne than hog fuel, the higher material density requires less transport by facilities staff making wood pellets more suitable to UNBC's facilities operations. Additionally, wood pellets are smaller and more uniform than hog fuel, and they also have significantly lower moisture content, leading to a predictable bulking feedstock.

5.2.2. Compostable Paper Products

Compostable paper products, such as used paper, cardboard, soiled napkins, and compostable cups, could be considered as further amendments to the IVC. Incorporating these would reduce the moisture content of the organic waste and lower UNBC's carbon footprint, while providing economic benefit by avoiding the associated tipping and recycling fees, and lowering the amount of bulker required. However, these materials could not be used to fully replace the bulker, as they do not increase the porosity or add to the structure of the produced compost (HotRot Organic Solutions, 2012). Before incorporating these compostable products to the IVC, it is recommended that the system first reach steady state to avoid unnecessary complications in reaching optimal microbial activity and temperatures. Additionally, a maximum of 15% compostable paper products to bulker is suggested, as to not overload the system with too much readily available carbon (HotRot Organic Solutions, 2012).

5.3. Residence Time and Volume Reduction

Residence time refers to the amount of time organic waste is in the vessel before it is discharged as immature compost. This residence time is directly related to the IVC volume, and the volume of organic waste fed into the vessel. Longer residence times are preferable, since it allows for greater volume reduction and steadier temperature profiles (personal communication, Jérémie Forget). However, residence time is not static, as certain portions of the organic waste will pass though the vessel faster than others. One may determine real time residence by adding foreign material with similar density to the organic waste, such as golf balls, to the vessel.

Volume reduction of organic matter during the composting process can range from 20 – 90% (Bonthal, 2011; Closed Loop Organic Recycling, 2015; Lyengar, 2006; van Ginkel, 1999). Personal communication with Jérémie Forget, who manages an IVC at École de Technologie Supérieure (ETS), revealed that they are able to achieve 60% volume reduction. To be conservative, it is assumed that 50% volume reduction will be achieved, which is used to determine the size of curing facility necessary (Section 7.2.2).

5.4. Compost Chemistry

In-vessel composting has multiple requirements for the chemical processes involved in the creation of compost. These include moisture content, oxygen inputs, pH levels, and the production of greenhouse gases.

5.4.1. Moisture Content

Moisture content is a parameter that plays an important role throughout the composting process. Moisture is necessary to support the microorganisms, serves as a major heat sink, and directly impacts the free airspace required for proper aeration (FAO, 2003; HotRot Organic Solutions, 2012). If the moisture content is too low, the composting process occurs more slowly, but if it exceeds 65% the compost is likely to develop anaerobic conditions (FAO, 2003). Organic food waste has average moisture content of 85%, whereas the optimal moisture content for compost is 35 – 60% (B.C. Reg. 18/2002; Zhang et al., 2007). Moisture content is controlled by the addition of bulking agents and the aeration rate; bulking agents absorb moisture and controlled aeration evaporates excess moisture (van Ginkel, 1999).

5.4.2. Oxygen Requirements

Aeration is another important factor in producing compost. The maximum air consumption of compost during the thermophilic stage is estimated to be 1 cubic meter per tonne of compost per hour (1 m^3/h/tonne) (Chevrier-Turbide, 2011). However, providing too much air may result in moisture content below the optimal range. Aeration is necessary to remove excess heat, water vapours, and other gases (FAO, 2003). To provide this oxygen, most in-vessel composters come equipped with variable speed input fans.

5.4.3. pH

The pH of compost is a function of the microbial activity, and the composting process has a natural buffering effect (Sundberg, 2005). During the initial stages of decomposition, organic acids are generated, resulting in a compost pH of approximately 4.6. Subsequently, acid generation ceases and the acids are consumed, resulting in a pH increase to approximately 8. As the compost stabilizes, the pH neutralizes (Sundberg, 2005).

There was an initial concern regarding the feedstock acidity, as a large part of the current system is comprised of coffee grounds. However, this is no longer a concern for the new composting system. Due to the increased variety and quantity of organic waste accepted, coffee grounds will no longer comprise an excessively large portion of the feedstock. Additionally, an in-vessel composter at ETS has a feedstock of approximately 50% coffee grounds, and is not experiencing any issues regarding the pH.

5.4.4. Greenhouse Gas Production

Byproducts of a properly operating compost process include carbon dioxide (CO_2), water, and ammonia (NH_3) (Section 2.1.1). However, the composting process also produces greenhouse gases (GHGs), and has the potential to produce nitrous oxide (N_2O) and methane (CH_4). Nitrous oxide, a gas that has a global warming potential 298 stronger than CO_2, can be produced if the C:N ratio of the composting process is too low (FAO, 2003; USEPA, 2015). Methane can be produced when there is failure to properly aerate the compost and anaerobic decomposition occurs (FAO, 2003). Although composting is a source of GHG emissions, the GHGs produced are just a fraction of those produced if the organic waste were to be deposited in a landfill (USEPA, 2014). GHG emissions were calculated to compare the design options in Section 4.1.1, and multiple online calculators were compared to one another to ensure consistency (Environment Canada Waste GHG Calculator; Institute for Global Environmental Strategies; WARM EPA GHG Calculator).

6. In-Vessel Composter Selection

Once it was determined how much organic waste UNBC would produce (1,400 – 1,700 kg/week), and the associated bulker that would be required for proper in-vessel composting (30%), several IVC manufacturers were researched and contacted.

6.1. In-Vessel Composters Considered

Seven different IVC manufactures were identified, and Table 4 below is a summary of the IVCs considered. Most specifications were provided, but residence time was calculated estimating an organics input of 1550 kg/week, 30% wood pellet bulker, and 40% air space within the vessel (see Appendix D for sample calculations).

Table 4: Overview and Specifications of In-Vessel Composters Considered

Composter	Max. Capacity (kg/week)	Volume (m^3)	Residence Time (day)	Dimensions (L*W*H) (m)	Cost (CAD)	Energy (kWh/day)
Big Hanna T240	400-1,200	4	4	4.8*1.4*2.1	$112,000	1.53
Big Hanna T480	800-2,400	8	9	6.4*2*2.2	$204,800	2.35
Brome 8110	3,000	5.7	6	3*1.3	$40,000	-
Brome 8100	7,000	14.4	16	4.9*1.8	$54,600	-
Bio Xact Systems	390-1,700	-	-	-	$60,000	-
HotRot 1206	1,900-2,800	-	-	7.2*1.4*1.6	$161,970	30
FOR Solutions	1,600	-	-	8*1.6*3.4	$164,588	23
CityPod XL	2,660	-	-	5.6*2*2	$146,100	4.5
CityPod L	1,575	-	-	5*1.4*1.7	$79,100	1.5
Rocket A900	875	12.6	14	4*1*1.6	$45,500	-
Rocket A1200	1,750	-	-	7*1.4*1.8	$88,000	-

Most vessels were eliminated from further considerations, as the manufacturer claimed maximum capacity was insufficient for UNBC's input of 1,400 – 1,700 kg/week; it was decided that even though the Rocket A1200 could handle the current input, there was no room for growth. Vessels not eliminated due to their size limitations were the Big Hanna T480, Brome 8110, Brome 8100, HotRot 1206, and CityPod XL. Of these remaining vessels, the Brome 8110, Brome 8100, and CityPod XL were researched in greater detail, since they had the lowest capital costs.

6.1.1. Case Study: CityPod by Vertal

The University of British Columbia (UBC) has recently acquired a CityPod IVC, and we contacted the Compost and Sustainability Coordinators to discuss their experience. The CityPod M, a prototype, was installed in the student union building (SUB) this summer, and the coordinators were quick to inform us that everything that could go wrong has. Although they were ensured that the CityPod would be self-maintaining, 25 hours of labour per week is currently being designated to maintaining the vessel. All of the sensors (moisture, temperature, etc) broke within months, ventilation fans became clogged, and the vessel is still leaking fluids.

One of the largest issues that UBC has encountered is that the system has gone anaerobic. This could be due to overloading the system as soon as it was installed, or only using 15% bulker, as per the manufacturer's recommendation. They still have not been able to remedy the issue, and the system is incredibly odourous since it is not running properly. Additionally, although the CityPod was specified to handle up to 700 kg/week, UBC has only been able to input half that amount, and have had to shut down the vessel for 1.5 weeks when it became too full.

Fortunately, the CEO of CityPod has given UBC lots of support, and they are working together to remedy the issues encountered. Even through all the problems they have encountered, the coordinators said they would pick CityPod again. They also suggested getting a larger vessel than what just meets your needs, and starting the system off slowly and bringing it up to steady state before inputting the maximum feedstock.

6.1.2. Case Study: Brome Composting Systems

École de Technologie Supérieure (ETS) in Montreal has been operating a Brome 8130 IVC since 2010, diverting 50% of the total organic waste generated on campus, or 19 tonnes per year. We spoke with Jérémie Forget, an environmental engineer and director of the composting program, about his experience with the Brome composter. Overall, he has been happy with the Brome IVC.

ETS is filling their IVC just over the recommended 60% of total volume, without any issue. The system is achieving 60% volume reduction, with a residence time between 7 to 15 days. Odour has not been an issue, but could become an issue if the ventilation system were to fail; the composter is vented into the kitchen's grease trap exhaust vent. There have not been any mechanical issues with the Brome 8130 since it was installed, but Jérémie did spend the first 10 weeks to bring the system to steady state and write procedures.

The only major issue that ETS had to overcome was installing a safety device to the vessel; the vessel would still rotate when the door was open, and a $500 device was added to prevent this issue. Another small hurdle is that the system requires more labour than additionally expected (1.5 hr/day vs. 1 hr/day). Once the compost has been produced, ETS sends it to an external facility since they do not have the space to mature the compost or uses for it; ETS is an urban university.

ETS has not seen positive economic or environmental impacts from their IVC, but this because they are not able to use the final product on campus and it is not a closed loop system. Despite this, Jérémie is still happy with Brome IVC, as it provides research and learning opportunities, student involvement, and composting visibility to ETS.

6.2. In-Vessel Composter Recommended for UNBC

We recommend that UNBC install the Brome 8100 (6x16 feet) in-vessel composter to manage its organic waste. This vessel is large enough to accommodate the current amount of organic waste produced by UNBC, while having additional capacity to handle future increases in organic waste production. Although the smaller vessel made by Brome (Brome 8110) could handle all of UNBC's organic waste, the larger vessel is recommended to achieve larger residence times; larger residence times lead to the production of a higher quality compost since there is more time for the organic waste to degrade. Additionally, the parts used to make the 8100 model are the same components used for a larger vessel size, which theoretically leads to a more robust product with an estimated lifetime of 12 years.

Brome has been in operation since 2005, and has a proven track record of delivering quality products. Furthermore, Paul Larouche, the CEO, has been incredibly helpful, providing excellent customer service even with the knowledge that this is a design project. Knowing that initial operation of in-vessel composters can be quite tedious, the importance of good customer service cannot be understated. Given the combination of the above factors, we believe the Brome 8100 to be the best in-vessel composter to manage UNBC's organic waste.

7. Location

In designing which location was best suited for the in-vessel composter, input from many of UNBC's maintenance and facilities staff was gathered. Aaron Olsen, Operations, Compliance, and Service Manager, provided input regarding estimates and feasibility of renovations. Ryan Goetzinger, Maintenance and Project Supervisor, also provided estimates for outside shelters. Stephen Patton, Facilities Services Supervisor, verified the feasibility of reorganizing the recycling room. Finally, Chris Knudsen, Facilities and Services employee, confirmed labour requirements regarding IVC operation.

7.1. In-Vessel Composter Location

Potential vessel locations were determined based on their proximity to the kitchen, as that is where over 60% of the organic waste is produced on campus (Section 5.1). Additionally, since IVC's achieve significant volume reduction (Section 5.3), a location closest to the kitchen will result in the least amount of material transport. Three potential locations were investigated for their suitability, and it is suggested that the IVC be located in the recycling room (Section 7.1.3).

7.1.1. Garbage Compactor Room

The first location considered was the garbage compactor room, located two doors from the kitchen. The trash compactor occupies the bottom half of the room, and a mezzanine above the compactor would need to be constructed to accommodate the IVC. Due to the size of the current compactor, a vessel located on the mezzanine would be limited to approximately nine feet tall, not accounting for the space required to load and unload the compactor. To determine if the compactor's operation and loading would affect the usable length and height of the room, we watched a Waste Management truck move the compactor; the entire height of the room was necessary to move the compactor into place. The Waste Management truck driver informed us that the bin could be lowered and pushed into place, but this would require renovations; the concrete lip at the entrance of the compactor room would need to be smoothed out, and guide rails would need to be extended to the edge of the bay door. The probability of damaging either the compactor or the mezzanine with a new exit and entry plan was deemed to be too great to continue pursuing this option.

The option of replacing the current compactor with a smaller one, to reduce the height required to move the compactor, was also investigated, but a shorter self-contained compactor was unable to be found. Using the garbage compactor room as a location for UNBC's IVC was abandoned, and other options were investigated.

7.1.2. Contractor Parking Lot

Many stakeholders identified the contractor parking lot as a potential location for an IVC, and this location was considered at length. This parking lot is located just outside of the garbage compactor room, and three parking spots would need to be removed to accommodate the IVC. We were informed that this would not be an issue as the parking lot is rarely full, the electric car charging point will be moved in the near future, and contractors could be supplied with parking passes or coupons if there was no room in the remaining three spots.

As per manufacturer recommendations, an IVC located outside would need to placed on a level concrete foundation, and under a shelter to protect the vessel from the elements. A conceptual drawing of what this shelter is shown in Figure 9 below, and would cost approximately $52,500 (Appendix E). A heater would be installed within the vessel to assist microbial activity in the winter, which would easily tie into the electrical supply currently used for the electric car.

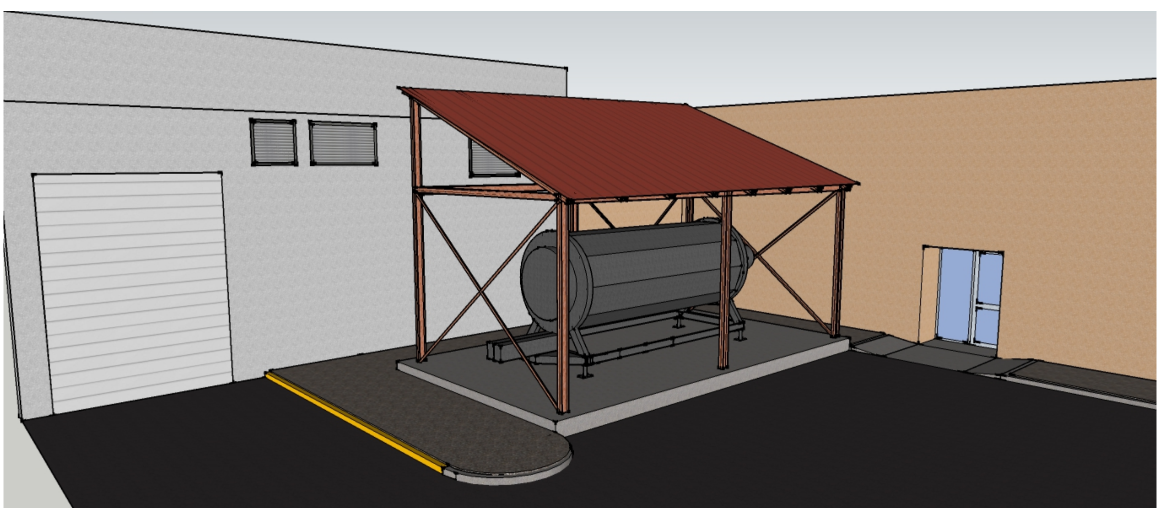

Figure 9: Conceptual IVC Shelter Drawing for Location at the Contractor Parking Lot

A large challenge in locating the vessel outside is convincing volunteers to bring the organic waste to the vessel in sub-optimal weather conditions. This would likely decrease the amount of volunteers available, and could potentially lead to safety concerns. To mitigate these challenges, constructing a conveyer input system was considered. The recycling room, where the organics are currently being collected, is located on the other side of the wall from the shelter, and a 20-foot conveyer ($32,300, Appendix E) could be used to feed the vessel. However, it is likely that the conveyer would require ongoing maintenance to unclog organic waste, and the mixer of organic waste and pellets would likely be quite odourous. Additionally, the vessel door would need to be consistently open, which would lead to heat loss and attract pests.

Locating the vessel outside was discounted for many factors, including the high capital cost of the shelter and conveyer, maintenance required for the conveyer system, and additional cost of heating the vessel during the winter. Additionally, while we believe that placing the vessel outside would provide social benefits and positive visibility of composting at UNBC, others believed that it would be an eyesore.

7.1.3. Recycling Room

The final, and recommended, location for the IVC is inside of the recycling room. This room is directly next to the kitchen, and is where the current organic waste is collected before being placed outside. This room currently houses a cardboard compactor, supplies for the composting system, and several recycling bins for paper, metal, cans, and other recyclables. A plan-view of the proposed reorganization of this room is found in Figure 10 below. Organic waste enters the vessel using the bin lift, and screened compost exits the vessel into the collection hopper.

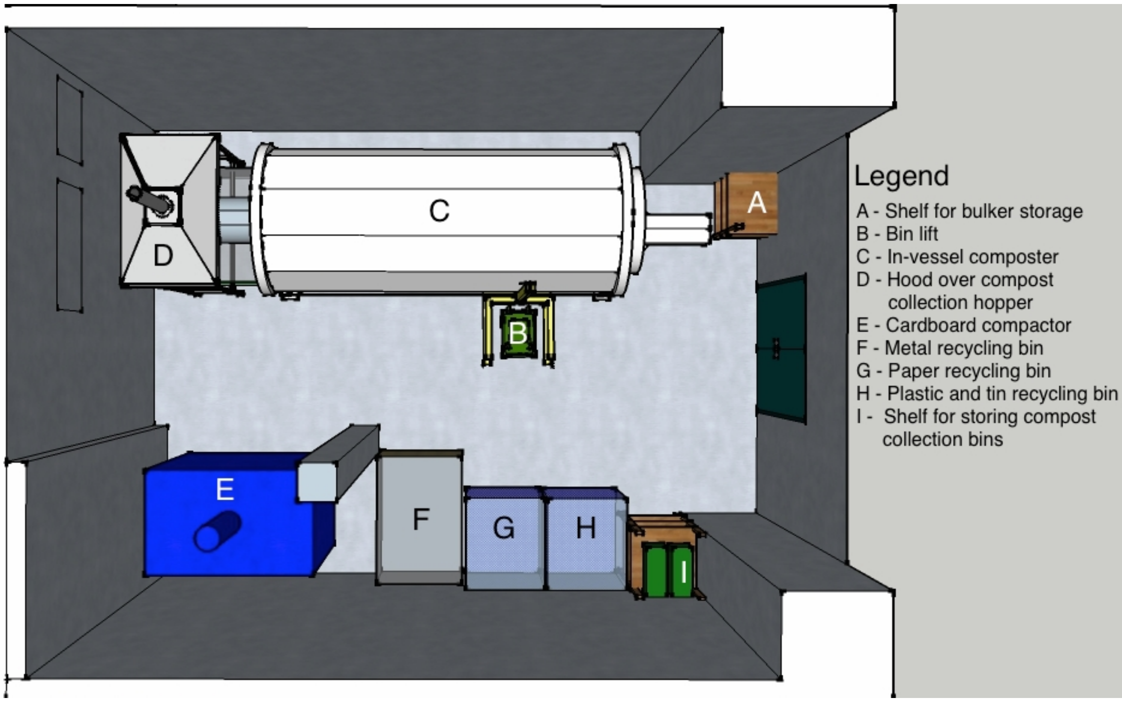

Figure 10: Conceptual Recycling Room Reorganization to House the IVC

Ample renovations are required to locate the IVC in the recycling room, totaling $15,500 (Section 9). These renovations include demolition and reconstruction of the recycling room entrance wall, as well as a hallway corner, in order to place the vessel inside the room. The renovations will not affect the structural integrity, and have been discussed at length with Aaron Olsen, UNBC's Operations, Compliance, and Service Manager; Appendix F shows the vessel installation floor plans. Other costs arise from relocating the cardboard compactor and the associated electrical controls, installing the electrical supply for the IVC, connecting the IVC ventilation to the kitchen grease trap exhaust, and performing airflow optimization for the exhaust. It is highly recommended that these renovations and the installation of the IVC be performed during the summer, since they will affect cafeteria operations.

Residual odour from the IVC is not a concern in this location, as it will be vented with the cafeteria exhaust; the amount of airflow from the IVC is minimal compared to that of the cafeteria. The biggest challenge with locating the IVC in the recycling room will be keeping it organized. Organization may be a larger issue in the first months of operation, as one of the paper recycling bins was removed in anticipation of using the paper as amendment (Section 5.2.2); paper recycling may need to be collected more frequently until steady state is achieved.

7.2. Compost Curing and Storage Location

In following to BC *Organic Matter Recycling Regulation* (OMRR), the newly produced compost must be cured for a minimum of 21 days to ensure the stability and maturity of the compost, as immature compost can inhibit plant growth, attract pests, and release odours (CCME, 2005). After the 21-day curing period, the stable compost can be moved to a long-term storage area. The location proposed for both the curing and storage areas is within the current composting site (Section 2.1.2).

7.2.1. Compost Curing and Storage Regulations

A compost curing site is defined in OMRR as being "an area where organic matter which has undergone the rapid initial stage of composting is further matured in a humus-like material" (OMRR, 2002). This location must meet all of the following requirements:

- Impermeable surface that can withstand normal wear and tear
- Roof or cover that prevents the collection of water around the base of the compost as well as prevents runoff water from entering the area
- Leachate collection system

Alternatively, if a qualified professional can prove, through an environmental impact assessment, that the environment will not be harmed and water quality guidelines met, than the above would not be required (OMRR, 2002).

After the 21-day curing period, the compost can be moved to a storage site. The requirements for this storage are less stringent than those for the curing site, and must meet the following requirements (OMRR, 2002):

- Located 30 m from any watercourse or any domestic water source
- Compost must not be stored for longer than 9 months
- Storage is such that the compost cannot escape the site

Prior to implementing the proposed design, a Land Application Plan must be prepared by a qualified professional, as per Section 5 of the OMRR.

7.2.2. Compost Curing and Storage Design

The proposed design is in compliance with the OMRR, and may be capable of achieving Class A compost; one of the requirements in achieving Class A compost is to cure the compost in piles that are a minimum of 3 m in diameter and 2 m high. The design includes two bays (3 x 4 m each), each with a capacity greater than the maximum amount of compost that would be produced in a 21-day period (7.8 m^3; see Appendix D for sample calculations). One bay is left to cure, while the other is filled with immature compost. These concrete-block bays are constructed on top of an asphalt base, and covered with a wood-framed shelter, as seen in Figure 11 below.

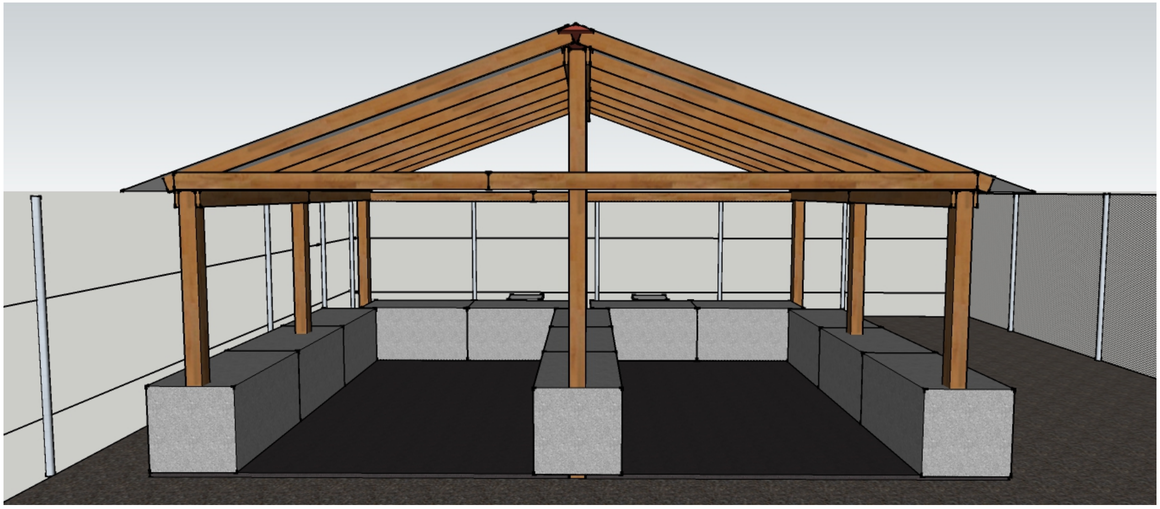
Figure 11: Conceptual Compost Curing Facility

The leachate control system consists of sloped drainage channels, or curbs, built into the asphalt, which will divert any leachate formed to the corner of the curing facility. If any leachate is produced, it will flow into a buried barrel, and will be collected and monitored for appropriate disposal. This collection point is shown in the bottom right of Figure 12 below.

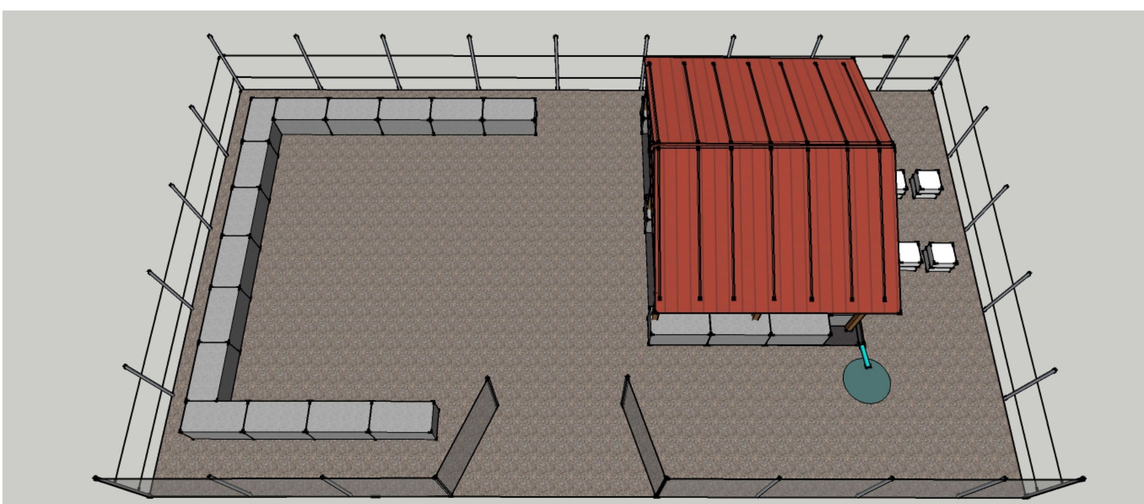
Figure 12: Conceptual Compost Curing (right) and Compost Storage (left) Facilities

The compost storage site is shown to the left of Figure 12 above. A maximum of 70 m^3 cured compost, approximately one years' worth, could be held in this site. Total cost for the compost curing and storage sites is $24,400 (Section 9).

8. Operating Plan

An operating plan for the organic waste collection and distribution systems has been developed, and summarized in Figure 13 below. Additionally, hazards associated with the in-vessel composting system have been addressed, and mitigation strategies identified in Section 8.3.

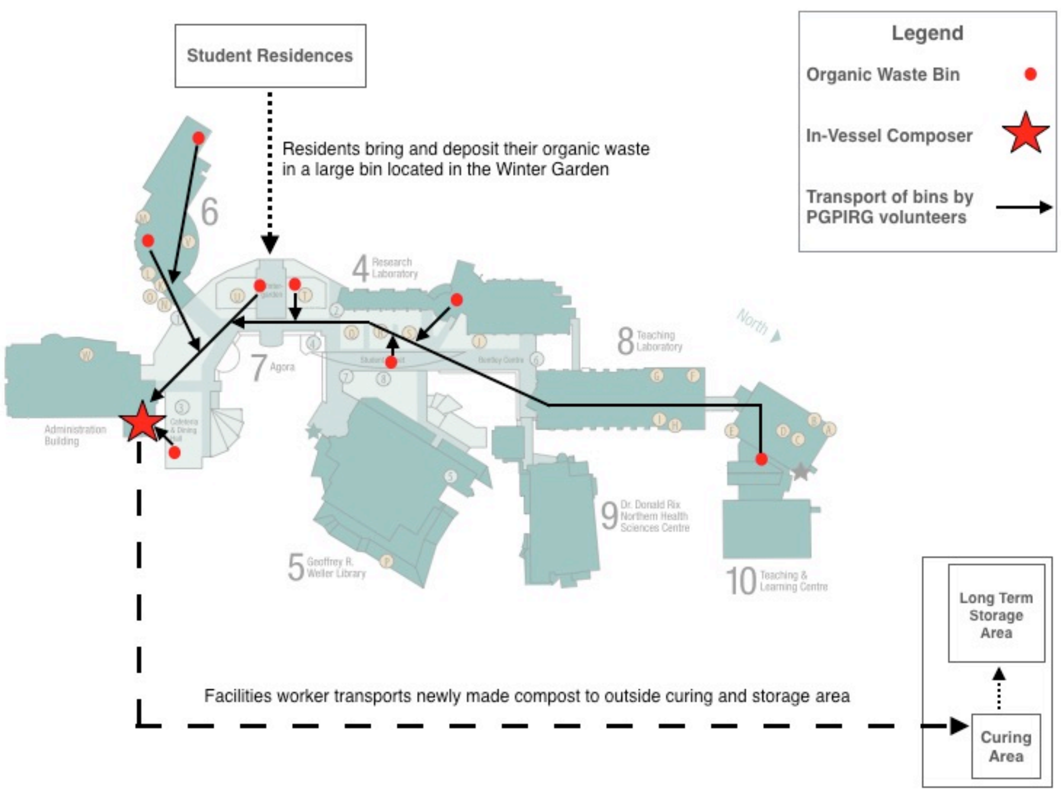

Figure 13: Process Flow Diagram for Organic Waste Collection Systems

8.1. Collection Systems

Collection of organic waste from the UNBC core campus would remain the same as the current system, and run by PGPIRG volunteers; three volunteers spend 1 hour per day collecting organic waste, 5 days a week. A larger (240-L) bin will be placed at the Thirsty Moose Pub to account for the increase of compostable material accepted, such as plate scrapings; two 240-L bins will be placed within Chartwell's Dining Hall (one for post-consumer material, one for the kitchen).

Volunteers will collect the organic waste bins, weigh and record the organic waste collected, load the vessel using the bin-lift, add the appropriate amount of bulker (30%), and rinse the bins. During the weekends, Chartwell's staff will be required to conduct these activities for the organic waste generated by the cafeteria.

8.1.1. Student Residence

Compost collection has never been included in the student residences before, but has been desired for many years. We proposed an opt-in program to Darrin Rigo, Residence Life Coordinator, and Raychill Snider, Green Residence Assistant, and they were fully supportive of this program. Students who want to participate in the composting program would be supplied with small, 7-L composting bin and compostable bin liners. They would then be responsible for bringing their organic waste to the Winter Garden, where a large, 240-L bin will be located. Volunteers will then collect the large bin, and empty the contents into the IVC as described in Section 8.1.

The cost of this program would be $800 (Appendix G), and would be covered by a Green Fund application, as suggested by Darrin. This plan circumvents two of the main obstacles that have prohibited residence collection in the past: labour requirements and storage of organic waste/collection points within the residences.

8.2. Distribution System

As the compost exits the IVC, it is automatically screened and deposited into a hopper. Particles that are too large are not screened, and exit into a 240-L bin; any noticeable contaminants must be removed, and the organic matter re-fed to the IVC to further decompose. Approximately twice per week, Chris Knudsen, a maintenance employee, will transport the full hopper to the curing facility. Once the compost has been cured for 21 days, Chris will then use the skid-steer to transfer the compost to storage location. PGPIRG will still be able to use the compost created on campus for their gardens, and facilities and maintenance staff will use the leftover compost for use on UNBC grounds.

8.3. Risk Analysis

Multiple hazards and operational failures were identified, as well as their probability, severity, and cause. Mitigation strategies were identified for each, and a summary of this risk analysis is presented in Tables 5 to 7 below.

Table 5: Human Health and Safety Risk Analysis

Human Health and Safety				
Risk	Probability	Cause	Severity	Solution
Back Strain	M	Lifting a heavy bin	M	Use bin lift
Slip and Trip	M	Inadequate site maintenance	M	Keep working area tidy
Pinch Points	M	Lack of surroundings awareness	M	Label and put caution signs where required
Pathogen Exposure	M	Handling of compost	M	Wash hands after handling of compost
Frostbite	L	Winter conditions	M	Proper clothing
Sharps	L	Contamination	H	Increase signage, more attentive pre sorting
Pests	L	Inadequate sanitation	M	Keep site clean of organic waste

Table 6: Malfunction Risk Analysis

Malfunction				
Risk	Probability	Cause	Severity	Solution
Electrical				
Power Outage	L	Hydro services disrupted	L	Do not load vessel until power returns
Motor	L	Unknown	M	Inspect, repair, or replace
Aeration Fan	L	Blockage	H	Inspect, repair, increase maintenance
Bin Lift	L	Overloaded bin	L	Reduce weight in bin
Mechanical				
Chain Slip or Break	L	Inadequate Oil	M	Repair or replace, increase servicing

Table 7: Composting Process Risk Analysis

Composting Process				
Risk	Probability	Cause	Severity	Solution
Odour	H	Improper C:N ratio or aeration rate, or rotation rate	H	Add bulker, increase ventilation, increase rotation rate
Vapour	L	Improper ventilation	M	Increase ventilation
Too much waste	L	Underestimation of organic waste production	L	Divert additional waste to trash compactor
Too little waste	L	Overestimation of organic waste production	L	Increase residence time
Leachate Production	H	Too little bulker (C:N), too little oxygen,		Add bulker, increase ventilation, increase rotations
Excess Methane Production	L	Too little oxygen	H	Add Bulker, increase rotation rate, increase ventilation

Becomes Anaerobic	L	Decreased temperature, moisture content too high	H	Increase rotation rate, increase ventilation
Contamination	M	Improper disposal of waste into organic's bin	L	Increase signage and awareness
Freezing	M	Extended period of extreme cold	L	Increase curing pile size during extreme cold

9. Economic Analysis

Capital and renovation costs for the Brome 8100 IVC are summarized in Table 8 and Table 9, respectively. The grand total for all one-time expenditures are expected to cost $131,300 ± 5%. However, the renovation cost for removing the corridor corner may be reduced to $1,500 if construction is performed by UNBC facilities (personal communication – Aaron Olsen). Annual operating costs are expected to be $9,600 ± 10% (Table 10). Bulker currently comprises 71% of the operating costs, however this could be reduced significantly if wood pellets designated for use in the Wood Pellet BioEnergy Project were used; it is not yet known how pellets could be transported from the silo to the recycling room with the current space restrictions. A summary of all total expenses is presented in Table 11, and details of each economic component can be found in Appendix H.

Table 8: Summary of Capital Costs

Capital	
In-Vessel + Shipping	$ 59,700.00
Bin lift	$ 12,750.00
Output Hood	$ 2,510.00
Output Screen	$ 1,170.00
On-site Training	$ 3,000.00
Web calculator and Remote Assistance	$ 2,500.00
Curing Site	$ 24,400.00
Co-op Compost Student Position	$ 8,400.00
Scale	$ 500.00
120L and 240L Wheelie Bins (x8)	$ 880.00
Total	**$ 115,810.00**

Table 9: Summary of Renovation Costs

Renovations		
Electrical	Electrician	$ 2,000.00
	Material	$ 500.00
Site Adjustments	Move compactor electrical	$ 500.00
	Relocate compactor	$ 1,500.00
	Removal of corridor corner	$ 10,000.00
In-Vessel Ventilation	Exhaust vent	$ 500.00
	Airflow optimization	$ 500.00
Total		**$ 15,500.00**

Table 10: Summary of Annual Operation Costs

Annual Operations	
Facilities Labour	$ 768.00
Electricity	$ 146.00
Summer Compost Coordinator	$ 2,500.00
Maintenance	$ 1,900.00
Web Calculator and Remote Assistance (optional after first year)	-
Bulker (Wood Pellets from Rona)	$ 6,827.40
Landfill Tipping Savings	$ -2,550.00
Total	**$ 9,600.00**

Table 11: Total Cost for UNBC's IVC

Capital + Renovations (±5%)	**$ 131,310.00**
Taxes (12%)	**$ 15,800.00**
Grand Total (±5%)	**$ 147,110.00**
Annual Operations (±10%)	**$ 9,600.00**

10. Conclusion and Recommendations

10.1. Recommendations

Several recommendations are made following the implementation of an in-vessel composter at UNBC. First, it is highly recommended that organic waste is still measured and recorded before placing in the IVC; tracking how much organic waste is diverted from the landfill is an excellent parameter to track success of the project, and can be correlated the amount of GHG's reduced. Monitoring the amount of bulker added to the system is also beneficial, both from an operational and research prospective, as there are few academic papers regarding bulker to organic waste ratios in in-vessel composters.

To reduce the operating cost by $4,800 a year, it is recommended to investigate a different source of wood pellets. The economic analysis was conducted using prices from Rona, however it is substantially cheaper to use pellets being delivered in bulk for the Wood Pellet BioEnergy Project. The only hurdle in this is transporting the pellets from the silo to the recycling room.

UNBC should strive for Class A compost, as outlined in Section 7, as Class B carries many restrictions and limitations. The only requirement that may pose a hurdle in achieving Class A compost, is that ambient air temperature during curing must be between 5 – 30 degrees Celsius (OMRR Schedule 2 s.2(b)); this requirement may be bypassed with approval by the regional director.

It is strongly recommended to install the vessel in the summer, when the cafeteria is closed, as the installation requires extensive renovations. Finally, it is recommended to hire a co-op student for the fall following installation. Bringing the system to steady state can be quite a tedious task, and requires consistent monitoring. The co-op could experiment with different amendments, including compostable cups and paper towels, and draft protocols for the IVC.

10.2. Conclusion

UNBC is in need of a new organic waste management strategy, since recent changes to the cafeteria have resulted in a system that is at capacity. After extensive stakeholder consultation, it was determined that an in-vessel composting system would best meet UNBC's needs. IVCs are able to handle the quantity and varieties of organic food waste generated on campus, provide positive environmental and social impacts, are able to decompose a large amount of organic waste in a relatively small footprint, and are suitable for use in Northern communities.

The vessel recommended for UNBC is the Brome 8100 in-vessel composter. This vessel is sized to accommodate future growth, and easily handles fluctuating organic waste feedstock. Wood pellets are recommended for use as bulker, due to their predictable size, low moisture content, and ease of use. Up to 15% other compostable paper products, such as paper, cardboard, and compostable cups, could be used as a compost amendment once the system has reached steady state.

This vessel will be located in the recycling room, directly next to the kitchen, as this is where 60% of the organic waste produced on campus originates. Organic waste is expected to achieve 50% volume reduction within the vessel, so this location also leads to the least amount of material transportation. Newly produced compost requires a 21-day curing period, and this location will be constructed where the current composting facility is located.

For the first time, student residence will also included within this organic waste management strategy; if students want to participate they will be supplied with organic waste bins and compostable liners, and required to deposit their organic waste in large bin located at the Winter Garden. Volunteers will collect the organic waste bins, adding the organic waste and bulkers to the vessel. UNBC facilities staff will transport the screened compost from the IVC to the curing facility, and then to the storage facility once curing is complete.

This entire organic waste management system will have a capital cost of $147,110 ±5%, and a yearly operating cost of $9,600 ±10%. This operating cost could be reduced by $4,800 if logistical issues surrounding transport of wood pellets from the Wood Pellet BioEnergy Program to the recycling room were addressed. Implementing this system would result in a diversion of 50 – 60 tonnes/year of organic waste from the landfill, resulting in an approximate reduction of 45-60 tonnes CO_2 e/year from the current system.

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John Paul – Transform Compost

Jennifer Sun – UBC Sustainability Coordinator

Kasha Foster – UBC Composting Coordinator

Bibliography

B.C. Ministry of Agriculture and Food. (1996, September). *Composting Factsheet.* Retrieved October 25, 2015, from http://www.agf.gov.bc.ca/resmgmt/publist/300Series/382500-7.pdf
B.C. Reg. 18/2002

Beyond the Market. (n.d.). *Buy Local*. Retrieved September 14, 2015, from Find a Farm: http://beyondthemarket.ca/buy-local/directory-listings/

British Columbia. (2011, October). *Ministry of Environment*. Retrieved September 15, 2015, from Landfill Gas Management Regulation: http://www.env.gov.bc.ca/epd/codes/landfill_gas/

Canadian Food Inspection Agency. (2015, February 11). *Chapter 3 - Specific Registration Information by Feed Type*. Retrieved September 14, 2015, from 3.19 Recycled Food Products: http://www.inspection.gc.ca/animals/feeds/regulatory-guidance/rg-1/chapter-3/eng/1329319549692/1329439126197?chap=19

CCME. (2005). *Guidelines for Compost Quaility.* Retrieved October 24, 2015, from Canadian Council for Ministers of the Envrionment: http://www.ccme.ca/files/Resources/waste/compost_quality/compostgdlns_1340_e.pdf

FAO. (2003). *On-Farm Composting Methods.* Rome: Food and Agriculture Organization of the United Nations.

HotRot Organic Solutions. (2012). *Amendments and Bulkers.*
IGES. (2013, September). *GHG Caluclator for Solid Waste Ver. II-2013.* Retrieved October 21, 2015, from Institute for Global Environmental Strategies: http://pub.iges.or.jp/modules/envirolib/view.php?docid=4273

Lebersorger, S., & Schneider, F. (2011). *Discussion on the methodology for determining food waste in household waste composition studies .* Institute of Waste Management, University of Natural Resources and Life Sciences, Vienna, Muthgasse , Department of Water, Atmosphere and Environment .

Mata-Alvarez, J., Dosta, J., Romero-Guiza, M., Fonoll, X., Peces, M., & Astals, S. (2014). A critical review on anaerobic co-digestion achievements between 2010 and 2013. *Renewable and Sustainable Energy Reviews , 36*, 412-427.

Michiel, D., Doherty, S., Boyd, S., Palazuelos, A., Fredeen, A., & Wilkening, K. (2013). *Compostable waste generation at the University of Northern British Columbia, Canada.* Research paper, University of Northern British Columbia, Prince George.

PGPIRG. (2006). *Prince George Public Interest Research Group*. Retrieved September 10, 2015, from Compost and Organic Demonstration Garden Action Group: http://pgpirg.unbc.ca/compost.htm

Rajan, J. (2015). *Food Waste Audit: UNBC Cafeteria.* University of Northern British Columbia, Prince George.

Smyth, D. P., Fredeen, A. L., & Booth, A. L. (2010). Reducing solid waste in higher education: The first step towards 'greening' a university campus. *Resources, Conservation and Recycling , 54* (11), 1007-1016.

U.S EPA. (2015, March). *Waste Reduction Model (WARM).* Retrieved October 21, 2015, from United States Environmental Protection Agency: http://www3.epa.gov/warm/

UNBC. (2015). *Canada's Green University*. Retrieved September 10, 2015, from University of Northern British Columbia: http://www.unbc.ca/green

UNBC. (2013). *Expanding UNBC's compost system.* University of Northern British Columbia, Prince George.

Vermont Waste Management Division. (2012, March). Retrieved October 20, 2015, from Procedure defining high carbon bulking agents used in composting: http://www.anr.state.vt.us/dec/wastediv/solid/documents/12321.HighCarbonBulkingAgentsCompostingProcedure.pdf

Watson, M., & Fredeen, A. (2015). *UNBC Organic Waste Audit on the Northern Undergraduate Student Society's (NUGSS) Food and Beverage Services .* University of Northern British Columbia, Prince George.

Appendix A – Detailed Decision Matrices and Rationale

Overall Score	
Landfill	3.5
Status Quo	3.1
Pile Composting	3.1
Anaerobic Digestion	2.5
In-Vessel Composting	4.4

Ranking Scale	
Very Poor =	1
Poor =	2
Fair =	3
Good =	4
Very Good =	5

Total Weight 25%	**Environmental Impacts**	Image	GHG	Potential for 100% Diversion	Score
Image = 33%	Landfill	1	1	1	1.0
GHG = 33%	Status Quo	3	1.4	2	2.1
Potential for 100% Diversion = 33%	Pile Composting	4	1.4	2	2.5
	Anaerobic Digestion	5	5	4	4.7
	In-Vessel Composting	5	4.0	5	4.7

Total Weight 25%	**Economics**	Net Present Value	Normalized
	Landfill	$59,382.02	5.0
	Status Quo	$72,063.89	4.9
	Pile Composting	$85,443.55	4.9
	Anaerobic Digestion	$991,028.88	1.0
	In-Vessel Composting	$167,854.67	4.4

Total Weight 12.5%	**Community Impacts and Involvement**	Student Participation	Research Opportunities	Score
Student Participation = 33%	Landfill	1	1	1.0
	Status Quo	3	2	2.3
	Pile Composting	3	2	2.3
Research Opportunities = 33%	Anaerobic Digestion	4	4	4.0
	In-Vessel Composting	4	4	4.0

Total Weight 12.5%	**Feasibility**	Labour Requirements	Ease of Transition	Score
Labour Requirements = 80%	Landfill	5	5	5.0
	Status Quo	3	5	3.4
	Pile Composting	3	4	3.2
Ease of Transition = 20%	Anaerobic Digestion	1	1	1.0
	In-Vessel Composting	4	4	4.0

Total Weight 25%	**Adaptability**	Self Sufficiency / Automation	Minimal Potential for Misuse	Handling of Feedstock Variability	Score
Automation = 33%	Landfill	5	5	5	5.0
	Status Quo	2	3	2	2.3
Misuse = 33%	Pile Composting	2	3	2	2.3
Handling of Feedstock Variability = 33%	Anaerobic Digestion	1	2	2	1.7
	In-Vessel Composting	4	4	5	4.3

Further Ranking Justification

Status Quo

The current system is operating at capacity, and is only able to divert approximately 25% of all organic waste on campus (Smyth et al., 2010). This option is quite labour intensive, and there are not enough volunteers to process additional organic wastes. Since it is a simple, backyard style composting system, heat production and pathogen removal cannot be ensured, and thus a limited amount of organic wastes may be accepted; only fruit and vegetable scraps, coffee grounds, tea bags, and eggshells are currently processed, while cooked foods, grains, meat, and dairy are sent to the landfill (PGPIRG, 2006). In the winter, the decomposition process is significantly showed due to the cold temperatures (Michiel et al., 2013). The hopper the collected organic waste is stored in before it is taken to the composting area, can be quite odourous, and attracts flies especially in the summer. This has led to complaints coming from staff who work in the area, detracting support from this system.

Pile Composting

Pile composting is comparable to a larger scale version of the current system operated by PGPIRG. Due to this it would face the same constraints as outlined in Status Quo above. It would also face additional challenges: it would require more labour and more temporary storage, which is already a major drawback to the current system. It also wouldn't be able to handle a more diverse feedstock since pathogen removal cannot be ensured.

In-Vessel Composting

Suitable for managing organic waste in a limited space, in-vessel composting is the system we are recommending as it best fits our stakeholders' needs. Compost can be formed continuously or in batches, and organic waste can be placed directly into it, eliminating the need for interim storage of organic waste. The vessel can also decompose all types of organic waste, allowing for the potential to achieve 100% diversion. Due to the entire process occurring in a closed vessel, the odour issues that are present with the current system will be eliminated under proper operating conditions (Bonhotal et al., 2011). On a per-weight basis, labour requirements will be reduced with the in-vessel system because manual turning of the compost is not required (Bonhotal et al., 2011). Retention times vary depending on the chosen vessel, but range from a couple days to a few weeks (Bonhotal et al., 2011). The newly created compost will require a curing and long term storage area, and the location of the current system has the potential to be re-purposed for this. Finally, in-vessel composting produces a high quality end product that is free of pathogens allowing for it to be easily used and potentially sold (Bonhotal et al., 2011).

Landfill

When organic waste is buried at a landfill, it is decomposed anaerobically and produces methane, a greenhouse gas with a global warming potential 25 times greater than carbon dioxide (Environment Canada, 2014; Environment Canada, 2015). Landfilling the organic waste generated on campus at UNBC would result in a generation of approximately 50 tonnes of CO2e/year. Although the Foothills Regional landfill has a gas capture facility, this option does not align with provincial commitments to reduce greenhouse gas emissions (Pacific Carbon Trust, 2015).

With respect to cost, at $72 per tonne and an estimated 1550 kg organic waste produced per week, this option would cost roughly $4,000 per year (Regional District of Fraser-Fort George). Lastly, landfilling organic waste would not align with UNBC's image as a steward in sustainability, and students would lose the opportunity to work on green initiatives with regard to organic waste management.

Livestock Feed

Unfortunately, feeding food waste to livestock has, due to various disease outbreaks such as foot and mouth disease, is either illegal or very difficult to do in many countries (Jordan, 2015). Canada does not ban the feeding of food waste to livestock but it does provide a comprehensive list of requirements that need to be met before being fed to animals (Canadian Food Inspection Agency, 2015). The regulations of note that pose the most difficulty for food waste generated on campus include:

- material being fed to livestock has to be traceable to its original source; this includes knowing where the individual ingredients originated,
- rotting or mouldy food cannot be fed to livestock,
- heat treatment of feedstock may be required if it is deemed to have a high moisture content,
- the farm where the organic waste is being used needs to have the facilities to cook the food waste into swill, as this cannot be done off-site.

Based on the difficulty in being able to meet the regulations, using the organic waste as livestock feed was not considered.

Anaerobic Digestion

Anaerobic digestion systems are complex and require close monitoring for proper operation. Feedstock composition must remain constant as not to disrupt the bacteria, as changes can alter the bacterial composition, and in turn impact methane creation (Mata-Alvarez et al., 2014). Another factor that affects methane production is temperature, which requires monitoring to be controlled and heating the system to the required temperature would require additional energy requirements.

Student participation would be severely limited because hydrogen sulphide is produced as a by-product and corresponding safety procedures would have to be implemented. Although there are additional benefits to anaerobic digestion compared to in-vessel composting, the production of biogas would not offset the additional costs required for an anaerobic digestion system (Pickering et al., 2013).

Appendix B – Projected Organic Waste Assumptions

The organic waste currently collected at UNBC represents 27% of a typical organic waste stream (Lebersorger, 2011). Reports specific to UNBC have concluded that the compostable organic matter comprised 21.6% of the total waste stream generated (Smyth et al., 2010). For simplicity and the fact that food services have changed on campus since 2010, we have assumed the current compost feedstock represents one-quarter of the total organic waste generated on campus. When applicable below, we have applied a factor of 4 to UNBC's current compost waste stream to project the total amount of organic waste that is possible to collect.

Core Campus

The Core Campus is comprised of the Cafeteria Kitchen, The Thirsty Moose Pub, the two Degrees Coffee locations, and Buildings 4 through 10. To get the organic waste generated just within buildings 4 - 10, information from audits specific to the food services was subtracted from a broader audit conducted in 2013 (Michiel et al., 2013). We have assumed that the small amount of organic waste created in the hallways will not increase relative to the waste audits previously conducted; we concluded that it is unlikely that people will discard cooked food from home into these bins.

Thirsty Moose Pub

A waste audit was conducted at the pub in 2015 and categorized the organic waste as future potential compostable organic waste (Watson & Fredeen, 2015). In order to distinguish the pub's organic waste stream from the core campus' organic waste stream, the daily average waste was reduced by a factor of 4 to represent the current system's capabilities.

Degrees Coffee

The same waste audit that reported on the Thirsty Moose Pub also analyzed Degrees Coffee (Watson & Fredeen, 2015). Since this waste stream consists of coffee grounds, filters, and minor compostable cups, we did not scale up for future acceptable compost.

Chartwells Dining Hall

There are differences between the cafeteria kitchen and dining hall when they have been reported in the waste audits. The data for cafeteria kitchen is part of the campus core, and is necessary to determine how much organic waste is in the bins from buildings 4-10.

It has not been carried forward for projected compost available in Table 1, since the Chartwells Dining Hall audit accounts for this amount (Rajan, 2015). Noted in the report was the difficulty of preparing staff at the cafeteria for the procedures required to perform the audit. The lack of preparation leading up to the first week's food waste collection resulted in missed collections as well as accidental discard of the food waste. Therefore, it is believed that the second week of the audit resulted in more realistic data compared to the first week's audit (Rajan, 2015).

While the audit was being undertaken, there were 210 students on the meal plan, compared to 319 that are subscribed this year (e-mail correspondence with Nicole Neufeld). We used this information to scale the amount of organic waste created by 1.5, and did not need to scale further since the audit classified organic waste as all potential items that could be composted without the restraints of the current system. We have assumed that the number of students visiting the dining hall without a meal plan would not change drastically from year to year.

Student Residence Buildings

We have assumed that the amount of organic waste from the residence buildings will increase by a factor of 2 compared to the organic food waste audit performed in 2012 (Michiel et al., 2013). This factor was applied rather than the usual factor of 4, since upcoming changes to the residences' will remove half of the ovens. These units without ovens will be inhabited by those students on the unlimited meal plan, meaning that there will be little to no organic waste being produced in the suites. These changes were discussed during a meeting with the supervisors on September 29, 2015.

Appendix C – Bulker Economic Analysis

Bulker Economic Analysis			
Bulker	per tonne	per week	per year (Including labour + delivery)
Cost of Wood Pellets	$255.00	$118.58	$6,800.00
Cost of Hog Fuel	$64.94	$30.20	$5,100.00
Cost of Pellets (Bioenergy)	$130.00	$60.45	$2,000.00

Note: Economic analysis was not performed on wood shavings due to the high cost of $440/tonne.

Appendix D - Sample Calculations

Cafeteria Kitchen daily weight:

$$209\ kg\ week^{-1} \times \frac{week}{7\ day} = 30\ kg\ day^{-1}$$

Degrees Coffee Daily weight:

$$124\ kg\ week^{-1} \times \frac{week}{7\ day} = 18\ kg\ day^{-1}$$

Degrees Coffee weekly weight:

$$17.7\ kg\ day^{-1} \times \frac{7\ day}{week} = 120\ kg\ week^{-1}$$

Thirsty Moose Pub daily weight:

$$24.6\ kg\ week^{-1} \div 4 = 6.1\ kg\ day^{-1}$$

Thirsty Moose Pub projected weekly weight:

$$24.6\ kg\ day^{-1} \times \frac{7\ day}{week} = 170\ kg\ week^{-1}$$

Core Campus weight excluding Thirsty Moose Pub, Degrees Coffee, and Cafeteria Kitchen:

$$(63.3 - 6.1 - 17.7 - 29.9)\ [kg\ day^{-1}] = 9.7\ [kg\ day^{-1}]$$

Residences weekly weight:

$$21\ kg\ day^{-1} \times \frac{7\ day}{week} = 150\ kg\ day^{-1}$$

Residences renovation factor:

$$Current\ Food\ Waste \times 4 \times \frac{Original\ Number\ of\ Ovens}{2} = 2 \times Current\ Food\ Waste$$

Residences projected weekly weight:

$150\ kg\ week^{-1} \times 2 = 300\ kg\ week^{-1}$

Cafeteria student meal plan factor:

$$\frac{[\#\ of\ 2015 - 2016\ Meal\ Plan\ Subscribers]}{[\#\ of\ 2014 - 2015\ Meal\ Plan\ Subscribers]} = \frac{319}{210} \cong 1.5$$

Cafeteria projected weekly weight:

$713\ kg\ week^{-1} \times 1.5 = 1070\ kg\ week^{-1}$

Thirsty Moose Pub projected 80% diversion

$170\ kg\ week^{-1} \times 80\% = 140\ kg\ week^{-1}$

Residences projected 80% diversion

$300\ kg\ week^{-1} \times 80\% = 240\ kg\ week^{-1}$

Cafeteria projected 80% diversion

$1070\ kg\ week^{-1} \times 80\% = 860\ kg\ week^{-1}$

In-Vessel residence time

$$\frac{Vessel\ Volume \times \%\ Useable\ Vessel\ Volume}{(Volume\ of\ Organic\ Waste\ per\ week + Volume\ of\ Bulker\ per\ week)} \times \frac{7\ days}{week}$$

Volume of Organic Waste per week

$$\frac{1550\ kg\ week^{-1}}{500\ kg\ m^{-3}} = 3.1\ m^3\ week^{-1}$$

Volume of Bulker per week

$$\frac{Mass\ of\ Organic\ Waste\ per\ week \times Bulker\ Ratio}{Bulker\ Density}$$

$$\frac{1550\ kg\ week^{-1} \times 30\%}{675\ kg\ m^{-3}} = 0.69\ m^3\ week^{-1}$$

Standard useable vessel volume is 60%.

For Brome 8100

$$\frac{14.4\, m^3 \times 60\%}{(3.1\, m^3 week^{-1} + \; 0.69\, m^3\, week^{-1})} \times \frac{7\, days}{week} = 16\, days$$

Compost volume accumulated during 21-day period assuming 50% volume reduction:

$$\frac{Mass\ of\ Organic\ Waste\ per\ week}{Bulk\ Density\ of\ Organic\ Waste} \times \frac{3\, weeks}{21\, days} \times 50\%$$

$$\frac{1550\, kg\, week^{-1}}{500\, kg\, m^3} \times \frac{3\, weeks}{21\, days} \times 50\% = 7.75\, m^3$$

Appendix E - Contractor Parking Lot Shelter Economic Analysis

Outside Shelter			Source
Concrete Pad		$ 20,000.00	Ryan Goetzinger
Shelter	Steel	$ 30,000.00	David Claus
	Roof	$ 2,500.00	Home depot and labour using 1:4 ratio
Hole in wall for conveyor		$ 10,000.00	David Claus
Mixer and Conveyer		$ 32,300.00	Quote - Brome
Total		**$ 94,800.00**	

Appendix F - In-Vessel Installation Floor Plans

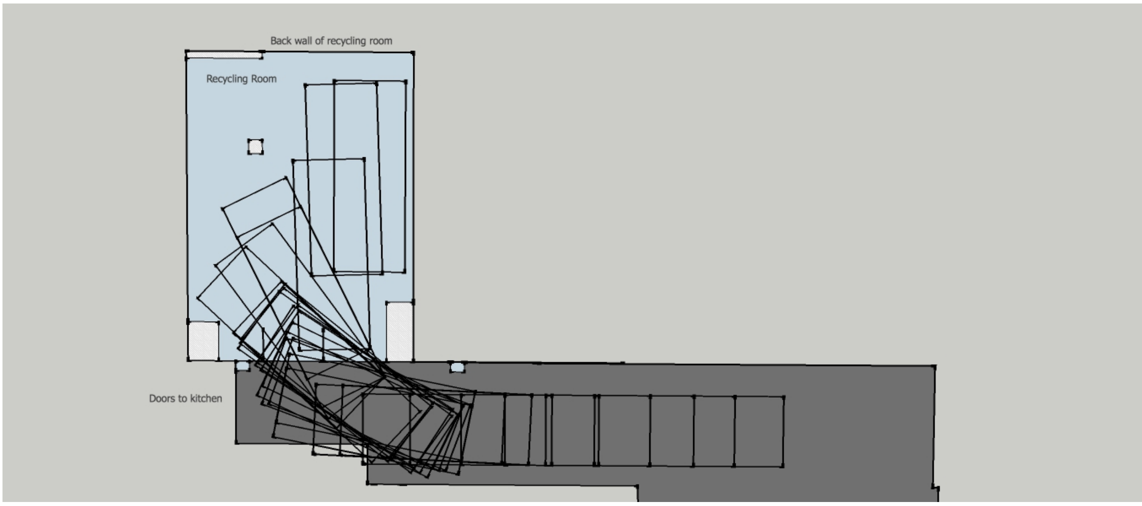

Figure F: diagram showing how the Brome 8100 (6'x16') vessel will fit into the recycling room.

Appendix G - Student Residence Compost Collection Economic Analysis

Residence	Unit Price	Amount Required	Capital	Budget per semester	Source
Small 7L Composting Bins	$ 15.00	40	$ 600.00	-	London Drugs
Compostable Bags	$ 0.06	80 per week	-	$ 80.00	Canadian Tire

Appendix H - Further Details of Detailed Economic Analysis

Summary of Economic Analysis

We applied contingency to capital expenses where applicable to obtain an expected range of ±5%.

Description of Economic components

Capital

- Scale

We recommend purchasing a floor scale to facilitate weighing the larger wheelie bins. The scale we have identified as being suitable for UNBC is the Salter Brecknell PS500-36S Floor Scale from Scales Galore. Regardless of the posted price online (including shipping), we carried 10% contingency.

- Compostable Bags

The compostable bags are Bag to Earth 2-ply 7L bin liners from Canadian Tire. They are listed at $2.49 per 40 bags. Regardless of the posted price online, we carried 10% contingency.

- Compost Buckets

The compost buckets are for students living in residence who chose to opt-in to the compost system. The buckets are 7L pails from London Drugs. Regardless of the posted price online, we carried 10% contingency.

- 240L Wheelie Bins

The wheelie bins are for accepting large quantities of organic waste, can be easily moved, and are designed for the bin lift to load the organic waste into the IVC. The price quoted as part of the economic analysis was from Rona. Regardless of the posted price online, we carried 10% contingency.

- Co-op Student Salary

The salary for a Co-op Student was calculated with an hourly wage of $15, at 35 hours per week, for 16 weeks.

- Curing Site

Calculated using estimates provided by Aaron Olsen and Ryan Goetzinger with 20% contingency due to contractor variability. Cost of concrete blocks was quoted and shipping and handling was estimated by supplier, therefore, we carried 20% contingency on the concrete blocks and shipping and handling.

- Cardboard Shredder

This is a potential option for UNBC to use cardboard as a carbon amendment for the compost. The cost of the shredder is not included in the economic analysis, but has a one-time investment cost of $21,850 excluding shipping, installation and taxes.

Renovations

- Electrical
    - Electrician

Electricians are required for installation of required electrical components, such as 600V wiring, converters, and relocation of current electrical equipment within recycling room.

- Material

Materials required by electricians, such as wiring and converter.

- Site Adjustments
  - Move cardboard compactor electrical

The recycling room will require rearranging of current materials, which includes moving the cardboard and its associated electrical components.

- Move cardboard compactor

The cardboard compactor must be relocated within the recycling room in order to fit the IVC into the room.

- In-House In-Vessel Installation
  - Exhaust vent

The IVC must have an exhaust vent that will be tied into the kitchen's grease trap vent to create negative air pressure within the vessel, which does not allow odours to escape from the vessel into the recycling room.

- Airflow optimization

Once the IVC's exhaust vent is tied into the kitchen's grease trap vent, airflow must be adjusted within the vent to ensure proper ventilation within the vessel.

- Removal of Corridor Corner

To get the IVC into the recycle room, a section of the corridor leading into the cafeteria's kitchen will have to be removed and reinstalled. Aaron Olsen estimated this to cost $10,000 if done by outside contractors. We used this value for the economic analysis and applied 10% contingency for this process. However, if done by UNBC's facilities labour, the removal and reinstallation of the corridor's corner is estimated to cost only $1,500.

Operations

- Facilities Labour

Facilities labour was determined through discussions with facilities staff to determine the difference in labour requirements of the current system and our proposed system. It was determined that our proposed system will require 2.5 hours of labour more per month from September to May.

- Electricity

Electricity was estimated assuming that our proposed IVC will consume similar amounts of energy as other IVC's that are similar in size and capacity, namely the CityPod XL and Big Hanna T480. Therefore, to be conservative, we estimate that our proposed IVC will consume 5 kWh/day throughout the year.

- Summer Compost Coordinator

The amount claimed is consistent with historical compensation for this position.

- Maintenance

Assumed a value of 2% of the project's capital cost.

- Web Calculator and Remote Assistance

The web calculator provided by the supplier allows for tracking of the composting conditions, which can be reviewed by an expert. The expert can then make recommendations to improve day-to-day operations. The supplier also uses the data entries to compile an annual report of the compost process. We recommend using this feature for the first year of operations in order for the IVC to reach steady state operations. However, we do not recommend this feature for future years given that sufficient information will have been acquired after the first year of operation.

- Bulker

Calculated assuming 30% bulker with 1550 kg/week loading and using wood pellets from Rona being delivered twice per month. Delivery costs $45, therefore, we recommend looking into possible storage location for wood pellets from Rona to reduce delivery charges. As it is currently proposed, wood pellets from Rona make up 74% of the annual operating costs. Therefore, we recommend looking into the feasibility of using wood pellets from the Bioenergy plant. The wood pellets from the Bioenergy plant cost less than 50% of the cost of the wood pellets from Rona, which could result in annual savings of approximately $5,000 compared to the wood pellets from Rona.

- Landfill Tipping Savings

Landfill tipping savings were calculated using the Foothills Landfill tipping rate of $72 per tonne and assuming a disposal rate of the difference between our proposed system (1550 kg/week) and the current system (440 kg/week) from September to May.

Outdoor Shelter

- Concrete Pad

A concrete pad is required as a base for an IVC and was estimated by Ryan Goetzinger.

- Shelter
    - Steel

Cost is estimated by David Claus using $7/pound of steel which includes construction labour.

- Roof

Roofing materials were found online using Home Depot's online store. The cost estimation for the roof was calculated assuming materials account for 20% and labour accounts for 80% of total cost.

- Hole in wall for conveyor

If the vessel were to be located outside, the compost material would have to be fed into the IVC using a conveyor from indoors. The cost for putting a hole in the wall for the conveyor was estimated by David Claus.

- Mixer and Auger

To feed the IVC at the outdoor location, the compost material would require mixing with the bulking agent and be conveyed into the IVC. The cost of the mixer and conveyor were acquired in a quote from Brome Composting Systems.