

An Investigation Into Composting Food Waste at the New Student Union Building

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APSC261

November 30, 2010

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ABSTRACT

The new Student Union Building (SUB) project at the University of British Columbia (UBC) is currently in the design phase with the goal of being an innovative and sustainable facility. The food waste that is generated from the Student Union Building is currently managed by UBC Waste Management, which transports compostable food waste to an in-vessel facility for further processing. Space has been allocated for a facility on the green roof to compost food waste as a sustainable alternative that satisfies the vision principles outlined in the design criteria of the new SUB.

This report found that an estimated 17m³ of compostable food waste will be generated by the new SUB each year. It was also found that a maximum compost output volume of 51 m³ can be managed by a facility on the green roof using bin composting. Application of the triple bottom line analysis was used to examine the social, economic, and environmental impacts of composting on the green roof. The investigation revealed that the in-vessel facility is more economically and environmentally beneficial for the new SUB. However, composting food waste on the new SUB has social advantages that the in-vessel facility does not. The recommendation of the report is that composting on the new SUB is done on a small scale for the social benefits of public awareness and as an educational opportunity.

LIST OF ILLUSTRATIONS

Figure 1. The UBC in-vessel composting system

Figure 2. Mock up of the new SUB's green roof layout. The area labelled F is the proposed composting facility

Figure 3. A common compost tumbler.

Figure 4. Household vermicomposting.

Figure 5. Compost bin locations on campus.

Table 1. Summary of the food waste generated from the SUB.

Table 2. A summary of the compost application volume in each phase.

Table 3. A comparison of traditional methods vs. vermicomposting

GLOSSARY

| | |
|------------------------------|--|
| <i>Aeration:</i> | The process of exposing a substance to air. |
| <i>Aerobic:</i> | Oxygen is present in the environment or process. |
| <i>Anaerobic :</i> | Oxygen is not present in the environment or process. |
| <i>Compost tumblers:</i> | A composting bin with a horizontal barrel that can be rotated using a lever. |
| <i>In-vessel composting:</i> | A composting technique that occurs in a closed container where variables such as temperature and airflow are controlled for an optimal composting process. |
| <i>Leachate:</i> | Liquid that contains solutes or substances from the material it passes through. In composting, it is the liquid that drains from the organic material. |
| <i>Vermicomposting:</i> | A method of composting using red worms to process organic waste into fertilizer. |
| <i>Windrow:</i> | A long and narrow pile of compost. |

LIST OF ABBREVIATIONS

SUB - Student Union Building

UBC - University of British Columbia

1.0 INTRODUCTION

Currently, compostable material in the SUB is gathered in green bins where it is collected biweekly by UBC Waste Management. The waste is transported to the In-Vessel Composting Facility on the South Campus. This is where UBC Waste Management staff operate an in-vessel composting unit capable of producing 5000 kg of compost per day [1].

The in-vessel system is an enclosed unit that is continually loaded with compostable material, see Figure 1. As the material moves through the system over the course of fourteen days, the computer controlled system maintains temperature, moisture, and aerobic conditions for optimal decomposition. Potentially harmful leachate is collected and recirculated within the system to ensure that it is contained. To prevent odour, a bio-filtration system is employed.

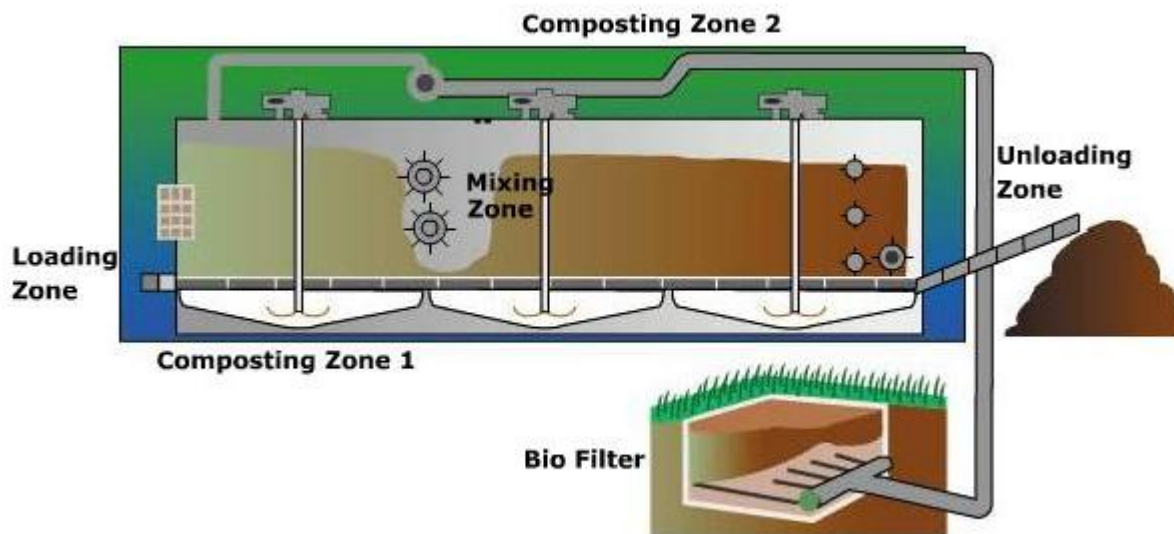


FIGURE 1. THE UBC IN-VESSEL COMPOSTING.

Source: <http://www.wrightenvironmental.com/flash/animation2.swf>

Since the in-vessel system is fully enclosed, it is able to keep out rats and other animals. This allows for a wider variety of organic material to be composted like dairy, meat, and grain products in addition to organic waste like fruit and vegetable scraps, yard trimmings, and paper plates or cups. Since the composting process is automated, the system requires only three hours per day of labour to load and operate the composting unit.

The design documents of the new SUB have allocated space for a composting facility on the rooftop of the new SUB to divert either a portion or the entire waste output from the South Campus facility. Such a facility would be able to handle food wastes such as fruit and vegetable scraps and would operate on a much smaller scale than the

in-vessel facility. It is proposed that the compost that is generated be used on the greenhouse and gardens of the new SUB's green roof. Figure 2 shows a mock up of the green roof's layout and where the composting facility may be situated.

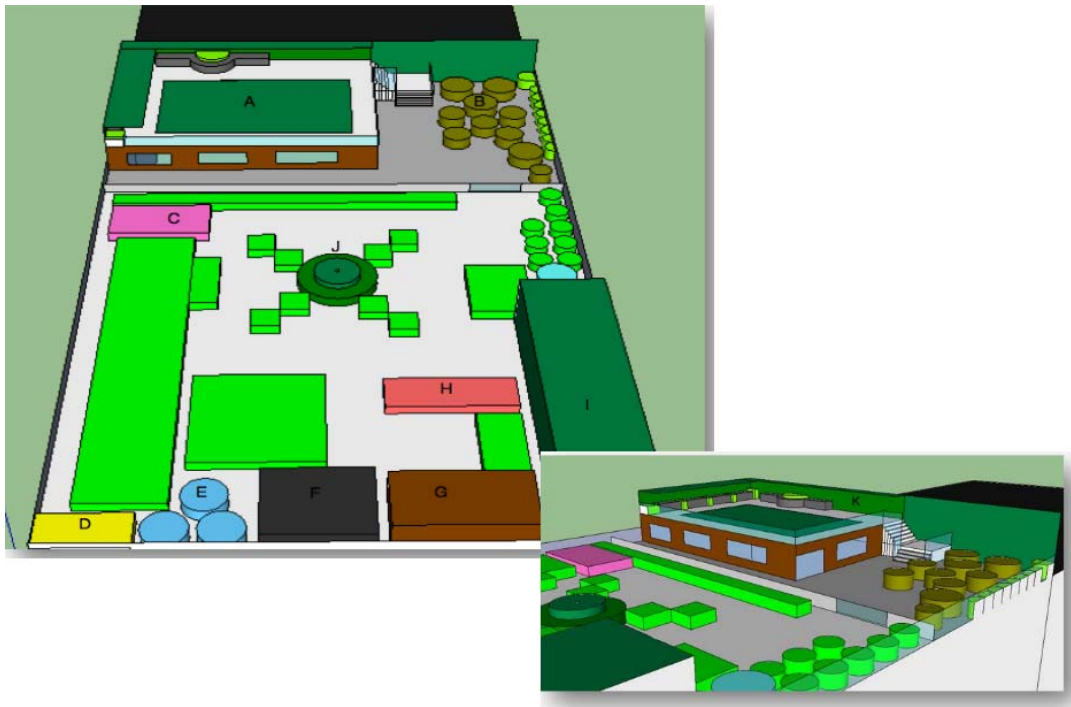


FIGURE 2. MOCK UP OF THE NEW SUB'S GREEN ROOF LAYOUT. THE AREA LABELLED F IS THE PROPOSED COMPOSTING FACILITY.

Source:

http://www.sustain.ubc.ca/sites/default/files/seedslibrary/Group%20and%2019%20BusinessPlan_Clean%20FINAL.pdf.

2.0 ROOFTOP COMPOSTING IMPLEMENTATION

Of the 30,000 ft² of space allocated for a green space of the New SUB, 480 ft² has been allocated for a composting area (MHPM Project Managers, “Roof Garden Program Area”, unpublished). These dimensions were used to estimate the amount of food waste generated by the New SUB that can be realistically composted on the green roof. The Roof Garden Program Area dimensions allocated 6500 square feet of garden space and 1500 square feet for a greenhouse for a combined growing space of 8100 square feet.

2.1 CAPACITY

The volume of composting bins varies between every application. Small scale composting bin sizes are within the range of 0.3x0.4 m (length by width) bins. Larger bin sizes may be appropriate for a compost facility on the green roof given the large area that is available to store and maintain compost. Pilot studies done in correctional facilities used bins that had volumes between 1 m³ and 7 m³ [2]. It was calculated that the maximum volume of compost that the rooftop facility is able to contain is 51 m³ by assuming a bin height of 1.5 m.

2.2 COMPOSTABLE FOOD WASTE GENERATION

From the SUB Waste Audit Summary, the estimated annual disposal of waste from the SUB is 88,000 kg [3]. Of the waste material from Table 1, food waste, paper, compostable dishes, and cardboard is compostable. Meat, oil, and dairy products should not be composted because they will attract rodents from the smell. It was found that a total yearly volume of 121 m³ of compostable waste is generated by the New SUB [4].

TABLE 1. SUMMARY OF THE FOOD WASTE GENERATED FROM THE SUB

| | Annual Mass (kg) | Density (kg/m³) | Annual Volume (m³) |
|---------------------------|-------------------------|-----------------------------------|--------------------------------------|
| Food waste | 18232 | 1029 | 17 |
| Other paper | 16703 | 228 | 73 |
| Compostable dishes | 6515 | 228 | 29 |
| Cardboard | 407 | 260 | 2 |
| total | 41857 | | 121 |

2.3 WASTE DIVERSION

A study on composting of household wastes reports results of up to 92% in volume reduction of the input [5]. The authors admit that in practice, a 65-70% volume reduction is more realistic outside the lab setting, which agrees with the results from Brown Creek where a 75% volume reduction was achieved [2]. Therefore, assuming a 65% volume reduction, the annual volume of waste that can be composted on the new SUB is 78m³. Theoretically 64% of the estimated food waste generated by the New SUB can be diverted from the South Campus compost pile.

2.4 ROOFTOP COMPOST APPLICATION

The compost application rate for newly established gardens should be between 0.05 m to 0.07 m deep [6]. For established gardens, an annual application of 0.02 m to 0.05 m deep is sufficient. The total amount of compost that can be applied to the crop areas and greenhouse during each phase of the New SUB, estimated with a 0.05 m application rate is shown in Table 2.

TABLE 2. A SUMMARY OF THE COMPOST APPLICATION VOLUME IN EACH PHASE

| | Phase 1 | Phase 2 | Phase 3 |
|---------------------------------------|----------------|----------------|----------------|
| Crops area (m²) | 93 | 302 | 604 |
| Greenhouse (m²) | 0 | 149 | 149 |
| Total (m²) | 93 | 451 | 753 |
| Compost application (m) | 0.05 | 0.05 | 0.05 |
| Compost volume (m³) | 5 | 23 | 38 |

2.5 METHODS OF COMPOSTING

Given that the composting area is located on the rooftop, it is mandatory to keep the composting bins sealed at all times when they are not accessed by labourers. This is to prevent attraction of vermin and birds, and also to keep odor to a minimum. Two methods of composting satisfy these requirements and are suitable for this scale of operation: traditional and vermicomposting. Both methods are compared and a recommendation for a suitable method is made for the new SUB.

2.5.1 Traditional Methods

Traditional methods range from anaerobic decomposition to aerobic decomposition with passive aeration [7]. These methods require turning over compost windrows periodically in order to regulate the amount of aeration. Frequent turning of

windrows result in a shorter composting of composting. Following the requirement of sealed bins on the rooftop, compost tumblers are suggested in replacement of traditionally practiced windrows, see Figure 3. Compost tumblers use the method of aerobic decomposition with passive aeration by making the process of turning over compost easily operable. The specific type of passive aeration that can be implemented here is based off of the Indian Indore Method.



FIGURE 3. A COMMON COMPOST TUMBLER. Source:

<http://goorganicgardening.com/compost/should-i-get-a-compost-tumbler>

2.5.2 Vermicomposting

Vermicomposting is a method commonly practiced by using red worms (*Eisenia foetida*) to digest organic waste. This method produces high quality compost that is rich in nutrients with a “hummus-like” quality [8]. It requires a composting bin containing red worms and a suitable environment of bedding and compost. The compost pile does not need to be manually turned over, but its internal environment has to be temperature and moisture regulated to be optimized for the worms to decompose organic material [9]. Figure 4 shows the small-scale vermicomposting process taking place in a worm composting bin.

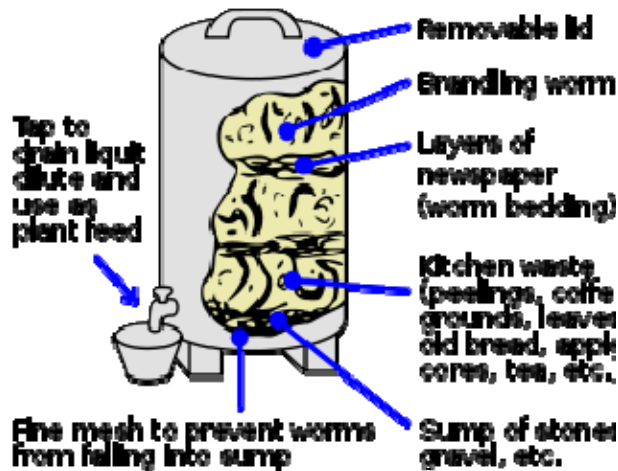


FIGURE 4. HOUSEHOLD VERMICOMPOSTING.

Source: <http://en.wikiversity.org/wiki/Vermicomposting>.

2.5.3 Comparison of the Two Methods

Table X provides a comparison of the duration, preparation, maintenance, labour requirements, and estimated cost of the two methods of composting suggested for the new SUB.

TABLE 3. A COMPARISON OF TRADITIONAL VS. VERMICOMPOSTING

| | Traditional Methods | Vermicomposting |
|--------------------|--|---|
| Duration | <ul style="list-style-type: none"> • ranges from 2 to 4 months [7] | <ul style="list-style-type: none"> • ranges from 6 to 12 weeks [7] |
| Preparation | <ul style="list-style-type: none"> • The compost pile needs to be prepared in a ratio of 1:4 waste to soil [7]. • Green materials are left to be dried for 2 - 3 days before it is mixed in the compost. • The waste component should be roughly 40% brown material (dried leaves, paper, etc.) and the rest should be green material (for example fresh vegetables wastes) [10]. | <ul style="list-style-type: none"> • Worms need to be purchased at the beginning of an operation, and more worms will need to be purchased in following cycles to make up for the loss of worms during the cycle. • Nitrogen-rich materials (wet and green), and carbon-rich materials (dry, brown) are used [11]. • Composting materials should first be shredded |

| | | |
|----------------------------------|---|--|
| | | into smaller pieces for faster vermicomposting [12]. |
| Maintenance | <ul style="list-style-type: none"> • The compost needs to be turned three times: first after 15 days, another after 15, then last after a month [10]. • Every turning of compost needs to be accompanied by adding enough water to the mix to keep it moist. • The compost can be modified to be turned every 15 days, but its duration will not be shortened significantly. | <ul style="list-style-type: none"> • Worms require a regulated compost temperature of 0 to 35°C [9]. • Bedding has to be kept with a moisture of greater than 50% water to hydrate the worms. • pH has to be kept around 7 to 8 [7]. • An abundance of nitrogen-rich and carbon-rich materials in the bedding will guarantee the desired temperature, moisture, and pH [11]. |
| Estimated Labour Required | <ul style="list-style-type: none"> • 6 hour needed to prepare dried green materials 3 days in advance • 6 - 12 hours needed to prepare and mix the compostable waste and soil at the beginning of every cycle (2 to 4 months) which includes mixing the 1:4 ratio of waste to soil, and loading it into the compost tumbler • 6 hour every 15 days to turn over the compost tumbler • 6 hour needed to retrieve and store the finished compost soil | <ul style="list-style-type: none"> • 20 - 30 hours needed to prepare the compostable waste and soil at the beginning of every cycle (every 6 to 12 weeks) which includes shredding the organic waste, adding the worms, and loading it into the compost bin • 1 hour twice a week to check the water-content, temperature, and pH conditions inside the compost bin • 20 hours needed to retrieve and store the finished compost soil and sort out the worms inside of it |

| | | |
|--|--|---|
| <p>Estimated Cost</p> <p>(Refer to Appendix A for all Calculations)</p> | <ul style="list-style-type: none"> The cheapest compost tumblers on the market ranges from \$100 - \$200, with inexpensive brands like the Sterling 463406 7-Cubic-Foot Roto Composter Jr. at \$159.99 [13]. Assuming that we need to produce a maximum capacity of 51 m³ of compost (see section 2.1), 26 Roto Composter Jr.'s are needed, totalling at \$4159.74 total labour cost for one cycle is calculated to be \$630.00 <p>Total cost per cycle: \$4789.74</p> | <ul style="list-style-type: none"> Stackable tray bins are most commonly used for vermicomposting. A 5-tray stackable bin can be found from \$177.49 [14]. Assuming we need 51m³ of compost (see section 2.1), 607 5-tray stackable bins would be required, totalling at \$107,761.79 Worm prices vary from \$10 - \$40 per pound [9] depending on the quantity purchased. The total cost of purchasing enough red worms to fill 607 5-tray stackable bins is calculated to be \$25,693.29. total labour cost for one cycle is calculated to be \$930.00 <p>Total cost per cycle: \$134,384.08</p> |
|--|--|---|

2.5.4 Recommended Method

As Table 3 shows, there is a significant cost difference of \$129,594.34 between traditional methods of composting and vermicomposting. This is largely due to the operational cost of a rooftop-scale composting plan. Where vermicomposting is more suitable to be adapted for household-size operations, it becomes very expensive when operated at a larger scale. It is therefore recommended for the new SUB rooftop garden to use traditional methods of composting. A traditional method using an adaptation of the Indian Indore Method is economically better.

3.0 TRIPLE BOTTOM LINE ANALYSIS

Both options, either composting at the in-vessel facility or at the new SUB, will be judged below in a holistic manner that examines the social, environmental, and economic aspects of each option.

3.1 SOCIAL ANALYSIS

This section aims to examine the social benefits of composting at the new SUB while also weighing its disadvantages.

3.1.1 Educational Opportunity

Composting on the green roof provides an excellent educational opportunity for people who would like to know more about composting. A rooftop garden club could be created by a group of UBC students and faculty members interested in urban farming and can be extended to include the composting facility. Workshops on home composting could be held on a weekly or monthly basis depending on public interest.

The UBC rooftop garden and compost facility could provide a similar educational opportunity to the UBC farm with the added benefit of being an even more accessible location as a center of student activity and food consumption. The UBC farm is a popular field trip location for classes that range from elementary and secondary school to university students. These trips have a focus on where food comes from in addition to the social and environmental impacts of the food production system. Learning about food disposal and composting at the rooftop garden completes a holistic picture on the food process from production, consumption, to disposal.

3.1.2 Public Awareness

In modern developed cities, waste collection is a service provided by the government or the private sector. The consumer throws away waste in the garbage bin and the waste collector transports it and manages the waste through landfills, recycling, incinerators, or other channels. From a standpoint of convenience, the technology of waste collection has reached the point where the system is so efficient that the process is invisible to the consumer. Waste management becomes a black box process to the general public and may cultivate an “out of sight, out of mind” mentality when it comes to waste. The in-vessel composting facility is a comparable system where the university transports and manages the waste at the convenience of students and faculty members. Composting on the new SUB moves a part of the management process to the source of disposal and brings transparency to the black box of waste management.

A composting system on the green roof satisfies many of the education principles with respect to the New SUB’s Vision Principle Objectives (Alma Matter Society, “SUB Vision Principles Objectives”, unpublished). According to this document, the New SUB should “make visible the operational use and flow of materials”, “demonstrate the food growing cycle in the building”, and “support positive sustainable behavior change.” The composting facility would go beyond the goal of demonstrating the food growing cycle as a visible demonstration of the disposal and recycling process. A visible and

prominent composting facility at a location highly frequented by campus staff and students combined with the available educational opportunities may inspire some to change their consumption and disposal habits.

3.1.3 Bin Contamination

The composting facility on the New SUB rooftop would not be able to handle food wastes such as dairy, meat, and grain products because they develop an unpleasant odour and will attract vermin. An unpleasant odour and the vermin it attracts would not only repel students from enjoying the rooftop garden, but also present health and safety issues. The current sorting system at the SUB that facilitates separation between garbage, compost, and plastics allows dairy, meat, and grain to be disposed in the bin for compost. Therefore, the current system of sorting would be incompatible with plans to compost on the new SUB. Either an additional sorting step would be needed, or manual sorting of the current compost would be required to remove unsavory materials. The in-vessel facility is able to handle dairy, meat, and grain waste and does not have a problem with vermin because it is a closed-loop process. The social issue of odour is also negligible because of its location at the South Campus far away from students and buildings.

A sorting station at the new SUB would potentially require four bins: garbage, plastic, compost for the in-vessel facility, and compost for the rooftop facility. An issue that already exists with the sorting stations at the current SUB is bin contamination, where people throw away waste that isn't compostable into the compost bin. Despite clear signs that indicate proper waste disposal at the bins, contamination of the bins still remains a problematic issue for UBC Waste Management staff [11]. It was found by MJ Waste Solutions in their Waste Audit Results that the compost bins already have a contamination rate of 10% [3].

Two compost bins each with different allowable waste may create further confusion among students and faculty. The New SUB would be the only location with a different sorting system compared to the other seventy or so locations that UBC Waste Management collects organic waste from. Consequently, an even higher contamination rate is expected in the more restrictive bins destined for the rooftop facility. The current SUB has already demonstrated that prominent visual instructions at the sorting stations can only eliminate so much contamination, and adding another bin would complicate sorting further. If implemented, the rooftop composting facility would be highly sensitive to even a small amount of contaminants and is likely to develop odour and pest problems.

The other option is to manually sort the compost afterwards to select materials that the rooftop system would be capable of composting. This method, however, would be extremely time consuming and contamination is still unavoidable.

3.2 ENVIRONMENTAL ANALYSIS

Some of the environmental concerns when comparing the two methods include transportation emissions, energy use, and water consumption. Byproducts of the

composting must also be considered, such as leachate runoff, odors, and pest problems.

3.2.1 Transportation Emissions

Clearly composting on site is superior because the organic waste must only be moved to the rooftop rather than being transported to the South Campus. In addition, the final product need not to be delivered, as it would be produced onsite.

3.2.2 Energy Use

Annually, the in-vessel facility uses approximately 200 000 kWh of energy to operate. This is equivalent to the average annual energy consumption of a dozen Canadians [14]. Since composting at the new SUB would largely involve manual labour, energy usage for the compost piles would be next to nothing.

3.2.3 Water Consumption

The In-Vessel Facility uses 58000L of water per year to rinse out compost bins and maintain ideal moisture levels for decomposition [15]. Water consumption for composting on the SUB rooftop would be comparable. Rather than using potable water as the in-vessel composting unit does, collected stormwater would be a much more environmentally friendly option.

3.2.4 Leachate Runoff

Since a certain moisture level is required for composting, regular water application of compost is needed. Watering compost produces a liquid runoff known as leachate when the compost is saturated and is a common occurrence [15]. The composition of leachate is mainly enzymes, hormones, and soluble nutrients absorbed from the compost. Although it is not an intrinsically toxic substance, leachate is considered an environmental pollutant when runoff from the compost site occurs. The substances in compost leachate that are known contaminants are ammonia and dissolved organic compounds. Leachate is a potential environmental hazard because the rooftop is such a highly accessible location. The benefit of the in-vessel facility is its closed-loop operation that prevents runoff of leachate and makes its management much easier.

3.2.5 Gas Escape

Another advantage of the in-vessel composting unit is that it uses a bio-filter to clean the air used for composting. An open compost pile like the one proposed for the new SUB rooftop has the potential to release unpleasant smelling gasses as a byproduct of the decomposition.

3.2.6 Pest Problems

Yet another issue solved by a closed system like the in-vessel composting unit is that it prevents pests like rats or birds from getting access to the compost. Open piles are much more susceptible to pest problems, and as a result, the health and safety issues that accompany them.

3.3 ECONOMIC ANALYSIS

3.3.1 In-Vessel Composting Costs

One potential advantage to composting at the new SUB would be reduced transportation costs. UBC Waste Management currently collects 47 tonnes of compostable material from the SUB [3]. This amounts to just over 1000 green bins per year, which results in an extra 32 trips per year for the refuse truck to haul this material to the in-vessel composting unit. In doing so, a diesel refuse truck uses approximately 215 litres of diesel per year. The total fuel costs per year for transporting food waste from the SUB is about \$250. See Appendix A for detailed calculations.

Aside from the fuel savings, there would be few other savings related to transportation. UBC Waste Management already services nearly 70 different locations on campus, see Figure 5, to collect organic material from nearly 200 bins. Discontinuing its service to the new SUB does not have a significant impact on its pick-up schedule [11].



FIGURE 5. COMPOST BIN LOCATIONS ON CAMPUS. Source: <http://www.batchgeo.com/map/?i=21511c87ab7bc9e1204112bab61d5eda>.

Composting at the new SUB would also reduce the volume of material that in-vessel composting unit must process. A student report estimated that the In-Vessel composting unit processes 213 tonnes of compostable material annually. Since 47 tonnes of this material originates from the SUB currently, there would be a 22% reduction in material moving through the composting unit [11]. Unfortunately, since the In-vessel system is largely automated, there would be little if any labour savings due to a reduced process load.

3.1.2 Rooftop Composting Costs

Conversely, composting at the new SUB using traditional methods, while inexpensive to get up and running, is very labour intensive. Startup costs vary widely depending on the application and type of composting. Inmates at the Brown Creek facility constructed compost bins by hand, which would be substantially cheaper than purchasing and shipping an industrial bin [2]. Products such as the “Earth Tub” cost nearly \$1000 per unit [15]. An optimal design outlined in a bin composting study could be construed for the new SUB with a low startup cost [5].

4.0 CONCLUSION AND RECOMMENDATIONS

After examining the social, environmental, and economic advantages and disadvantages of composting on site in the new SUB, it is clear that the in-vessel composting facility is the better option. The in-vessel composting system at UBC is already an established program that has founded a consistent composting policy across the entire campus.

Primarily due to labour costs, it is more favorable economically to compost at the in-vessel facility. This is due to the scale of the operation at the South Campus. Since so much organic waste is processed at this location contributed by the rest of campus, waste from the SUB is only responsible for a fraction of the operating costs.

Environmentally, it is preferable not to transport the entirety of the SUB's organic waste to the South Campus, and transport the compost after processing back to the SUB for use. However, the in-vessel composting unit removes many environmental concerns related to the composting itself as a closed and controlled system. Composting at the SUB creates concerns about leachate leaking, and odor emissions at a potentially popular location.

From a social perspective, composting at the SUB is a good concept. Rather than keeping the process at the South Campus, composting can be prominently displayed at work in the new SUB. This will hopefully spur awareness of the sustainability issues surrounding waste disposal and could potentially positively affect user consumption and disposal habits.

Students, faculty, and users of the university have been presented with a unified set of standards for what compost bins around campus can and cannot accept. Creating a competing compost process exclusively for the new SUB would require unique compost bins. These bins will be less accepting of the spectrum of organic materials than is currently being collected. This lack of consistency between these two systems could lead to user confusion, and betray the image of composting as being a simple and easy process for the consumer.

Therefore, it is our recommendation that UBC Waste Management continue to deal with the majority of organic waste generated at the SUB. They already have the capacity to do so in a well organised and responsible manner. It is still important however, that some form of composting occur at the new SUB in order to foster awareness about composting, and to support the new SUB's goals of a world leading example of sustainable design. Composting at the SUB would need to be on a smaller scale where the labour and space requirements are more manageable.

Also, to avoid confusing users with different types of compost bins, we recommend that organic material for the rooftop composting should be sourced only from pre-consumer waste. This way only certain staff at the new SUB would be required to sort out organic waste for the rooftop composting. Contamination would be lower than through public sorting, and SUB users would not have to deal with multiple types of

compost bins.

APPENDIX A

CALCULATION OF TRANSPORTATION COSTS

Density of food waste: 514kg/m³

Annual SUB compost waste: 46750kg

Capacity of Bin: 120L

Truck capacity: ~32bins

Fuel economy: ~0.84L/km

Trip distance from south campus facility to SUB and back: 8km

Fuel Cost: 115cents/L

Bins on average are only filled to 75 percent so:

$$514\text{kg/m}^3 * (0.75)120\text{L} = 46.26 \text{ kg/bin}$$

$$(46750\text{kg/year}) / (46.26\text{kg/bin}) = 1011 \text{ bins/year}$$

$$(1011 \text{ bins/year}) / (32 \text{ bins/trip}) = 32 \text{ trips / year}$$

Since bins at the SUB are collected with other bins around campus, annually the SUB is only responsible for an extra 32 collection trips per year.

$$32 \text{ trips/year} * 8 \text{ km/trip} = 256 \text{ km/year}$$

$$256 \text{ km/year} * 0.84\text{L/km} = 215.04\text{L/year}$$

$$215.04\text{L/year} * 1.15\$/\text{L} = 247.30\$/\text{year}$$

COMPARISON OF ENERGY USAGE OF IN-VESSEL COMPOSTING UNIT

Annual electricity consumption per capita in Canada:

17 321.0 kWh/person

Annual energy consumption of In-Vessel composting unit:

200 000 kWh

$$200\ 000/17\ 321 = 11.547 \text{ people}$$

CALCULATION OF ROOFTOP COMPOSTING CAPACITY

Bin height: 1.5 m (assumption)

Bin area: 75% of the allocated space (assumption) = 75%*45 m = 33.75 m

Rooftop composting capacity: 1.5 m*0.75*45 m = 51 m³

CALCULATION OF COMPOSTABLE FOOD WASTE GENERATION

Annual food waste mass: 36464 kg

Compostable annual food waste mass: 50% of the annual food waste mass
(assumption) = $50\% * 36464 \text{ kg} = 18232 \text{ kg}$

Annual food waste volume: $(18232 \text{ kg} / 1029 (\text{kg}/\text{m}^3)) = 17 \text{ m}^3$

The annual waste volume for each of the remaining waste categories was calculated using the above method.

CALCULATION OF WASTE DIVERSION:

Annual compostable waste mass: 41857 kg

Compost volume reduction: 65% (assumption)

Rooftop composting capacity: 51 m^3

Annual waste mass that can be composted: $51 \text{ m}^3 / 65\% = 78 \text{ m}^3$

Waste diversion: $78 \text{ m}^3 / 121 \text{ m}^3 = 64\%$

CALCULATION OF ROOFTOP GARDEN COMPOST APPLICATION VOLUME

Compost application depth: 0.05 m (assumption)

Phase 3 greenhouse and crop area: 753 m^2

Phase 3 compost application volume = $0.05 \text{ m} * 753 \text{ m}^2 = 38 \text{ m}^3$

The compost application volume for phase 1 and 2 were calculated using the above method.

CALCULATION OF THE AMOUNT OF COMPOST TUMBLERS NEEDED AND TOTAL PRICES FOR TUMBLERS

Amount of compost needed to be produced: 51 m^3

Capacity of tumbler: 7 ft^3

Converting capacity to m^3 : $0.02831 \text{ m}^3 * 7 \text{ ft}^3 = 1.981 \text{ m}^3$

Amount of tumblers needed: $51 \text{ m}^3 / 1.981 \text{ m}^3 = 25.7 \text{ tumblers} = 26 \text{ tumblers}$

Total prices for 26 tumblers: $26 * \$159.99 = \4159.74

The amount of stackable tray bins were also calculated using the above method, with the assumed dimension of: 16" x 16" x 21".

CALCULATION OF ESTIMATED LABOUR COSTS NEEDED FOR TRADITIONAL AND VERMICOMPOSTING

Hourly wage for a hired labour to do gardening: \$15/hour (assumption)

Traditional:

$$42 \text{ hours} * \$15 = \$630$$

Vermicomposting:

$$62 \text{ hours} * \$15 = \$930$$

CALCULATION OF VERMICOMPOSTING WORM COSTS

Cost of worms: \$30 per lb (estimated assumption)

For each 0.1 m² of surface area, 100 g of breeder worms are added to the boxes.
dimension: 16" x 16" x 21"

Amount of worms needed:

$$607 \text{ stackable trays} * 12.8\text{cm}^3 \text{ surface area} * 5 \text{ surface areas per tray} = 38848 \text{ cm}^2$$

$$38848\text{cm}^2 * 10^{-2} = 388.48\text{m}^2$$

$$388.48\text{m}^2 / 0.1\text{m}^2 * 100\text{g} = 388,480\text{g}$$

Total cost of purchasing worms:

$$388,480\text{g} * 0.0022046 = 856.44\text{lb}$$

$$856.44\text{lb} * \$30 = \$25,693.29$$

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