UBC Social Ecological Economic Development Studies (SEEDS) Student Report

UBC Zero Waste Planning Tool

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A UBC SEEDS REPORT

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Executive Summary

The University of British Columbia has an ambitious vision that includes fostering a *'sustainable society'*. A part of such a society is the production of Zero Waste, or 100% diversion of used materials. The University has made strategic moves, such as the hiring of Zero Waste and Water Engineer, Bud Fraser, to produce a Zero Waste Action Plan that will set the University on the path of Zero Waste by 2030.

In order for the Zero Waste plan to be accepted, it needs sophisticated evidence-based modelling surrounding the waste predictions, greenhouse gas emissions and costs associated with a University wide shift. The overall waste production at UBC in the 2010-2011 Waste Audit revealed a total site recycling rate of 59%, with 43% operational waste diversion. Operational waste[1] diversion targets are 70% by 2015 and 80% by 2020, before achieving Zero Waste by 2030.

The team modeled expected waste by 2020, the expected greenhouse gases per diversion stream by 2020, and modeled expected costs by 2020. The modeling was done in Microsoft Excel for UBC waste and did not include construction and demolition waste.

The model allowed manipulation of diversion rates for each building type for each stream. There were three buildings types considered: ancillary, tenant and core buildings. For diversion the following streams were considered: organics, mixed paper, returnable containers, cardboard, e-waste, construction materials (but not construction and demolition stream), as well as recyclables and non-recyclables.

With these major modelling parameters in mind (amongst many others), a Zero Waste Case was produced considering 80% overall diversion by 2020. This case was compared with the Business as Usual case, and was compared to composting the organics in-house versus outsourcing to an industrial composter, such as Harvest Power.

The results were as follows:

- In all three models produced, the total waste generated is expected to be 6,490 tonnes of operational waste per year
- In the business as usual case, diversion was expected to be maintained at 42% for operational waste. In the Zero Waste case, diversion increased to 77% (where 80% UBC Waste diversion was considered possible factoring in construction and demolition waste and total UBC waste)
- The Zero Waste model would save UBC 4,750 tonnes of CO_2 equivalents from 2014-2020
- The Net Present Value, using the Jaccard discount rate of 3.5%, and 2011 to 2020 time period, was found to be:
    - Lowest Cost - $3.82 Million for Zero Waste with outsourcing to an industrial composter
    - Medium Cost - $3.90 Million for Business as Usual Case

[1] *Note: operational waste does not include construction and demolition waste, which is quite high at 81% diversion.*

- Highest Cost - $4.37 Million for Zero Waste model with UBC in-house composting

Major assumptions are as follows, further details of other assumptions are in the full report contained herein:

- Waste generation in kg per building type per m^2 per year was equivalent for each year
- Costs per tonne were fixed for the duration using 2011 costs (except increasing costs for disposal tipping fee)
- U.S. EPA 2006 based greenhouse gas emissions
- Assuming that waste generation increased with building development on campus and proportionally to the fixed waste generation rate (i.e. kg per m2 per year per building type)

Eight recommendations were made for UBC Policy:

1. Outsource Organics
2. Implement Sustainable Supply Chain Management
3. Implement Zero Waste Challenge Comparing Building-to-Building
4. Aspire to and Achieve Zero Waste by 2030
5. Communicate, Brand and Engage the entire UBC Community, get buy-in for a Zero Waste University
6. Our endorsement of the 10 Steps in the Preliminary 'Zero Waste Action Plan Content Summary' by Bud Fraser
7. Introduce an Environmental Management System to manage the Zero Waste Plan
8. Pursue Methods to Reduce Waste Generation per Facility, so it decreases over time and does not remain at the current waste generation rate, in further Zero Waste Planning Tool updates

Further modeling is required to examine optimizations in greenhouse gases, costs and waste diversion. This is a preliminary assessment and provides an indication as to where UBC should look to invest time and resources to become Zero Waste by 2030.

After phase I of the Zero Waste Action Plan is under way, a Phase II Zero Waste Action Plan will need to be created and implemented; this should be examined closer to the year 2020. In the meantime, the model and the Zero Waste Action Plan should act as a living document in the attainment of the 2015 and 2020 waste diversion goals, 70% and 80% respectively. Continuous updates will ensure success of the Zero Waste Targets, this is the intent of the model, to be continuously used and improved as the University strives for Zero Waste.

The Zero Waste Action Plan, once ratified by the UBC Board of Governors, should be acted upon with urgency – 2015 is just around the corner.

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1 Introduction

The University of British Columbia (UBC) has an ambitious vision and yearns to lead advances towards a "*sustainable society*".[2] The University has developed many strategies which include sustainability, including the *Climate Action Plan, Place and Promise: The UBC Plan,* and *The Sustainability Strategy*. In the last of these strategies, UBC claims to be "*Canada's Leader in campus sustainability*"[3]. Sustainability encompasses economic, social and environmental management. One of such pillars is the management of waste, where UBC has many ambitious targets that include: waste reduction, pollution reduction, conservation of resources, and sustainable supply chains. They also conducted a waste audit and set a goal to reduce Operational waste to 55% diversion by 2010 (which was subsequently attained). Despite UBC's ambitious sustainability targets, the campus did not make the top ten list of Canadian Sustainability Campus Rankings for 2012[4]. There is much work to be done and the campus has hired a Zero Waste and Water Engineer, Bud Fraser, to continue work on the University's Zero Waste Action Plan.

As a part of the Zero Waste Action Plan, a model is needed to predict waste scenarios based on investments and expected waste outcomes. Data on costs and total waste output is important, as well as knowledge of the greenhouse gas emissions associated with disposal and diversion scenarios. Working towards a Zero Waste future requires detailed planning on policy implementation and resource allocation. To fully grasp the decision making, a prediction model needs to be created which examines the diversion amount per category for the three factors mentioned: cost, waste production (as mass and percentage, greenhouse gas emissions per stream and total emissions. Different diversion stream impacts will also need to be accounted for examining: organics, mixed paper, returnable containers, cardboard, e-waste, construction materials (not construction and demolition waste, but maintenance construction), other recyclables and non-recyclables.

These scenarios require comparison to actively determine the best strategy in which to move forward under the umbrella of a sustainable University. Scenarios for consideration are business as usual (BAU) case and two Zero Waste Action Plan cases – one in which UBC's composting facility handles diverted organics, and one in which Harvest Power's Richmond facility handles the diverted organic waste stream.

These scenarios need to share a common framework including a well-defined inventory known as a baseline of current UBC operations and waste inventory including where the waste ends up: landfill, waste to energy, compost and recycling. This framework, once defined, is to be used to predict waste growth based on established UBC metrics and best estimates. In order to determine the overall effect of various scenarios variable parameters such as the amount of recycling and composting need to be

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[2] (University of British Columbia, 2012)
[3] (UBC Sustainability, 2005)
[4] (Universitas Indonesia, 2013)

altered to determine cost effective GHG reduction scenarios which demonstrate the most effective allocation of resources in the future.

The following report details the methodology of the modelling which was completed, inclusive to their results and recommendations for actions and further study for the Zero Waste Action Plan. This report entails the details surrounding the *UBC Zero Waste Planning Tool*.

2 Background Information

2.1 Social Ecological Economic Development Studies (S.E.E.D.S)

S.E.E.D.S, an organization within University of British Columbia supports student research areas of sustainability on campus while gaining credit for their work. Students collaborate with faculty on issues such as waste management, water management, climate change, transportation and conservation. Bud Fraser, the waste engineer for S.E.E.D.S, wanted a cost and greenhouse gas emissions model to be able to quantify different waste scenarios, create evidence based zero waste policy, and to understand the benefits associated with implementing a Zero Waste Action Plan for the University of British Columbia by 2030.

2.2 Context

UBC has been viewed as a leader of sustainability initiatives, but when researching the operational disposal and diversion rates of the 2010-2011 fiscal year, 3100 and 2300 tonnes, respectively had been discarded.[5]Only 43% of Operational waste was being diverted to recycling facilities, which is a good start, but when implementing the Zero Waste Action Plan there are hopes to reach diversion rates of 70% by 2015, 80% by 2020 and 100% by 2030.5 Therefore, policy measures must be implemented in the near future to attain this goal. Currently, the waste is going to multiple facilities including the Delta and Cache Creek Landfill, the waste-to-energy facility in Burnaby, and multiple transfer stations in the lower mainland, and UBC composting facility on campus[3].

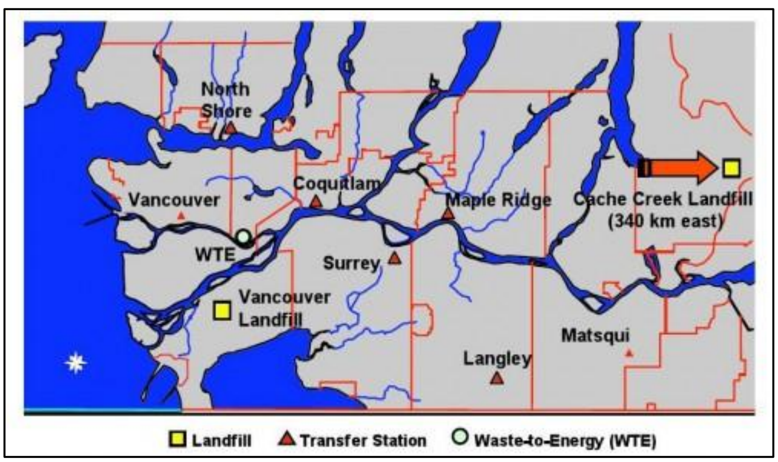

Figure 1: Regional solid waste facilities[6]

2.3 Motivators for UBC Waste Policy

The city of Vancouver plans to be the greenest city in the world by 2020.[7]The Greenest City Action plan was started in 2009 with the input of city staff, social media and hundreds of organizations all looking to

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[5] (UBC Vancouver Campus Zero Waste Action Plan, 2012)
[6] (News1160, 2011)
[7] (City of Vancouver, 2013)

make change. Through 10 key areas of action, Vancouver will focus on three areas: carbon, waste and ecosystems. A large motivator for UBC is Vancouver's tough upcoming waste policies. By 2015 Vancouver plans to have implemented a ban on organics sent to the landfill, as well as a 50% decrease in total waste produced by 2020 (compared to 2008 levels)[8]. In turn, this will have spill over effects to the UBC municipality in terms of tipping fees and other projected costs. Although the amount of waste from UBC is only a small fraction of the total waste of Greater Vancouver Region District (0.28%), the Zero Waste Plan could have a first mover advantage in terms of showing sustainability leadership in the region and across Canada.

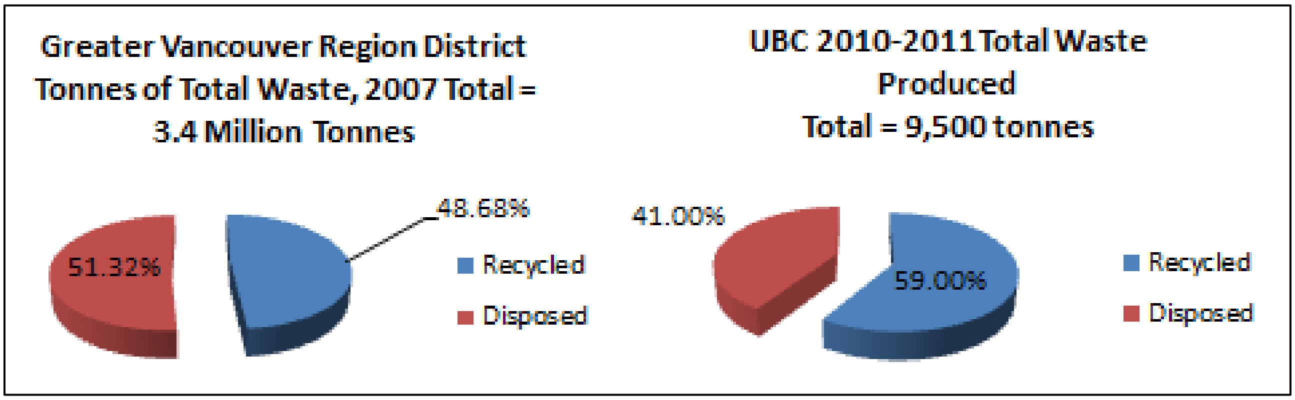

Figure 2: Waste portfolios for greater Vancouver and UBC[9]

3 Methodology

3.1 Time Frames

The timeframes studied in this report will assume 2011 as the baseline year with 2015 and 2020 used as future benchmarks. Intermediate years were extrapolated based on averaging over the benchmark timeframes. The timeframe did not expand past 2020 due to incomplete UBC growth prediction data used in the analysis, as well as future uncertainty.

3.2 Waste Streams

Subcategories were used in order to obtain finer granularities in the waste dispersion based on type of material on top of modeling the baseline scenario with respect to the 2011 UBC waste audit. There are eight waste categories used in this model that were defined by Bud Fraser. The categories are summarized in Table 1.

[8] (City of Vancouver, 2013)
[9] (Waste Management Greater Vancouver, 2007)

Organics – food, compostable packaging
Recyclable mixed paper
Recyclable & returnable containers – cans, bottles/glass, metal, plastic
Recyclable cardboard
E-waste, lamps, bulbs and batteries
Construction materials including wood, gypsum, metal & concrete
Other recyclables
Non-recyclables

Table 1: Model's Waste Categories

3.3 UBC Building Categories

This study divided the UBC campus buildings into three categories: Core, Ancillary and Tenant. These categories were picked in order to accurately model the waste audit information in 2011 on top of combining common disposal and/or diversion costs.

3.4 Project Waste Scope

The model included the core, ancillary and tenant buildings outlined above and did not include large industrial construction waste. The Construction and Demolition (C&D) waste disposal and diversion rates were not included, because often C&D outsource waste to third party contractors. According to the 2011 UBC Waste Audit, C&D have achieved diversion rates of 81% in 2011 and are projecting 85% and 90% by 2015 and 2020 respectively. The buildings in this study have a current operational diversion rate of 43% and plans to push the 2015, 2020 levels to 60 and 70% respectively. These rates were chosen to reach an overall UBC waste diversion that fits within the Zero Waste projection outlined above.

3.5 Waste Mass Fraction and Growth Predictions

The mass fraction of each building type's waste stream (Table 1) has been modelled by Bud Fraser based on a 2011 waste audit. This inventory was then scaled to 2015 and 2020 based on a UBC building floor space (m^2) growth prediction. The growth predictions did not take into account any waste production reduction measures through the time period such as assumptions based on future packaging reductions, etc. This assumption was valid for this study since the main outcome of interest was the change of diversion rate on cost and GHG emissions and therefore, all other parameters of waste reductions were kept constant. It is important to note that the option to introduce waste production reduction is implemented in the model but was not utilized throughout this study.

3.6 End of Life Categories and GHG Emission Factors

The end of life of a material is defined as the period after its service has been fulfilled or more commonly: disposal (garbage) and diversion (recycling/composting). The waste's various potential "final destinations" will have different impacts on the environment that need to be quantified. The metric of interest of this study will be Green House Gas (GHG) emissions in metric tonne CO_2eq. This unit scales the various emissions with greenhouse gas potential to one common metric. A method to quantify the effect of various waste disposal/diversion methods is to determine the "emission factor" for each end of the life stream. Emission factors correspond to "Metric Ton of Carbon Equivalent per Metric Ton of Solid Waste". Therefore if we have one tonne of waste going to a landfill instead of composting, for example, the two different emission factors will be able to quantify the impact on the GHGs emitted. In order to model each end of life scenarios it was important to estimate emission factors for each of the streams given in Table 1 for each potential end of life destination.

The emission factors were modelled based *on 2006 Environmental Protection Agency (EPA) Solid Waste Management and Greenhouse Gases Life-Cycle Assessment of Emissions and Sinks*[10] and then scaled based to local properties such as disposal fractions, waste content etc. Once the emission factors were modelled they were kept constant throughout the 2011, 2015 and 2020 time periods.

Each waste stream in Table 1 was assigned four emission factors: WTE, LFG, LG and recycling/composting.

3.6.1 Disposal: WTE, LFG, LF

UBC's waste disposal is broken into three parts due to the various disposal sites used. These sites consist of:

- LFG (Land Fill Gas Recovery)
  - Delta landfill that has gas recovery, in turn, recovering emitted methane.
- LF (Land Fill no Gas Recovery)
  - The Cache Creek land fill where no methane gas recovery was assumed to take place
- WTE (Waste to Energy)
  - Burnaby Waste to Energy Facility where waste is combusted and electricity and heat is produced.

3.6.1.1 Waste Breakdown

The waste site disposal composition was modelled on data from the city of Vancouver's waste management data that is summarized in Table 2.

	Fraction
WTE: Burnaby	22%
LFG: Vancouver	40%
LF: Cache Creek	38%

Table 2: Metro Vancouver waste disposal breakdown. UBC was modeled on this breakdown[11]

3.6.2 Diversion: Recycling and Composting

The diversion stream will be broken into two categories: off-site recycling and on-site/off-site composting. The UBC on-site composting facility is located on the south side of the campus whereas the off-site composting is Harvest Power in south Vancouver. The off-site Recycling depot is located at the South Vancouver Transfer Station.

[10] (United States Environmental Protection Agency, 2006)
[11] Source: Waste Management in Greater Vancouver.

3.7 Emission Factors

The emission factors used throughout the analysis are summarized in Table 3. Details of the assumptions and modeling are outlined in Appendix A: GHG Emission Factor Model Details.

	Solid Waste WTE tonne CO2 eq/tonne	Solid Waste LF tonne CO2 eq/tonne	Solid Waste LF with LFG tonne CO2 eq/tonne	Total Disposed Emission Factor tonne CO2 eq/tonne	Diverted Downstream Emission Factors tonne CO2 eq/tonne	Diverted Upstream Emission Factors tonne CO2 eq/tonne
Organics - food, compostable packaging	0.02	0.4	0.09	0.2	-0.04	0
Recyclable mixed paper	0.02	0.5	0.1	0.3	0	-0.9
Recyclable & returnable containers	0.5	0.0	0.00	0.1	0	-0.5
Recyclable cardboard	0.2	0.6	0.1	0.3	0	-0.8
E-waste, lamps, bulbs and batteries	0.1	0.0	0.00	0.02	0	-0.6
Construction materials	0.02	0.3	0.1	0.1	0	-0.6
Other recyclables	0.1	0.5	0.1	0.3	0	0
Non-recycable	0.4	0	0	0.09	0	0

Table 3: Emission factor summary for various ends of life scenarios.

3.8 GHG Emission Scope

In order to correctly apply the above modelled EPA based emission factors and quantify emission and GHG changes between scenarios, it was chosen to define the end of life categories into two categories: Upstream and downstream. The downstream emission factors consist of the Burnaby WTE, Delta LFG, Cache Creek LF and composting whereas the upstream consists of recycling. This division is illustrated in Figure 3.

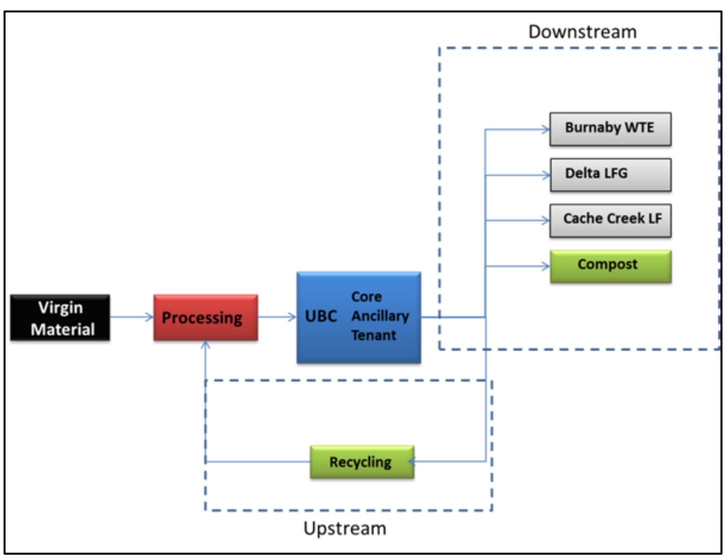

Figure 3: GHG upstream and downstream emission categories.

The importance of this division becomes apparent when one studies the source of the emission factor modelling. The downstream emission factors take into account all of the emissions from the process of depositing the waste in a corresponding facility not taking into account virgin material, processing or

UBC onsite transportation/handling emissions[12]. The upstream emission factors, summarized in Table 3, model the change in emissions between creating a material from virgin or from recycled material. This category does not, therefore, measure inventory emissions but instead gives the change in emission value of material manufacturing. Therefore, if one wants to accurately look at the emission and GHG changes between scenarios these two categories must be treated separately until being combined at the end.

Δ Downstream Emissions Δ Diverted Upstream Δ NET Emissions + Diverted	tonne CO2eq

Table 4: Emission and GHG reduction modeling outline.

This process is illustrated in Table 4. The downstream emissions were calculated for the baseline and the Zero Waste Scenario and their change (Δ Downstream Emissions) was determined. This was then repeated for the upstream change in emissions and a baseline/scenario difference was also determined (Δ Diverted Upstream). These two changes were then added in order to obtain an overall net GHG reduction.

4 Results

4.1 Waste Breakdown

Diversion rates of the individual waste streams were adjusted for each discussed building type taking into consideration individual feasibility on top of cost constraints. Details of the various proposed diversion rates are summarized in Appendix C: UBC Zero Waste Model Diversion Rates. The BAU operational waste diversion rates were constant at 43% throughout whereas the operational building Zero Waste model showed 43%, 62% and 77% up to 2020, changing respectively through progressing years. Figure 4 summarizes the BAU and Zero Waste dispersion rates.

[12] Transportation emissions to the various sites in included Appendix A: GHG Emission Factor Model Details.

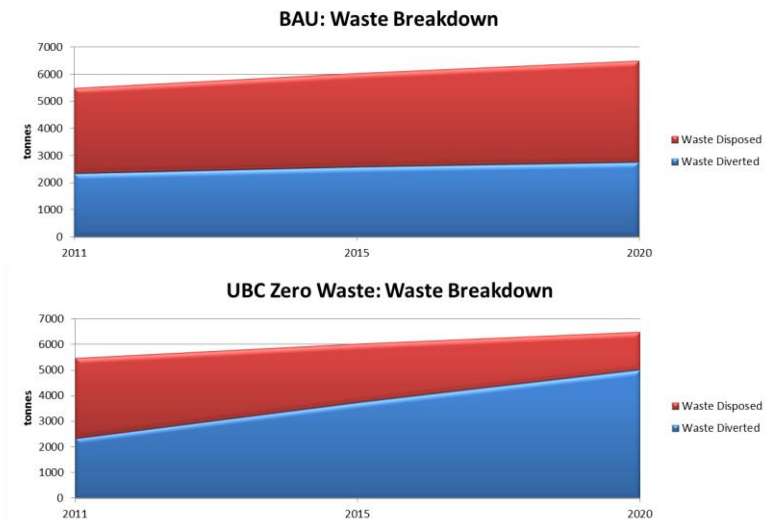

Figure 4: Waste Breakdown for BAU and Zero Waste.

As can be seen above, Zero Waste model accounts for the increase in operational waste diversion, up to 77% by 2020. BAU case remains at 43% operational waste diversion. Both models predict a total waste of 6,490 tonnes by 2020 based on the model predictions. Model predictions assume a fixed waste generation rate per building type per square meter per year, assuming growth rates in Universities size as the main growth factor.

4.2 GHG reductions between BAU and Zero Waste

The overall annual GHG reduction rates can be seen in Figure 5 where it is apparent that increasing the diversion rates over time in turn does increase the annual reduction rate in GHG's as expected. The cumulative reduction of GHG's by applying the Zero Waste strategy guidelines versus the business as usual between 2014 and 2020 is over 4,755 tonnes of CO_2eq based on the model parameter specs.

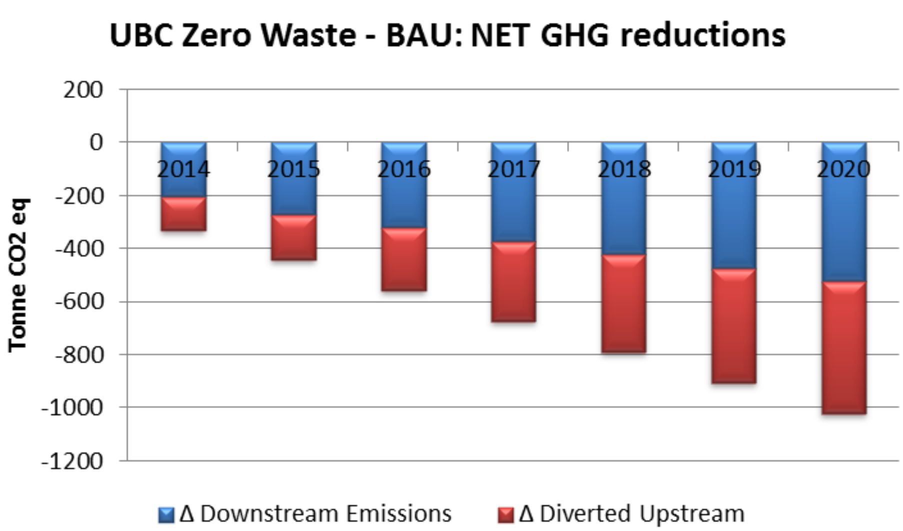

Figure 5 : Net GHG reduction between the Zero Waste and business as usual scenario.

4.3 Comparisons of Cost and Efficacy of Mitigation Strategies

According to data collected by UBC Waste Management during 2009-10, 55% of the Operational waste heading to landfill at UBC was organic material[13]. Drastically reducing the amount of organics disposed is important to reducing the disposal rate, and is a major factor in the cost analysis for the UBC Zero Waste Action Plan. Other important reasons for placing a premium on the compost diversion: first, Metro Vancouver's planned 2015 ban on organics sent to the landfill (and associated fines), and second, because of the volume of organic waste produced, managing organics diversion costs is very important in choosing a Zero Waste strategy.

The scope of the diversion and disposal costs was focused on UBC's Operational waste streams, not its Construction and Demolition streams. The diversion costs for the waste material streams were obtained from recycling contractors and UBC staff. The tipping fee (disposal cost) forecasts were obtained from Metro Vancouver's Finance Committee. However, the financial framework the committee used was more conservative than in previous years due to current economic conditions and may be reassessed and adjusted in the future. Further details on the cost analysis can be found in Appendix B: Cost Model Details.

The three different scenarios that were used to account for costs in order to calculate the most feasible way to become a Zero Waste campus by 2030 are: Business as Usual [BAU], UBC Composting and Harvest Power Composting. The results are illustrated in Figure 6 and explained in detail below.

Note: Dollar values have not been inflated over time; therefore they may under-represent the actual cost.

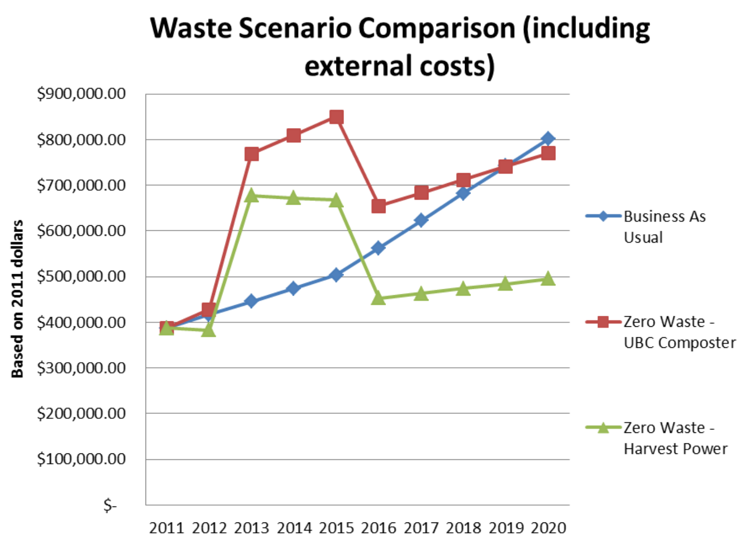

Figure 6: BAU and Zero Waste Cost Predictions. Zero Waste is modelled for two composting locations: UBC composter and Harvest Power.

[13] (UBC Campus Sustainability, 2012)

4.4 Business as Usual [BAU] (Scenario 1)

When looking at the cost associated with the model "Business as Usual" it is apparent that the costs are increasing due to the amount of waste that is projected to occur with zero change. The BAU scenario represents UBC campus waste and diversion costs if the current rates of waste disposal and diversion remain constant. By 2020 the waste costs on UBC's Vancouver campus will increase from approximately $400,000 in 2011 to a staggering $800,000 per year. Although our study did not include the amount of innovation that companies may or may not be forced to partake in to reduce the amount of packaging, this is something that UBC could look at in the future models. This model has been created as a comparative baseline for our more innovative diversion models. Costs associated with diversion stay relatively constant at around $100,000. This model is unrealistic due to the pressure that Vancouver will bring by their plans to become the greenest city in the world by 2020. However, the costs associated with this model are relative to that of upgrading the UBC compost facility.

4.5 UBC Composting (Scenario 2)

As diversion of UBC's recyclable materials increases to meet the Zero Waste Plan diversion targets, so do the associated costs. The cost scenario in which the UBC in-vessel composter is used has a higher diversion cost due to running the on campus facility and its lower processing volume in comparison to other organics processing facilities in the region. The current estimated cost to divert one tonne of organic material using UBC's facility is $300; this is however a contentious issue and the true price of compost at UBC is still being determined, this number represents today's best estimate. Due to economies of scale, the expected per tonne processing cost is hoped to decrease to $120 by 2015 and remain at that level. Currently UBC's composting facility is running at approximately 1/3 of its full capacity. Although there is the possibility that the per tonne cost to process organics may decrease over time due to the facility reaching full capacity, the rate is likely going to remain around $120 per tonne due to the cost of running the facility.

This scenario is beneficial because it allows UBC to keep all organics processing on campus and the in-vessel composter's output can be reused on site. However, there will be an added cost of approximately $150,000 (2013), $300,000 (2014-15) and $225,000 (2016) to implement UBC's Zero Waste Action plan. From 2017 onwards there will be an annual maintenance cost of $75,000. This significantly raises the costs of Scenario 2; however, in the long term (projecting past 2020) it will cost less than the BAU scenario.

4.6 Harvest Power Composting (Scenario 3)

The Zero Waste Plan cost scenario in which Harvest Power's facility in Richmond is used to divert UBC's organic waste stream is the most beneficial in terms of costs. Although Scenario 3 also includes the added cost of approximately $150,000 (2013), $300,000 (2014-15) and $225,000 (2016) for the Zero Waste Action Plan implementation, as well as the 2017-2020 annual $75,000 maintenance cost, Harvest Power is able to process all of UBC's organics waste for approximately $65 per tonne because of economies of scale.

Within the Harvest Power scenario, the total diversion costs are much smaller in comparison to the annually increasing disposal costs mandated by Metro Vancouver. The downside of this scenario is that UBC will have to develop a strategy to transition from using UBC's composting facility to Harvest Power, dealing with the end-of-life of the in-vessel composter and develop a system to deliver UBC's compost to Harvest Power's facilities.

4.7 NPV Calculation

A net present value (NPV) calculation was performed on the three scenarios using a Social Discount Rate of 3.5%[14]. The most valuable project in terms of NPV of costs is the Zero Waste Plan with organic waste being diverted to Harvest Power's facility (seen in Figure 7). It is evident that the results of the NPV calculation back up our previous cost results. The costs are not inflated and presented in the baseline year (2011) dollar valuation for ease of comparison from 2011 to 2015. The real NPV numbers are summarized here:

- Lowest Cost - $3.82 Million for Zero Waste industrial compost outsourcing
- Medium Cost - $3.90 Million for Business as Usual Case
- Highest Cost - $4.37 Million for Zero Waste model with UBC in-house composting

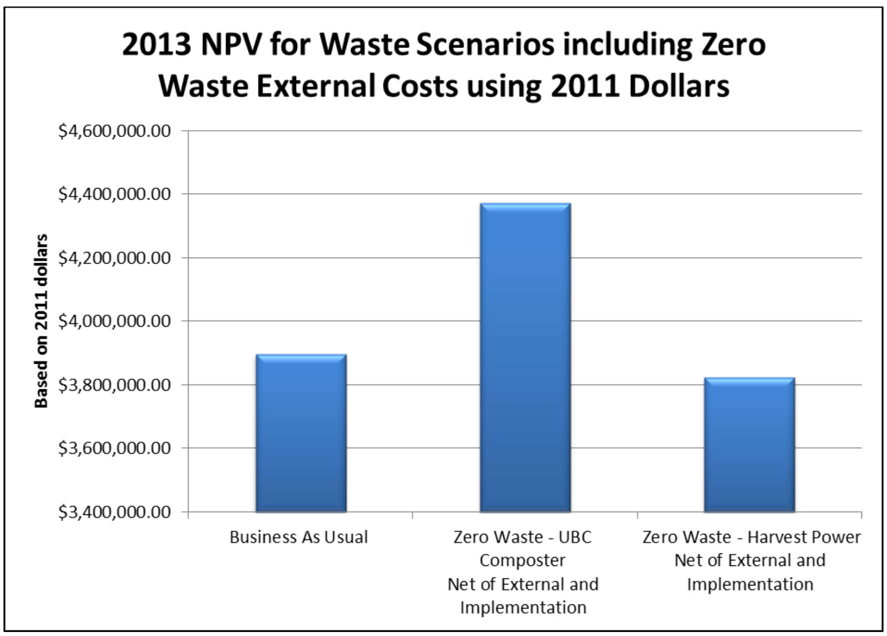

Figure 7: 2011 NPV for BAU and Zero Waste Scenarios.

4.8 Cost Summary

Originally, our group believed that the "Business As Usual" model would be the most expensive cost. After collecting the data, we found that upgrading as well as increasing the UBC composter to reach the facilities capacity is almost just as expensive as BAU for diverting organics. Unfortunately, Harvest Power had not been created when UBC took initiative to create a compost facility. Switching to Harvest Power will not only save UBC almost $300,000 per year after 2020, it will also have very little effect on

[14] (Time Preference, costs of capital and hidden costs: a committee on climate change note, 2013)

the amount of greenhouse gas emissions to a minimum (around 1%). It is unrealistic to upgrade or take advantage of the UBC compost facility. Although, it would be much more convenient to utilize this already running building it is not economically feasible for the future.

Note: All scenarios did not account for economies of scale nor the reduction in the amount of packaging companies may have innovated to. Also, both the Harvest Power and UBC composting scenarios account for an added Zero Waste Plan implementation cost of $150,000 (2013), $300,000 (2014-15), $225,000 (2016) and a 2017-2020 $75,000 Zero Waste Program maintenance cost. Costs do not take into account any research that is done on the composting facility or research on campus that will be done, nor do costs consider decommissioning costs of the UBC composter should be an option.

5 Recommendations and UBC Policy

The following are recommendations with justifications moving forward for the *Zero Waste Action Plan*:

1. ***Outsource Organics*** – The total costs of the project increases drastically when UBC manages the organic waste. The UBC organics is best outsourced for cost efficiencies, the pilot plant should be kept for research and UBC Community engagement focused uses.
2. ***Implement Sustainable Supply Chain Management*** – There should be:
    a. Minimum standards for procurement and environmental impact for the UBC supply chain, including a *'green vendors*' list
    b. A system which includes some or all of the following should be included in the UBC sustainable supply chain:
        i. Green score cards
        ii. Environmental product declaration (EPD) for all products purchased
        iii. Green Decision Matrix which selects the vendors and green products to be purchased and not purchased based on scoring criteria for products purchased (including waste generated)
        iv. A green vendor list
    c. Extended producer responsibility should be pushed on to the UBC Supply Chain
    d. UBC Community: faculty, staff, students, residents and all others who interact with UBC should partake in waste management *gamification:*
        i. The 'Zero Waste Game' is a concept surrounding an incentive based *gamification* of the Zero Waste University
        ii. The *gamification s*hould focus on teams and not individuals (building VS building)
        iii. The *gamification s*hould have team scores per department or per building based on diversion rates, EPD impact
        iv. *Gamification* should use live monitoring of waste using weigh scales located in the main sections of each building displaying the waste measured per day, per week, per month and live monitoring of this can indicate to janitorial services when waste bins are to be collected.

3. ***Implement a Zero Waste Challenge comparing building-to-building*** - A team competition in Zero Waste Management should be emphasized. For example, building-to-building comparisons of waste with faculties located in similar buildings working together to have their building further invested in. Investments in buildings or faculties would be small, and would be rewarded based on Zero Waste goal attainment and 'best in class' results. Such investments may include bike rack upgrades, art for the building, tree planting, biowall, or other worthy projects for the winning team's building that would be installed the year of the win (likely during the summer after the school year is completed).
4. ***Aspire to and achieve Zero Waste by 2030*** – The preliminary Zero Waste Action Plan indicates an ambitious goal of Zero Waste by 2030, this goal should be maintained. It is ambitious, and achievable; this type of leadership is needed by society, UBC can provide such advancements and maintain as a leader in sustainability.
5. ***Communicate Brand and Engage the entire UBC Community, get buy-in for a Zero Waste University***- some of the preliminary actions required of the UBC Waste Management Services do not require UBC Community buy-in. The installation of more convenient devices will only encourage people to divert their waste, often times naturally. The major gains will require significant UBC Community member culture change and their early adoption of the UBC Zero Waste Campaign. Proper branding, proper awareness, proper engagement and a UBC Sustainability Culture will need to be created around the Zero Waste Campaign for it to be successful.
6. ***Our endorsement of the 10 Steps in the Preliminary 'Zero Waste Action Plan Content Summary' by Bud Fraser***[15]– the team believes the following ten steps should be acted upon, either in conjunction or having the seven other policy recommendations included in this section.
    1. *Cross Cutting Programs*
    2. *Waste Reduction and procurement review*
    3. *Development of Re—Use Systems*
    4. *Electronics Reuse and Recycling*
    5. *Organics Reduction and Management*
    6. *Recycling Collection and Management*
    7. *Zero Waste Events*
    8. *Measurement and Verification of Zero Waste*
    9. *Construction and Demolition Waste Reduction*
    10. *University Neighbourhood and UBC Collaboration*
7. ***Introduce an Environmental Management System to Manage the Zero Waste Action Plan*** – becoming ISO 14000 certified with the waste management system will support the goals of the UBC Waste Management Plan. Such a system will allow for the tracking and management of the UBC waste management regarding goals, investment and effectiveness.
8. ***Pursue Methods to Reduce Waste Generation per Facility, so it decreases over time and does not remain at the current waste generation rate, in further Zero Waste Planning Tool updates***- the current Zero Waste Tool does not examine the effects of waste generation reduction as it

[15] (Fraser, 2013)

assumes generation will increase with increased building development and campus building square footage increase (i.e. with equal tonnes of waste produced per m2 of building increase per year). The costs to decrease generation should be researched further and included in future models.

6 Conclusion

Major milestones and findings in the report include:

- UBC has an overall waste diversion rate of 59% whereas the city of Vancouver has a waste diversion rate of 48.7%.
- The Zero Waste model was completed in Microsoft Excel, and includes parameter manipulation for diversion rates for each building type for each stream. The assumptions of the model, concerning costs, greenhouse gases and waste generation per building type have all been included in the latest information in this report and appendix. Should new information be available, it may be used to adjust the model to produce the latest up to date information.
- The different building types considered was ancillary, core and tenant buildings. The waste streams examined were disposal and diversion. For diversion the following streams were considered: organics, mixed paper, returnable containers, cardboard, e-waste, construction materials (but not construction and demolition stream), as well as recyclables and non-recyclables.
- Business as Usual (BAU) case and Zero Waste case, as modelled produced similar generation rates by 2020, 6,490 tonnes of waste generation per year. This does not include construction and demolition, but does include all other waste streams. The business as usual diverted 42% of all Operational waste, compared to the Zero Waste model that diverted 77% of all waste.
- Carbon dioxide emissions were examined using the delta emissions due to the difference in scope of the life cycle analysis around the diverted and disposed streams. Acting upon the Zero Waste model (versus the business as usual model) will save 4,750 tonnes of CO_2 equivalents from 2014-2020.
- The costs were completed for the Zero Waste Model for Harvest power compost and for UBC Compost compared with the business as usual case. Lowest Net Present Value at the Jaccard discount rate of 3.5% were found to be $3.82 Million for Zero Waste Harvest as the lowest, followed by Business as Usual at $3.90 Million, followed by Zero Waste UBC Compost at $4.37 Million. From a cost standpoint the Zero Waste model using Harvest Power's compost facility with increased operational diversion to 77% by 2020, is the most economic.
- Eight recommendations and UBC Policy changes were suggested as findings from this report:
    1. Outsource Organics
    2. Implement Sustainable Supply Chain Management
    3. Implement Zero Waste Challenge Comparing Building-to-Building
    4. Aspire to and Achieve Zero Waste by 2030

5. Communicate, Brand and Engage the entire UBC Community, get buy-in for a Zero Waste University
6. Our endorsement of the 10 Steps in the Preliminary 'Zero Waste Action Plan Content Summary' by Bud Fraser
7. Introduce an Environmental Management System to manage the Zero Waste Plan
8. Pursue Methods to Reduce Waste Generation per Facility, so it decreases over time and does not remain at the current waste generation rate, in further Zero Waste Planning Tool updates

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8 Appendix A: GHG Emission Factor Model Details

This appendix provides the methodology and reasoning behind the generation of emission factors in Table 8.

8.1 Units

Emission factors were estimated using the *2006 Environmental Protection Agency (EPA) Solid Waste Management and Greenhouse Gases Life-Cycle Assessment of Emissions and Sinks*[16] . The EPA emission factors are given in "Metric Ton of Carbon Equivalent per Short Ton of Solid Waste". The emission factors used in this report are "Metric Ton of Carbon Equivalent per Metric Ton of Solid Waste" and therefore a conversion factor of 0.9072 (metric ton per short ton) was applied between the EPA and this models emission factors.

8.2 Linking Waste Categories

The UBC Zero Waste Management Tool and the EPA file used to determine GHG emission factors do not have the same defined waste categories. Therefore it was a necessary first step to outline the linkage between categories in the two models. The linking process ranges from a straight match such as Organics and extends to a more detailed weighting scheme that is the case for Recyclable and returnable containers. These categories include a summary table outlining the chosen EPA factors for completeness. Table 5 summarizes the assumptions used to enable category matching and also include links to further detailed links. Comments for future work are also included for categories such as other recyclables.

UBC Stream	EPA	Comment
Organics – food, compostable packaging	Food discard	None
Recyclable mixed paper	Mixed Paper	Could break into Residential and Office.
Recyclable & returnable containers – cans, bottles/glass, metal, plastic	Aluminum Cans, Glass, HDPE, LDPE, PET.	See Table 6 for details.
Recyclable cardboard	Corrugated Cardboard	None
E-waste, lamps, bulbs and batteries	Personal Computer	None
Construction materials including wood, gypsum, metal & concrete	Dimensional Lumber, Medium Density Fibreboard, Copper Wire, Concrete	See Table 7 for details.
Other recyclables	Mixed MSW	NEED adjustment
Non-recyclables	Carpet	NEED adjustment

Table 5: Linking the EPA and UBC Zero Waste Management waste stream categories.

[16] (United States Environmental Protection Agency, 2006)

8.3 Recyclable and Returnable Containers

The 2011 UBC's waste audit broke the recyclable and returnable containers into three categories: Plastic, Metal and Glass at 80%, 10% and 10% respectively. In order to determine emission factors consistent with the EPA categories, grouping and weighting was applied as outlined in Table 6.

Recyclable and returnable containers (EPA)	R&R UBC	R&R fraction %	Comment
Aluminum Cans **Steel Cans**	Metal	10	Averaged Aluminum and Steel Cans
Glass	Glass	10	
HDPE **LDPE** **PET**	Plastic	80	Averaged HDPE, LDPE and PET

Table 6: Recyclable and reusable container fractions

8.4 Construction materials including wood, gypsum, metal & concrete

EPA's construction categories are: Dimensional Lumber, Copper Wire, Concrete and Medium Density Fibreboard. It is important to remember that this does not model industrial construction waste but just materials from operational waste. Table 7 summarizes the link of the 2011 UBC Waste Audit breakdown to these categories.

	Waste Audit Mass (lb)	Waste Audit Maa (lb) EPA	Waste Audit Mass (lb) grouped	Fraction (%)	Comment
Clean Wood	561297	Dimensional Lumber	1119243	85%	Grouped Clean and Commingled Wood
Commingled Wood	557945				
Metal	167948	Copper Wire	167948	13%	
Concrete	11514	Concrete	11514	1%	
Gypsum	11122	Medium Density Fibreboard	11122	1%	

Table 7: Construction material breakdown

8.5 Waste: End of life destinations

The methodology of mapping emission factors from the EPA report to the UBC model for various end of life scenarios are outlined below. To reiterate, EPA emission factors are given in "Metric Ton of Carbon Equivalent per Short Ton of Solid Waste" and therefore a conversion factor of 0.9072 (metric ton per short ton) was applied between the EPA and this models emission factors.

Due to the uncertainty due to lab conditions and US averages used in the EPA emission factors; a single significant digit was use for the UBC model emission factors.

8.6 Downstream:

The scope of the downstream emission factors includes the emissions originating from material depositing and therefore ignores manufacturing, transportation or collection.

8.6.1 Waste to Energy (Burnaby)

The Emission Factors for the WTE disposal stream were taken from Exhibit 5-6 on page 77 of the EPA report. The energy release from the combustion of waste is used to create electricity that partially offsets the released GHG's from the garbage's combustion. BC has 93% Hydro generated electricity and therefore the offset was not used and Gross GHG emissions were used as outlined in Table 8.

	Solid Waste WTE tonne CO2eq per tonne
Organics - food, compostable packaging	0.02
Recyclable mixed paper	0.02
Recyclable & returnable containers - cans, bottles/glass, metal, plastic	0.5
Recyclable cardboard	0.2
E-waste, lamps, bulbs and batteries	0.1
Construction materials including wood, gypsum, metal & concrete	0.02
Other recyclables	0.1
Non-recyclable	0.4

Table 8: Waste to Energy GHG Emission Factors

Table 9 and Table 10 show the Recyclable & Returnable containers and construction calculation respectively. Values were scaled according to Table 6 and Table 7 respectively.

	EPA tonne CO2eq per tonne	Averaged Factors	Scaled to R&R Fraction	UBC tonne CO2eq per tonne
Aluminum Cans	0.01	0.01	0.001	0.5
Steel Cans	0.01			
Glass	0.01	0.01	0.001	
HDPE	0.7	0.6	0.5	
LDPE	0.7			
PET	0.5			

Table 9: WTE Recyclable and Returnable Containers

	tonne CO_2 eq/tonne	Scaled to Const. Fraction	Total tonne CO_2 eq/tonne
Dimensional Lumber	0.02	0.02	0.02
Copper Wire	0.01	0.001	
Concrete	0.00	0.000	
Gypsum	0.00	0.000	

Table 10: WTE Construction Emission Factor

8.6.2 Solid Waste Landfills

The two solid waste landfills of interest in this study, Cache Creek and Delta, differ in their emissive gas recovery strategies. Delta has a land fill gas recovery system in place where an offsite company Maxim Power Corporation utilizes the gas to generate electricity and heat. The electricity is sold back to the BC Hydro grid whereas the excess heat is used to warm up nearby greenhouses (Village Farm Greenhouses). The Cache Creek landfill has a landfill gas recovery system in place that will start operation in June of 2013. It is important to note that these estimates do not give an accurate description as each landfill varies based on location; ambient temperature, precipitation and electricity offset credits due to the area's electricity production. In order to study the effects that diverting has on GHG emissions with respect to disposing waste in a landfill it was decided to assume constant emission factors for each landfill throughout the study period (2011 to 2020). This enables attributing emission and GHG reductions to the diversion rate change instead of appending landfill gas recovery improvement effects to our results. EPA data from exhibit 6-8 on page 93 were used to estimate emission factors for both land fill sites. The Delta landfill was modelled using the Net GHG emissions landfills with LFG recovery and flaring whereas the Cache Creek landfill was modelled using the NET GHG emission landfills without LFG recovery. The electricity production was not given credit at the Delta landfill since BC's main electricity production is hydro. Transportation is NOT included and the factors were again adjusted to be in metric tonne CO_2 per metric tonne of waste. This generic landfill emission factor modeling method of the EPA has a lot of potential room for error (order of magnitude) when using it for our landfills of interest but since we are interested in the change of GHG emissions while adjusting diversion rates these errors largely cancel out giving us a good estimate to the effects of interest.

Stream	LF GHG Emission Factors standard (tonne CO_2 eq/tonne)	LF GHG Emission Factors gas capture (tonne CO_2 eq/tonne)
Organics – food, compostable packaging	0.4	0.09
Recyclable mixed paper	0.5	0.1
R&R – cans, bottles/glass, metal, plastic	0.0	0.0
Recyclable cardboard	0.6	0.1
E-waste, lamps, bulbs and batteries	0.0	0
Construction materials	0.3	0.1
Other recyclables	0.5	0.1
Non-recyclables	0.0	0.0

Table 11: Landfill emission factors for standard and gas capture.

Recyclable and returnable containers have no GHG, as they do not decompose in a reasonable timeframe. Construction emission factors calculations for LF and LFG are summarized in Table 12.

	tonne CO_2 eq/tonne	Scaled to Const. Fraction	Total tonne CO_2 eq/tonne
Dimensional Lumber	0.3	0.2	0.3
Copper Wire	0.0	0.0	
Concrete	0.0	0.0	
Gypsum	0.3	0.002	

	tonne CO_2 eq/tonne	Scaled to Const. Fraction	Total tonne CO_2 eq/tonne
Dimensional Lumber	0.07	0.06	0.1
Copper Wire	0.00	0.00	
Concrete	0.00	0.00	
Gypsum	0.07	0.001	

Table 12: Construction Landfill emission factors Top: LF, Bottom: LFG

8.7 Diversion (Recycling and/or Composting)

This category goes into two sections, composting and recycling. The quantifying approach of the recycling emission factors is based on the avoided burden principle, giving recycling an "emission" credit as it offsets virgin material production by returning the material back into the production chain. This method was chosen for this study, as we are not interested in the cradle to grave GHG emissions but in the difference in GHG emissions based on various diversion/disposal scenarios. Composting data was taken from EPA Exhibit 4-6 on page 61 while the rest is taken from Exhibit 3-8 on page 46 and include transportation.

Stream	WTE GHG Emission Factors (tonne CO_2 eq/tonne)
Organics – food, compostable packaging	-0.04
Recyclable mixed paper	-0.9
R&R containers – cans, bottles/glass, metal, plastic	-0.5
Recyclable cardboard	-0.8
E-waste, lamps, bulbs and batteries	-0.6
Construction materials	-0.7
Other recyclables	0
Non-recyclables	0

Table 13: Composting and/or Recycling Emission Factors

The category in Table 13 that still needs work is the other recyclables that has been omitted for now. Details of the recyclable containers and construction are given below.

	EPA tonne CO2eq per tonne	Averaged Factors	Scaled to R&R Fraction	UBC tonne CO2eq per tonne
Aluminum Cans	-3	-2	-0.2	-0.5
Steel Cans	-0.4			
Glass	-0.1	-0.1	-0.01	
HDPE	-0.3	-0.4	-0.3	
LDPE	-0.4			
PET	-0.4			

Table 14: Recycling and Reusable Containers recycling emission factor

	tonne CO_2 eq/tonne	Scaled to Const. Fraction	Total tonne CO_2 eq/tonne
Dimensional Lumber	-0.6	-0.5	-0.7
Copper Wire	-1	-0.2	
Concrete	0.0	0.000	
Gypsum	-0.6	-0.005	

Table 15: Construction recycling emission factor

8.8 Transportation

Transportation emissions were calculated based on the destination distance and truck type. The overall effects of transportation were small and therefore not discussed in detail.

8.9 Summary

A complete summary of emission factors for the disposed and diversion categories is given in Table 16. The total disposed emission factors were scaled according to the waste site breakdown in Table 2.

	Solid Waste WTE tonne CO2 eq/tonne	Solid Waste LF tonne CO2 eq/tonne	Solid Waste LF with LFG tonne CO2 eq/tonne	Total Disposed Emission Factor tonne CO2 eq/tonne	Diverted Downstream Emission Factors tonne CO2 eq/tonne	Diverted Upstream Emission Factors tonne CO2 eq/tonne
Organics - food, compostable packaging	0.02	0.4	0.09	0.2	-0.04	0
Recyclable mixed paper	0.02	0.5	0.1	0.3	0	-0.9
Recyclable & returnable containers	0.5	0.0	0.00	0.1	0	-0.5
Recyclable cardboard	0.2	0.6	0.1	0.3	0	-0.8
E-waste, lamps, bulbs and batteries	0.1	0.0	0.00	0.02	0	-0.6
Construction materials	0.02	0.3	0.1	0.1	0	-0.6
Other recyclables	0.1	0.5	0.1	0.3	0	0
Non-recycable	0.4	0	0	0.09	0	0

Table 16: Emission factor summary for various ends of life scenarios.

9 Appendix B: Cost Model Details

The scope of the diversion and disposal costs were focused on UBC's Operational waste streams, not its Construction and Demolition streams. The diversion costs for the waste material streams were obtained from recycling contractors and UBC staff. The diversion costs for Operational construction waste were averaged from quotes received from UBC's waste contractors. The tipping fee (disposal cost) forecasts were obtained from Metro Vancouver's Finance Committee. This study assumed that organics were diverted to the UBC compost.

	2011		2015		2020	
	Diversion cost $/tonne	Disposal Cost $/tonne	Diversion cost $/tonne	Disposal Cost $/tonne	Diversion Cost $/tonne	Disposal Cost $/tonne
Organics - food, compostable packaging	$300	$97	$120	$119	$120	$187
Recyclable mixed paper	-$10	$97	-$10	$119	-$10	$187
Recyclable & returnable containers - cans, bottles/glass, metal, plastic	$0	$97		$119	$0	$187
Recyclable cardboard	-$65	$97	-$65	$119	-$65	$187
Recyclable mixed OPF (0.12% of total recyclable cardboard)	-$116	$97	-$116	$119	-$116	$187
E-waste				$0		$0
Stewardship ($20/ 350lb cage) Est 80%	$126	$97	$126	$119	$126	$187
Non-Stewardship (0.70/kg) Est 20%	$700	$97	$700	$119	$700	$187
Construction materials (average)	$96	$97	$96	$119	$96	$187
Other recyclables	$50	$97	$50	$119	$50	$187
Non-recyclable (5% of total waste)	$0	$97	$0	$119	$0	$187

Table 17: Summary of diversion and disposal costs

10 Appendix C: UBC Waste Model Diversion Rates

The diversion rates modeled are illustrated below. The baseline has been adjusted based on a 2011 UBC Waste Audit. The Zero Waste Plan diversion factors were altered according to feasibility and a great cost to GHG reduction benefit. The diversion factors are the main parameters of our model and can therefore easily be edited in order to model future waste plans.

	CORE BLDGS			ANCILL BLDGS			TENANT BLDGS		
	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate 2020	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate 2020	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate2020
UBC Zero Waste Plan	19%	60%	80%	19%	60%	85%	12%	60%	70%
	45%	55%	70%	45%	55%	70%	50%	50%	50%
	30%	50%	80%	30%	50%	80%	60%	60%	60%
	70%	75%	85%	70%	75%	85%	70%	70%	70%
	60%	65%	75%	60%	65%	75%	50%	50%	50%
	71%	75%	85%	71%	75%	85%	0%	0%	0%
	85%	85%	85%	85%	85%	85%	0%	0%	0%
	CORE BLDGS			ANCILL BLDGS			TENANT BLDGS		
	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate 2020	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate 2020	Diversion Rate 2011	Diversion Rate 2015	Diversion Rate2020
BAU	19%	19%	19%	19%	19%	19%	12%	12%	12%
	45%	45%	45%	45%	45%	45%	50%	50%	50%
	30%	30%	30%	30%	30%	30%	60%	60%	60%
	70%	70%	70%	70%	70%	70%	70%	70%	70%
	60%	60%	60%	60%	60%	60%	50%	50%	50%
	71%	71%	71%	71%	71%	71%	0%	0%	0%
	85%	85%	85%	85%	85%	85%	0%	0%	0%

Table 18: Waste model diversion rates used in analysis.