FEASIBILITY OF COMPOSTING MUNICIPAL WASTE IN THE RDKS

by

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ABSTRACT

The Regional District of Kitimat-Stikine (RDKS), located in northwest British Columbia, has embraced the goals of Zero Waste and would like to adopt a zero organics strategy for its' landfills.

The 2009 Waste Composition Study determined that 2002 tonnes of organic material is being delivered to the landfills in the Terrace Area. If this organic material were to be composted the cost to windrow compost wood and yard/garden waste would be \$88.46/tonne or \$44.23/m^3. If food waste is incorporated into the feedstock costs would increase to \$127.19/tonne or \$91.05/m^3, utilizing aerated bins and windrow composting.

From a strictly financial perspective the costs of composting outweigh the benefits. It was determined that purchasing compost to be used as a final cover at the Thornhill Landfill from a supplier is more cost effective than producing compost from a RDKS composting facility. A diversion of organics from the Thornhill Landfill has no material effect on the post closure leachate treatment costs or on the extension of the useful life of that landfill. The benefits of diverting organics from the Forceman Ridge Landfill on the leachate treatment facility could not be monetarily quantified as that landfill is still in the design stages. The capacity of the Forceman Ridge landfill is 50+ years. An organic diversion policy will extend the useful life of that landfill but assigning a monetary value to a benefit that will be accrued 50+ years in the future was not done due to the inherent inaccuracies in predicting something so distant in the future.

In anticipation of a zero organics strategy the RDKS should consider promoting backyard or decentralised composting and implement a pilot project of composting wood and

yard/garden waste and a pilot project incorporating food waste. Unless the pilot project indicates otherwise any future composting facility should be established at the Thornhill Landfill due to the inherent transportation cost savings.

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Most importantly Roger Tooms and Laurie Gallant of the Regional District of Kitimat-Stikine need to be thanked for allowing the author to even undertake this project. The hope is that it will be of some value to RDKS Staff and the RDKS Board.

CHAPTER 1 – INTRODUCTION

Organic municipal waste (i.e. yard/garden waste, woody debris and food waste) can cause leachate problems for landfills. The result is leachate treatment facilities and potentially increased post closure costs. Another issue is the emission of methane gas that is emitted during the decomposition / breakdown of organics once they are buried in the landfill. Composting of municipal organic waste is a method of addressing the issue of leachate and methane gas production. Composting can also reduce the amount of material being buried in a landfill, thus extending the life of the landfill.

At the end of 2007 composting of municipal waste was occurring in 36 facilities throughout British Columbia, processing 257,000 metric tons (Antler, 2008). Furthermore, the amount of municipal organic waste being composted in Canada has grown significantly from 275,000 metric tons in the early nineties to 4 million metric tons at the end of 2007 (Antler, 2008).

Unlike other jurisdictions in the province there is no composting facility present in the Regional District of Kitimat Stikine (RDKS). At the Thornhill Landfill yard/garden waste and wood debris is placed into a pile and burned quarterly (R.Tooms, personal communication, Oct 9th, 2009). Food waste is buried along with the other municipal waste.

The Regional District of Kitimat-Stikine has committed itself to the Zero Waste Initiative as reported on the RDKS website accessed on April 19th, 2010.[1] The goal of Zero Waste is to go beyond the traditional mantra of Reduce, Reuse and Recycle. Instead, the concept of Zero Waste is a closed loop system where materials are recycled back into the

[1] http://www.rdks.bc.ca/content/about-us?q=node/15

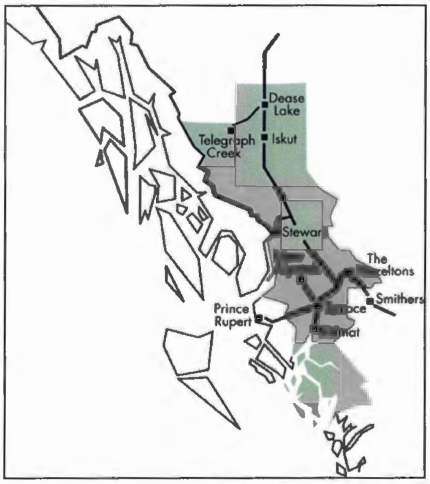
economy or the environment (i.e. turned back into something else). To work towards Zero Waste the RDKS has established priorities for Solid Waste Management for 2009-2012.[2] One of the priorities is to establish and implement a zero organics in its landfill strategy.

[2] Ibid

Background

The Regional District of Kitimat-Stikine encompasses an area of approximately 100,000 km^2 in North Western British Columbia. Member municipalities are Kitimat, Terrace and Hazelton.[3]

Figure 1: Regional District of Kitimat-Stikine

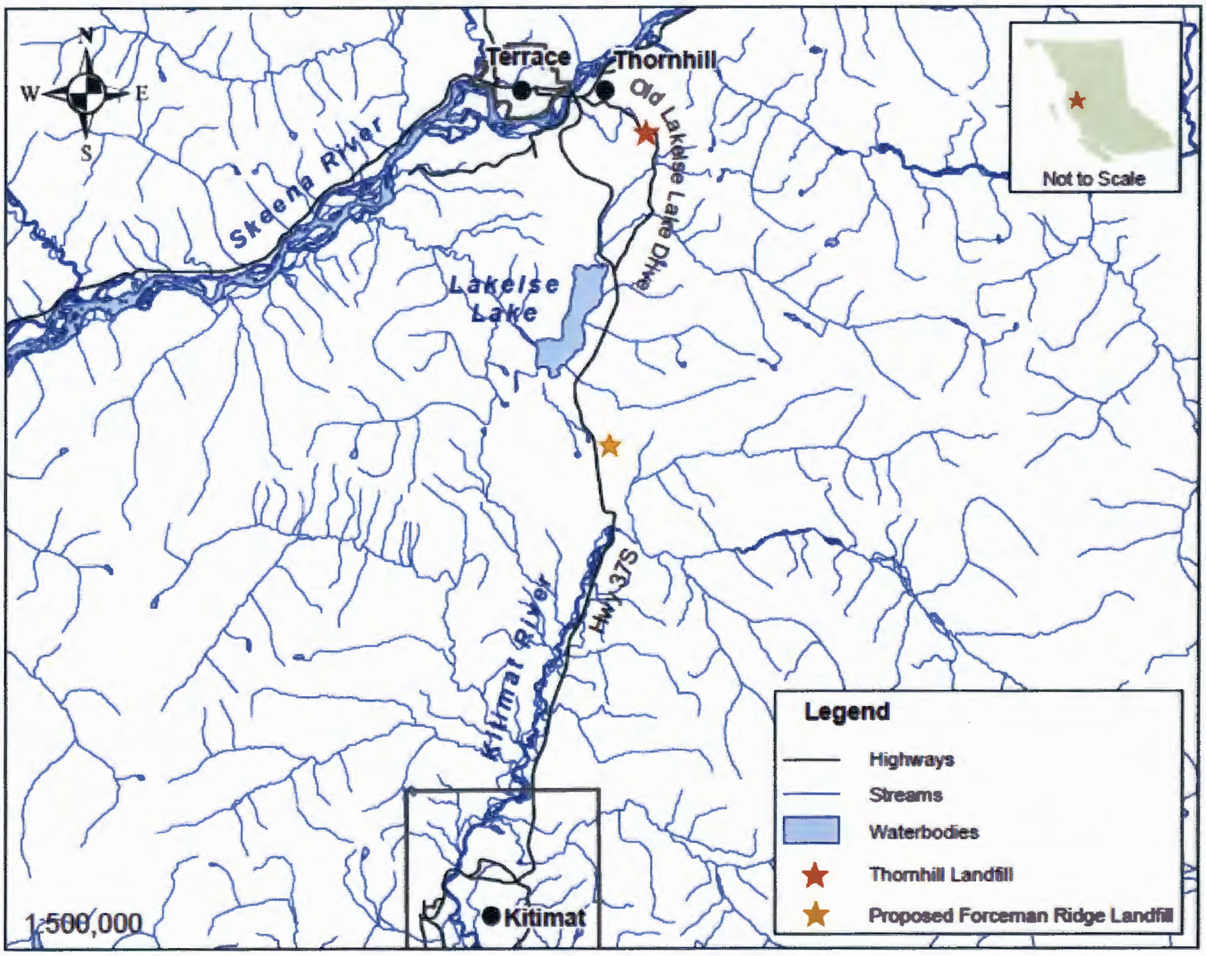


Of the numerous functions tasked to the RDKS one is waste management. The Thornhill Landfill is one of seven landfills operated by the Regional District of Kitimat-Stikine. In 1995 a Solid Waste Management Plan (SWMP) was completed. One of the recommendations was to create a regional landfill for both Thornhill (unincorporated community adjacent to Terrace) and the City of Terrace (RDKS, 1995). The SWMP suggested expanding the existing Thornhill Landfill and transforming it into a regional landfill or choose a new landfill location. After several years of studies (Forgie, 1999, 2000) the RDKS selected to pursue a new regional landfill at Forceman Ridge (26 km south of Terrace along the Terrace-Kitimat Highway). Currently the proposed Forceman Ridge

[3] http://www.rdks.bc.ca/content/about-us

Landfill is in the design stage with construction starting in the fall of 2010 or spring of 2011 (R.Tooms, personal communication, August, 2009).

Figure 2: Overview Location of Thornhill Landfill and Forceman Ridge Landfill



CHAPTER 2 – OBJECTIVE

In the near future (1-2 yrs) the RDKS could be considering the implementation of a zero organics policy at the Thornhill and proposed Forceman Ridge Landfill. Diverting organic matter from the landfill would require a centralised composting facility. Prior to implementing such a policy it would be beneficial to have an understanding of the cost / benefits of a centralised composting facility as no local information currently exists.

The objective of this project is to determine the economic feasibility in the Regional District of Kitimat-Stikine establishing a composting facility at either its existing landfill in Thornhill or the proposed landfill at Forceman Ridge.

CHAPTER 3 – LITERATURE REVIEW

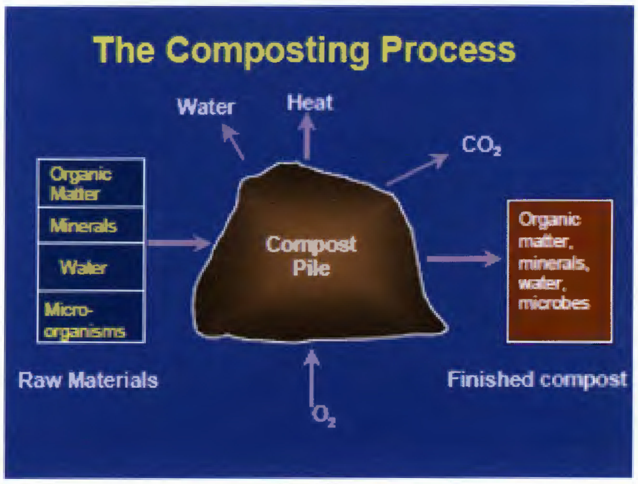
Composting

Composting can be defined as the chemical and physical alteration of organic materials (i.e. grass clippings, paper, food scraps) through the action of aerobic and / or anaerobic microbial decomposition in an environment that contains some level of oxygen, water and nutrients (Tressler, 1991). The end product from the process of composting is called compost. It is commonly dark brown to black in color and is moist, spongy and earthy smelling. Finished compost is characterized by being resistant to further decomposition and displays no further temperature increase when stored.

The benefits of compost are: increased soil organic matter content, nutrients for plant growth, reduced soil erosion, plant disease resistance, weed suppression, water conservation, less leaching of nutrients and chemicals in the soil and generally improved plant vigor (Barlaz et al., 2003). Compost is commonly used in agriculture and by landscapers, municipalities, and homeowners as a soil amendment.

To achieve finished compost the compost pile goes through an active phase and a curing phase (Cooperbrand, 2002). The active phase occurs within 24-72 hours of pile formation, when temperatures in the pile heat up to 55° - 65°C for a period of several weeks. It is during the active phase that the majority of the decomposition occurs and temperatures are high enough to kill pathogens. It is during this phase that oxygen needs to be replenished through passive or forced aeration, or turning of the pile. Once temperatures in the pile decrease to 35°C the compost enters the curing phase. Oxygen consumption has declined and the compost can be stockpiled with no further turning. During the curing phase decomposition still is occurring but at a slower rate – the final stages of the transformation process from organic matter to a stable humic substance is being made. If the curing process is insufficient the compost could damage or kill plants if used as a soil amendment. The length of the curing process depends on the composting methodology utilized; however an average time for commercial operations is 1-4 months.

Figure 3: The Composting Process (Rynk et.al, 1992)



There are six fundamental factors required to transform organic materials into compost. They are micro-organisms, water, oxygen, pH, carbon / nitrogen (C:N) ratio and temperature (°C) (Tressler, 1991; Cooperbrand, 2002).

Micro-organisms are the most critical component in transforming organic matter to compost. Studies have shown that even if the other five factors are present at the appropriate levels, the absence of microorganisms will result in no or very little decomposition. Microorganisms can be classified as bacteria, fungi and actinomycetes. Although each has a different role, microorganisms primary function is breaking down the cellulose, hemicelluloses, lignin, pectins and starches of organic matter (Tressler, 1991).

If the percentage of water falls below 45-50%, the efficiency of the composting process declines. Water levels below 12-15% will stop the composting process altogether (Tressler, 1991).

The presence of oxygen aids in the oxidation of complex organic compounds as the majority of the micro-organism species require oxygen for their metabolic activities. Studies to determine the ideal amount of oxygen have been unsuccessful due to the variability in the chemical composition of the organic matter. Experienced composters know that when odour arises from the compost anaerobic conditions are beginning to occur (Tressler, 1991; Cooperbrand 2002).

Organic matter that is too acidic or basic will render microorganisms ineffective. Hence a typical pH range of composting organic matter is a pH of 6-8 (Tressler, 1991; Cooperbrand 2002).

Carbon and nitrogen are the two most important macronutrients for microorganism productivity. An optimal C:N ratio is between 25:1 to 30:1. If the ratio becomes too high the compost will not heat up. If there is too much nitrogen (low ratio) the excess nitrogen is converted to ammonia that will lower the overall nutrient value of the compost and cause odour issues (Tressler, 1991; Cooperbrand 2002).

The optimum temperature range for the compost pile is between 40 to 60° C. If the temperature is too high, the microorganisms will begin to die off. Too low of a temperature and the decomposition process will not even occur (Tressler, 1991; Cooperbrand 2002).

Although the decomposition of organic matter is a naturally occurring process the more intervention and management of the six fundamental factors in the composting process, the quicker the process will be (Cooperbrand 2002; Western BioResources, 2005a; Ripley and Mackenzie, 2008; Forgie et al., 2004).

Table 1 summarizes the acceptable and ideal conditions of the six fundamental factors required for successful composting.

Table 1: Optimal Conditions for Rapid Aerobic Composting (Cooperbrand, 2002)

	Acceptable	**Ideal**
C:N Ratio	20:1 to 40:1	25-35:1
Moisture Content	40-65%	45-60%
Oxygen Concentration	> 5%	> 10% (or more)
pH	5.5 – 9.0	6.5 – 8.0
Temperature	43-66°C	54-60°C

Composting Techniques / Methods

There are a variety of techniques to create compost from organic materials. Methods range from low cost, low technology to very capital intensive systems utilizing proprietary knowledge and technology. Composting techniques can be categorized into four broad categories: Static Pile, Windrow, Aerated Static Pile and In-Vessel. Appendix A summarizes the advantages and disadvantages of each process.

Static Pile

Composting utilizing a static pile is the simplest and least costly method of composting. It is essentially piling all the organic material into one large pile. As there is no intervention (i.e. turning) the compost quickly turns anaerobic resulting in a very long time (1-2 yrs) for the feedstock to be transformed into compost. The final product is quite heterogeneous as material on the outside of the pile will have had less decomposition compared to the inner pile (Cooperbrand, 2002).

Windrow

Placement of the feedstock into elongated piles (windrows) is also a low technology form of composting. Pile size can vary, however common dimensions are 3-6 m wide at the base of the pile and 1-3 m high. To achieve a more homogeneous final product windrows are often turned at varying frequencies to re-introduce oxygen into the pile, provide a more even distribution of micro-organisms within the pile and allow the entire pile to be exposed to the higher temperatures located at the center of the pile. The more frequent the turnings the quicker the transformation from organic matter to compost (Cooperbrand, 2002; Western BioResources, 2005a; Ripley and Mackenzie, 2008; Forgie et al., 2004).

For example, the Vancouver Landfill produces finished compost after 6 months through turning windrow piles of yard/garden waste once a month (N.Steglich, personal communication, Dec 3, 2009). Turnings can be made either with machinery specialized for windrow turning or simply with a front end loader or excavator.

Figure 4: Examples of Windrow Composting

Photo Credit: City of Vancouver

Photo Credit: Ecowaste Industries

<u>Aerated Static Piles</u>

Aerated Static Piles have oxygen introduced into the pile either passively or forced to avoid anaerobic conditions. The piles usually are in some form of a windrow. Passive Aerated Piles have perforated pipes placed in the windrow to allow oxygen convection through the pipes and into the pile (Cooperbrand, 2002).

Figure 5: Example of a Passively Aerated Pile

Photo Credit: The Art and Science of Composting

Active Aerated Static Piles have blowers attached to the pipes which forces air through the pipes and into the piles. Active aerated piles can have pipes located within the pile or embedded in channels beneath the pile. If located in an uncovered environment, active aerated piles commonly have covers or tarps over the piles for odour control and to keep rainwater off.

Figure 6: Active Aerated Static Piles

Photo Credit: Forgie et.al, 2004

Photo Credit: Engineered Compost Systems

The advantage of active aerated static piles over conventional windrows is that the composting process is substantially quicker, particularly for aerated static piles that have air forced into them – 2 to 3 months (Ripley and Mackenzie, 2008). Another benefit of an active aerated static pile is the ability for the process to occur in bays or bins.

<u>In-Vessel</u>

In-Vessel is the most expensive and technologically advanced method of composting. In-vessel comes in many forms such as tunnels, containers or bins. It provides the most control over the compost process and should only be considered if food waste is a component of the feedstock. In-vessel technology is commonly used in areas where there are space limitations and where odours would cause a significant issue (Ripley and Mackenzie, 2008).

Figure 7: Examples of In-Vessel Composting

Photo Credit: Engineered Compost Systems

Photo Credit: ICC Group – Nanamio B.C. Facility

Composting Costs

Composting costs are highly dependent on the level of technology utilized, the size of the facility and the type of feedstock. Generally the more technological intensive of a process used and the more complex the feedstock the more it will cost per tonne to produce compost. For example, in-vessel composting of food waste is more costly than windrow composting of only yard/garden waste as the legislated requirements for composting food waste are more stringent than composting yard/garden waste. Discerning the cost differences between different composting methods is challenging because of the limited information to be found in the literature and of the variability in reporting. For example, some of the costs reported in the literature are not actual costs, but projected costs from a detailed analysis for a specific form of composting. To add further variability, some costs may exclude the initial capital costs, whereas other published costs will have the capital costs amortized and included with the operational costs. There is even inconsistency in the unit measurement of the inputs. Some facilities report in volume (yd^3 or m^3) whereas others in weight (tons or tonnes).

The challenge in locating comparable published costs in the literature is not a new occurrence. Tsilemou and Panagiotakopoulos (2006) who were trying to derive cost functions for solid waste treatment facilities from reviewing data of facilities in the European Union found *"publication of cost data is scarce and most of the published studies deal with management issues"* and *"the great variety of available organizational, financial and management schemes............renders the economic analysis a complex endeavour."* Steutville (1996) and Renkow and Rubin (1998) experienced similar issues in their studies of composting economics. Both found that public facilities were more willing to share financial information than private facilities but obtaining the information could be challenging. In a survey conducted by Renkow and Rubin (1998), of the 17 facilities contacted only 9 provided sufficient information that would allow a cost/tonne comparison to be made with the other facilities. Renkow and Rubin (1998) also found that for some facilities the requisite costing information was simply unknown.

Despite the variation in composting methods, technology and financial accounting four universal pieces of equipment for a composting operation is a grinder, a loader and/or turner, a mixer and a screener. Raw materials need to be converted into a state for the composting process to occur. Woody debris (i.e. yard/garden waste) needs to be ground up, and food waste needs to be mixed with a bulking agent. After the compost has cured screening is needed to remove any foreign matter. A loader of some form is required for all phases for handling of the material.

Windrow Composting

The Vancouver Landfill which serves the cities of Vancouver B.C. and Delta B.C. has had a windrow composting facility since 1995. In 2008 it processed 49,833 tonnes of yard and garden waste on its' 4.8 ha site utilizing two front end loaders, 2 trommel screens, one linear feed grinder and one excavator operating seven days a week (Annual Report, 2008). Its' initial capital costs to construct and equip the operation was \$2.5 million. The average (2002-2008) seven year cost/tonne is \$44.45/tonne for windrow composting (Appendix B). This cost per tonne includes all revenue derived from the sale of the compost (\$10/m³)[4] to customers and amortization of capital costs.

[4] N.Steglich, email to author, Dec 14, 2009. The Vancouver Landfill sells all the compost that it produces in any given year and the revenue that these sales generate is subtracted from the costs to produce compost. As the eight year cost/tonne is \$44.45/tonne revenue from sales clearly does not exceed costs.

The City of Kelowna operates a windrow composting operation at the Glenmore Landfill. The cost for windrow composting approximately 20,000 tonnes of yard and garden waste is $36.54/tonne (Glenmore Landfill, email to author, January 25th, 2010). This cost is less than the Vancouver Landfill most likely because screening of the compost material is taken off site and completed by a contractor[5] (not included in the cost) and the composting site is situated on a closed portion of the Glenmore Landfill (Appendix B). Capital costs are minimized as no special site preparation is required (i.e. paved surface or installation of impermeable liner) to manage for leachate.

In Lehigh County Pennsylvania an audit in 2005 of the county and municipal composting facilities calculated a cost of US $29.05/tonne or CDN $33.12/tonne[6] (capital cost amortized) to compost approximately 13,500 tonnes of yard and garden waste (Oshins et al., 2005). When grants from the Pennsylvania Department of Environmental Protection are included the cost/tonne is reduced to CDN $26.20/tonne (Appendix B).

At a 25,000 tonne facility in Amherst New York, the average cost of windrow composting yard and garden waste over an 18 year period (1991 to 2008) was calculated at US $17.99/tonne or CDN $20.51/tonne (Miller and Angiel, 2009) (Appendix B). The costs from the Amherst facility include amortized capital costs and the benefits from the New York State Municipal Waste Reduction and Recycling Grant Program. Fifty percent of the purchase price of any new equipment that is used for the composting process (i.e. grinder, windrow turner, screener) at the Amherst facility is paid for by the grant program.

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[5] The cost of screening the material by the independent contractor was not made available.

[6] CDN $1.14 - 2009 average value of the CDN dollar vs. the US dollar.
Source: http://www.bankofcanada.ca/pdf/nraa09.pdf

Although the data is limited it appears windrow composting facilities in the United States (U.S.) have lower costs compared to their counterparts in Canada. A possible explanation for this is: (1) the majority if not all of the composting equipment is manufactured in the U.S. and priced in U.S. dollars. Any Canadian operator will be paying more due to the currency exchange, freight and brokerage fees[7] resulting in higher capital costs. (2) labour costs are traditionally lower in the U.S. and (3) fuel costs are also lower in the U.S.

Summarizing, the cost to run a windrow composting facility will range between CDN $35.00 to $45.00/tonne (Table 2). It is interesting to note that the CDN $35.00 to $45.00/tonne cost is higher than the windrow composting cost of CDN $20.00 to $30.00/tonne as reported by Western BioResources (Western BioResources, 2005a) in their Literature Review, however no background information was provided in the Western BioResources Report to determine the difference in the reported costs.

Table 2 summarizes the windrow composting costs in Canadian Dollars of facilities in Vancouver B.C., Kelowna B.C., Pennsylvania State and New York State.

Table 2: Summary of Windrow Composting Costs

Facility	**Windrow Composting Costs (CDN $/tonne)**
Vancouver Landfill, Vancouver B.C.	44.45
Glenmore Landfill, Kelowna B.C.	36.54
Lehigh County, Pennsylvania U.S.	33.12 or 26.20 (with Grants)
Amherst, New York U.S.	20.51 (with Grants)

[7] Gemaco, email to author, Dec 15, 2009.

Aerated Static Piles

Ripley and Mackenzie (2008) stated that the City of Kelowna in 2006 constructed a new composting facility utilizing aerated static pile technology for composting municipal biosolids and wood waste. Capital cost was $7.0 million and the operating cost is $57.00/tonne. Ripley and Mackenzie (2008) also reported that the City of Vancouver in 2008 conducted trials using a Gore™ cover system. It was estimated that the cost for a 2 month rental of a small Gore™ cover system to compost organic wastes would cost approximately $150,000 (literature did not specify the quantity produced).

Net Zero Waste, a company that designs and provides technical advice on composting facilities, was contacted regarding the cost of a Gore™ cover system in the Terrace Area. The capital cost was estimated at $150/tonne for a facility with less than 10,000 tonnes/yr of feedstock and the operating cost was estimated at $50/tonne (Net Zero Waste, email to author, October 28, 2009). These costs included leachate collection and capture, automated control capable of handling any type of organic waste (provided the correct moisture content and C:N ratio is achieved) and full data capture of both oxygen demand and temperature throughout the pile every hour during the 2 month process. Assuming the capital costs are amortization over a 5 year period annual cost/tonne for an aerated static pile is $80/tonne.

In-Vessel

In-vessel technology is even more expensive. The Region of Peel in 2003 built a new facility to process 60,000 tonnes/yr of yard/garden and food waste utilizing in vessel composting technology. The cost for the Christianens In-Vessel Composting System and related operational equipment cost $8.3 million (cost of biofilter, facility structure and vecoplan shredders not included) or $138/tonne (Spencer, 2007). In 2008 the City of Yellowknife commissioned a feasibility study for a centralized composting facility in that community to compost 400-600 tonnes/yr. A quote it received from Wright Environmental for a 1.0 tonne/day system was $285,000 and $385,000 for a 1.8 tonne/day system (Ripley and Mackenzie, 2008). These costs did not include the cost of a heated building, concrete floor, electricity and costs for operating the facility 7 days/week. Western BioResources (2005a) reported a cost/tonne of $180 to $200 from an estimate for a Wright In-Vessel system to compost 10,000 tonnes/yr.

Engineered Compost Systems (ECS) was contacted for an estimated cost of the CV Composter™ in-vessel system. The cost quoted for four vessels (capacity of each vessel is ~ $30m^3$) was approximately $450,000 USD. Cost included the vessels, aeration control and monitoring, mixer, loading conveyor, biofilter, start-up and training. Site construction, taxes, permits, freight or installation and operating costs was not included. Additional vessels were ~$50-70,000 each depending on quantity (ECS, email to author, December 15, 2009).

<u>Economies of Scale</u>

The literature notes the importance of economies of scale. Both Western BioResources (2005) and Tsilemou and Panagiotakopoulos (2006) report the financial performance of a composting facility improves with economies of scale (i.e. composting a greater amount of material). However there may be limitations. Addla Surender (2007) hypothesized that a regional facility, serving the communities of Harlingen, Edinburg and Mission Texas would result in a more cost effective composting facility due to economies of scale and costs being distributed amongst the three facilities. However the study actually determined that due to the transportation costs of hauling feed stock to a centralized regional facility it was more cost effective for the City of Harlingen to construct their own facility.

Full Cost Accounting

To completely evaluate the costs of composting some proponents suggest that the true cost or full cost accounting of the environmental and health benefits of composting should be considered. This is to be accomplished through a Life Cycle Analysis which has been defined as looking at the *'the true environmental impact of products and processes from cradle to grave'* (Morawski, Feb/Mar 2008). The environmental benefits are the sum of the monetized value of greenhouse gas emissions, human health particulates, human health toxics, human health carcinogens, acidification, ecosystem toxicity and the avoided pollutants from compost replacing pesticides and synthetic fertilizers (Morawski, 2008).

In a study completed for the Niagara Region in Ontario, Canada where 47,200 tonnes of organics are composted (14,900 tonnes food waste, 32,300 tonnes yard waste) at a cost of $81.77/tonne for food waste and $33.83/tonne for yard waste the environmental benefit was calculated at $ 49.59/tonne (CM Consulting, 2008). What this infers is that the 'true' cost of composting yard waste accrues a net benefit of $15.76/tonne, whereas composting food waste only costs $32.18/tonne. Using a narrower scope of environmental benefits (net carbon flux and the benefits of less pesticide and fertilizer use) Miller and Angiel (2009) calculated an environmental benefit of $13.85/tonne in the operation of a 20,000 tonne composting facility (yard waste).

A limitation with the Life Cycle Analysis and quantifying environmental benefits is that compost can be used for a variety of applications. Hence it is difficult to determine or know how the application of compost eliminates the need for some other product or material and assigning a monetary value to that (Barlaz et al., 2003). Despite the short falls considering the net environmental benefits can provide a more complete view to the cost of composting.

Benefits of Composting on Landfills

Landfill Gas Reduction

Compost has been shown to be very effective in reducing greenhouse gases that are emitted from a landfill. Methane gas is the primary gas released from landfills due to the anaerobic decomposition that occurs within landfills. Methane gas is considered to have 21-23 times more impact on global warming than carbon dioxide (Tanthachoon et al., 2007; Lechner et al., 2002). However if methane gas is provided with an aerobic medium it will further oxidize to produce carbon dioxide (CO_2). For methane oxidation to occur there needs to be a supply of methanotrophic organisms: compost is a suitable medium for such organisms. Field trials by Lechner et al. (2002) at Austrian Landfills showed that 90-100% of the methane gas produced or emitted from landfills was eliminated where the compost with a depth between 0.6m-1.2m was the final cover layer on the closed landfill. Tanthachoon et al., (2007) found similar results in a laboratory experiment in which the compost reduced the methane gases by 90% and compost was demonstrated to provide higher methane oxidation efficiency when compared to a sandy loam soil.

Even if compost is not used as cover over the landfill it is estimated that for every tonne of organic waste composted rather than landfilled results in a greenhouse gas reduction of 0.2 tonnes of CO_2 (C.M Consulting, 2007).

Extending the Useful Life of a Landfill

With organic material comprising 30-40%[8] of the waste material at landfills, composting this organic waste will reduce the amount of material thus extending the life of the landfill. Also, with less organic waste being buried the amount of leachate being produced by the landfill will be less which could mean less expensive closure costs in the future and potentially less leachate treatment during the active life of the landfill. Western BioResources (2005) who analyzed the feasibility of a centralized composting facility for the Regional District of Central Kootenay (RDCD) and the Regional District of Kootenay Boundary (RDKB) calculated with the construction of a composting facility the life of the seven landfills in the RDCD and RDKB was extended by a total of 174 years and there would be a 50% reduction in closure costs.

For a municipal composting facility (yard waste) in Amherst NY Miller and Angiel (2009) calculated a cost savings CDN $ 67/tonne for avoided landfilling costs. In the absence of a composting facility the town of Amherst would have had to haul their yard and garden waste to the nearest landfill, 40 miles away.

[8] 2004 waste composition study for the Regional District Naniamo – 35% of total waste was compostable organic material. http://www.rdn.bc.ca/cms.asp?wpID=942

Conversion of Weight to Volume

Throughout the literature most incoming feedstock of organic material is always given in weight. For facilities in the United States of America (USA) the most common unit used is tons (or commonly referred to as short tons) while in Canada it is tonnes.[9] It is necessary to convert this weight to a volume by multiplying the weight by its bulk density (kg/m³) as volume calculations are needed for machine productivity, windrow dimensions, aerated bin capacity and determination of final compost quantity. In the literature there is a substantial degree of variability in the conversion factors used from weight to volume. In her Master Thesis for a composting facility in Garland Texas, Tressler (1991) used 0.21 tonnes/m³ for wood and yard/garden waste after it was shredded or grinded; whereas Addla Surrender (2007) in her Master Thesis, for a facility also in Texas, used 0.42 tonnes/m³. The variability in the conversion factors also applies to food waste. Tchobanagous et al. (1993) used 0.89 tonnes/m³, Rynk et al. (1992) reports 0.94 tonnes/m³ and Engineered Compost Systems uses 0.47 tonnes/m³ (ECS, email to author, December 15, 2009). When reviewing or analyzing costs for a proposed composting facility the reader should be aware of the conversion factors used and apply their judgement if the weight to volume conversion is appropriate. The higher the conversion factor is for a product, the less volume that will be calculated for a given weight. An artificially low volume will result in reduced operational costs (less volume to be handled) but it could also result in under design of a facility.

[9] 1 ton = 0.907 tonnes.

Organic Matter Recycling Regulation

The Organic Matter Recycling Regulation (OMRR) was enacted by the Province of British Columbia on February 5th, 2002. The OMRR applies to the construction and operation of composting facilities and the production, distribution, storage, sale and use or land application of biosolids and compost (Forgie et al., 2004). The purpose of the OMRR is to specify the statutory requirements for the operation and management of a composting facility.

For new facilities producing more than 20,000 tonnes/yr of finished compost, the first requirement under the OMRR is to conduct an Environmental Impact Study (EIS). The purpose of the EIS is to determine the impact of the composting facility on human health and the environment and to propose measures to address or mitigate undesirable impacts. The EIS would identify potential issues such as odours, vectors (i.e. birds, rodents and bears), noise pollution and leachate that could arise from the composting facility. The EIS needs to be submitted to the Ministry of Environment (MOE) no less than ninety (90) days prior to construction. Although an EIS is not required for facilities producing less than 20,000 tonnes/yr of finished compost it is still prudent for such facilities to consider the elements contained in an EIS prior to their establishment to identify any potential issues.

For any new facility, regardless of size, the design of the composting facility is to be prepared by a qualified professional. Key elements of the plans and specifications are:

a) all works to be constructed on the site;

b) design capacity of the composting facility;

c) a leachate management plan which stipulates how leachate generated from any and all stages of the composting process will be minimized, managed, treated or disposed;

d) an odour management plan which stipulates how air contaminants from the composting facility will be discharged in a manner that does not cause pollution and;

e) an operating and closure plan for the composting facility (OMRR BC Reg. 18/2002).

Plans and specifications do not need to be submitted to the MOE; however a Notice of Operation is a requirement of the OMRR. The Notice of Operation must be submitted to the MOE ninety days prior to the start of operations and include the compost facility location and design capacity, contact person, type of waste (or feedstock) to be composted, intended distribution of compost and a copy of the training program that demonstrates personnel have the specific training needed to operate a composting facility in compliance with the OMRR.

Some general requirements from the OMRR for the production of compost are:

a) Pathogen Reduction Process: specifies the length of time the compost must attain a minimum temperate (55° C) to eliminate pathogens in the compost. For windrows the minimum length is 15 days with 5 turnings whereas for an aerated static pile or in-vessel 55° C needs to be maintained for only 3 days.

b) Vector Attraction Reduction: refers to methods for the compost to become stable so not to attract vectors. One method is to ensure the compost remains aerobic for 14 days or longer during which the temperature of the compost must be greater than 45° celcius and the carbon to nitrogen ratio is between 15:1 and 35:1.

c) Pathogen Reduction Limits: stipulates the maximum fecal coliform limits that is to be present in the finished product.

d) Quality Criteria: states maximum concentration of 11 elements such as lead, selenium, zinc and copper.

e) Sampling and Analyses: details the protocols and frequency requirements of taking samples and analyzing the samples.

f) Record Keeping

There is a distinction in the OMRR of compost that is strictly from wood and yard/garden waste versus compost that has food waste as a component of the feedstock. Many of the requirements are less stringent when compost is exclusively from wood and yard/garden waste as the risk of pathogens or vector attraction is significantly reduced. For instance, for the Pathogen Reduction Process windrow piles are only required to be turned periodically, instead of the 5 turnings in 15 days when food waste is a feedstock. For Pathogen Reduction Limits no determination of fecal coliform is required (OMRR BC Reg. 18/2002; Forgie et al., 2004).

CHAPTER 4 – METHODOLOGY

Overview

To determine the feasibility for the Regional District of Kitimat – Stikine to compost wood debris and yard/garden waste or a mixture of wood debris and yard/garden and food waste at the Thornhill or Forceman Ridge Landfill the costs and benefits of operating a compost facility needs to be analyzed. The costs will include operating and capital costs. The benefits will be tangible savings incurred to the RDKS as a result of the composting operation. Once the analysis is concluded if the costs exceed the benefits it will be argued that from a strictly economic perspective the composting facility is not financially viable. However, there may be some intangible benefits (i.e. greenhouse gas credits from the Pacific Carbon Trust) that could be considered into the decision making matrix of whether to proceed or not with a composting operation, but a Life Cycle Analysis will not be completed or considered.

Field Tour

To meet the objectives of the project it was realized during the initial scoping that a review of some existing composting facilities would be beneficial and provide valuable insight. Field tours allows one to converse with individuals who operate or are involved in the composting industry and can provide a good source of information.

Compost facility tours were conducted in the Lower Mainland of British Columbia due to time constraints. Since the Lower Mainland has numerous composting facilities the most expedient was to fly to Vancouver and tour three facilities over a period of three days.

The time of year (Dec 1-3, 2009) for the tours was also a factor in selecting the Lower Mainland. Even if there was more time available it is unlikely that an alternate location(s) would have been selected, such as the Southern Interior, as the likelihood of below zero temperatures at that time of year in the interior of the province would have slowed or stopped any composting activity.

The two main criteria in selecting a compost facility was the willingness of the composting facility to conduct a tour and to have a sample of different composting methodologies.

In total eight facilities were contacted (Appendix C). The names of the facilities were provided to the author by Dave Forgie of Associated Engineering[10] (D.Forgie, personal communication, Oct 27, 2009). Of the eight facilities one did not return a message inquiring of the possibility for a tour, one stated that they do not conduct tours and two stated that they would conduct tours but at the time one was in the process of reconfiguring their facility and the other was in the process of changing their composting methodology. Of the four remaining, the one located on Vancouver Island was eliminated due to time constraints of travelling from the mainland to the island.

The three facilities selected were the Vancouver Landfill, the Whistler Composting Facility and Transform Compost Systems.[11] The Vancouver Landfill utilizes windrow composting technology and the Whistler Composting Facility utilizes the Wright Environmental In-Vessel system. Transform Compost Systems arranged and accompanied

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[10] Associated Engineering is a consultant to the RDKS and is designing the Forceman Ridge Landfill.

[11] Transform Compost System is not a facility but is a company that designs compost facilities and is involved in the composting industry. Prior to travelling to Vancouver they had indicated they would be able to arrange a tour of a local composting facility.

the author on a tour of the Kent Municipal Waste Treatment Plant which utilizes aerated static pile technology that was designed by Transform Compost Systems. Also with Transform a composting site under construction was viewed at the Greater Vancouver Zoo in Aldergrove.

The purpose of the tours was for the author to get a better understanding of the composting process. The structure of the field tours was informal and the information gathered during the tours was factual data, such as the length of time to produce compost, equipment used, odour issues, quantity composted. The tour leaders were representatives of their designated facility.

Prior to the field trip to the Lower Mainland the prevailing thought of the author was that cost data could be obtained from the facilities viewed and then that information would be used for the cost of composting in Terrace. However, the most significant outcome of the field trip was the realization that there is a multitude of ways to compost organic matter and each composting facility has a unique set of costs, depending on the quantity of feedstock, the equipment utilised and the design / structure of the facility.

Upon the conclusion of the field trip it was determined the most appropriate method to determine the cost of composting in Terrace would be to select a composting process / methodology and cost out a facility/operation using the knowledge gained from the field trip and the literature review.

Literature Review-Opportunity for Improvement

The literature review confirmed what was observed during the field tours, that the economics of composting is highly variable, even when using the same methodology (i.e.

windrow composting). The largest variability is in the capital costs, as the literature does not provide sufficient detail to analyze operational costs. For example, one facility may have to purchase land to operate a composting facility, whereas another will have a facility located on or adjacent to an existing landfill. Another facility may invest in specialized windrow turners, while another facility may utilize front end loaders.

Hence it is not surprising that when economic data is found in the literature it may be incomplete (i.e. only report operational costs, while excluding capital costs) and difficult for comparison purposes. However, when data is reported it could be made more useful if the assumptions and parameters behind the financial data was always made known and if the costing data was broken down by function.

Ideally the reported data should clearly specify and delineate between capital and operating costs. Capital costs would include items such as: land acquisition, site improvements (i.e. roads, composting area), facilities (i.e. buildings) and equipment (i.e. turner, grinder, screener). The amortization period of capital costs should also be clearly stated. Operational costs would include labour (wages), fuel, maintenance, utilities and other day to day items. It would be naive to expect that all reported data in the capital and operating categories will be stated uniformly, however if sufficient explanation is provided one could analyze the data better and enable one to make 'apple to apple' comparisons. The costing methodology to be used for the RDKS will clearly state the rationale for all the costs.

Overlying Assumptions

Several over-arching assumptions have been made for a composting facility in the Terrace area. The first assumption is the composition of the feedstock. Feedstock is only to consist of wood and yard/garden waste and municipal food waste.[12] The source (i.e. residential, commercial or industrial) is immaterial. Also the exact mixture of the feedstock that will result in the preferred ratios (i.e. C:N, moisture) for ideal composting will not be considered. It is assumed that over time and with experience the proper mixture will be derived. Composting of municipal biosolids is not being considered. The second assumption is that the financial calculation does not include the additional costs that likely would be incurred in curb side collection of yard/garden and food waste compared to the current practices by municipal employees of the City of Terrace, or private contractors in the RDKS. Additional costs would be the capital investment in the appropriate garbage containers and new garbage trucks. The tabulation of the composting cost begins after the feedstock (raw material) is delivered to the landfill. This process is consistent with the study conducted by Tressler (1991) who investigated the feasibility of a yard and garden waste composting facility for the City of Garland Texas. The third assumption is that the finished compost will be used as final cover for the closure of the Thornhill Landfill or be available for sale to the public or commercial enterprises.

Selection Process

From the literature review and field trip windrow composting is the least costly method for composting wood and yard/garden waste and will be the method on which the financial analysis will be based on. Static Pile composting would actually be less expensive

[12] Food Waste is defined as kitchen scraps such as potato peels, leftover food, rotten fruit etc...In essence all food products that is organic and can be composted.

than windrow composting, but will not be considered given the length of time (1-2 yrs) required to produce compost.

Incorporating food waste into the feedstock complicates the composting process as odour issues and attraction of vectors (rodents, birds, bears) need to be taken into consideration. Conventional windrow composting, as proposed for wood and yard/garden waste, is not appropriate. The only three options are (1) an outside aerated static pile with forced air and a cover (i.e. GORE™), (2) an in-vessel system or (3) an aerated static pile indoors in a bay or bin configuration. Since there is a concern with snow and sub-zero temperatures during the winter in Terrace[13] an assumption was made the composting process would have to be within an indoor facility. It was also assumed that food waste will be delivered to the compost facility on a daily basis (Monday-Friday). There will be times in the winter when the food waste will be frozen. To properly mix it with a bulking agent (wood and yard/garden waste – a necessity as the moisture and nitrogen content of food waste is too high for it to be composted individually) the food waste will have to be thawed. Also, for the active composting process to occur the air temperature will have to be above zero degrees. If the composting process is to occur outside there is a strong possibility that when Terrace experiences a period of sub-zero temperatures the composting process would stop, causing material flow issues (i.e. continual supply of raw material but no composting occurring). For this reason the aerated static pile with a synthetic membrane (i.e. GORE™ or Compotex™)

[13] According to the National Climate Data and Information Archive (www.climate.weatheroffice.gc.ca) between November to February the Terrace Airport on average (30yrs of data: 1971-2000) experiences 44 days where the maximum daily temperature is < 0°C and 90 days where the minimum daily temperature is < 0°C.

was discounted. There is also concern the snow[14] and ice build-up along the edges of an aerated static pile would cool the lower portion of the pile, causing the material to not compost properly which would result in a more heterogeneous final product. An indoor facility presents two options – an in-vessel system or an aerated static pile in a bay/bin configuration. Once again from the literature review and the field trip to the Lower Mainland the bay/bin system is viewed as the least expensive option and will be the method used in the financial analysis when composting a mixed feedstock.

Quantity of Feedstock

The waste composition study that was done by the RDKS at the Thornhill Landfill in September 2009 will be used to estimate the amount of municipal organic waste that is available on annual basis as feedstock for compost. The study was completed September 19-29th and 30 samples were collected (RDKS, 2010). Thirteen (13) samples were from Residential Self-Haul, nine (9) samples from Commercial Only and four (4) samples from the City of Terrace (RDKS, 2010).

Composting Wood and Yard and Garden Waste

The first step in calculating the cost of a windrow composting facility is to calculate the area required for the active composting phase. The input tonnage needs to be converted to cubic meters. After determining the input volume financial calculations will be categorized into capital or operational costs. Capital expenditures are real or tangible assets that are

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[14] On average between October to March the Terrace Airport experiences 98 days of snowfall. National Climate Data and Information Archive (www.climate.weatheroffice.gc.ca).

acquired for the long-term use in the business (Lasher et. al, 2008). Operating expenses are expenditures that a business incurs on a day-to-day basis to conduct its business (Lasher et. al, 2008). To be in compliance with the Organic Matter Recycling Regulation the windrow composting facility requires an impermeable surface to manage leachate during the active composting phase. Three options will be considered. The first option will be the construction of an asphalt pad. The second option will be the installation of an impermeable liner covered with a layer of compacted gravel. For both the first and second option, leachate will be collected and directed toward the active landfill where the leachate is already currently being managed. The third option is to windrow compost on the landfill in which no additional works will be required for leachate control, as is done on the Glenmore Landfill near Kelowna (personal communication, Gordon Light, January 2010).

The second step will be to calculate the cost of the equipment to operate the composting facility. For any equipment that is purchased the capital cost will be amortized over its' useful life using straight line amortization. Since a front-end loader is a mandatory piece of machinery at any landfill it will be assumed that it will be available for use at the composting site and the capital cost of the front-end loader will not be accounted for. Operational costs will include grinding of the feedstock, creating and turning the windrows and moving the windrows to the curing area. Hourly equipment rates will be used to determine operational costs. Unless specifically stated the costs for windrow composting and the material processed will be assumed to be the same for a site located at the Thornhill Landfill or at the proposed Forceman Ridge Landfill. The source of capital and operational costs will be clearly stated.

Once the costs are tabulated the final step will be quantifying the benefits of windrow composting, such as the potential savings from using compost at the Thornhill Landfill for a final cover instead of purchasing material from a third party, and revenue derived from compost sales.

Composting Yard and Garden and Foodwaste

In calculating the costs of an indoor composting facility it will be assumed that a facility will need to be constructed and a construction estimate will be calculated. Capital and Operational costs will be calculated using the same methodology as with composting strictly wood and yard/garden waste.

Source of Costing Information

The majority of costs have been derived through email communication with suppliers and manufacturers in which specific cost data (i.e. cost of a grinder) was requested. A total of ten suppliers and manufacturers were contacted. The selection of the most suitable piece of equipment (i.e. grinder, trommel screen, Bobcat) was based upon an Internet review of the models in the marketplace and comments from suppliers/manufacturers. Given the small quantity of material being composted in Terrace, the smallest and least expensive model was generally selected. Appendix D summarizes the suppliers, manufacturers and individuals contacted for calculating the cost of composting wood and yard/garden and food waste in Terrace. Appendix E provides some pictures of the equipment to be utilized for the composting operations.

CHAPTER 5 – RESULTS

Waste Composition Study

The Waste Composition Study completed by the RDKS found that from the thirty samples eighteen percent (18%) of the total weight consisted of Compostable Materials, defined as wood clean construction, yard/garden and food waste (RDKS, 2010). To convert this weight percentage into an actual figure that can be utilised the following process was followed. The total population of Terrace and surrounding area is 18,144 residents[15] and the average rate of waste generation per capita in B.C. is 0.613 tonnes per year.[16] Multiplying the two values equates to 11,122 tonnes/yr (18,144×0.613) of waste generated in Terrace and surrounding area. Since 18% of the sample weight from the waste composition study was compostable, 11,122 tonnes/yr of waste results in 2002 tonnes of organic matter generated per year (11,122×0.18). The percentage breakdown (33% - wood, 23% - yard/garden, 43% food waste) in the compostable category from the Waste Composition Study was used to calculate the tonnes/yr for each product.

Table 3 summarizes the amount of material that will be available for composting on an annual basis. The input weight of each product category was converted into a unit of volume by multiplying the tonnes generated per year by the average bulk density (tonnes/m³) of each product.

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[15] BC Stats: Census 2006. http://www.bcstats.gov.bc.ca/ City of Terrace = 11,320; Electoral Area 'E' (Thornhill) = 4,002; Electoral Area 'C' (Rural Terrace) = 2,822.

[16] BC Municipal Solid Waste Tracking Report 2006. www.env.gov.bc.ca/epd/epdpa/mpp/pdfs/tracking-rpt2006.pdf.

Table 3: Quantity of Material available for Composting

Category	Waste Generation (tonnes/yr)	Waste Generation (m^3/yr)	Average waste density (tonnes/m^3)
Wood –clean construction	661	2203*	0.30[1]
Yard and Garden	460	1533*	0.30[1]
Food Waste	881	1377	0.64[2]
Total:	**2002**	**5113**	

* volume after shredding

[1] General Measurement Standards and Reporting Guidelines http://www.ecy.wa.gov/programs/swfa/grants/docs/OutcomeMeasureConvSht.pdf

[2] National Recycling Coalition Measurement Standards and Reporting Guidelines; EPA; FEECO and CIWMB 2006

Wood and Yard/Garden Composting

The volume of wood and yard/garden feedstock available for composting is 3736 m^3 (Table 3: 1533m^3 + 1377m^3). Figure 8 provides a schematic of how a potential wood and yard/garden composting operation would appear.

Figure 8: Wood and Yard/Garden Composting Schematic

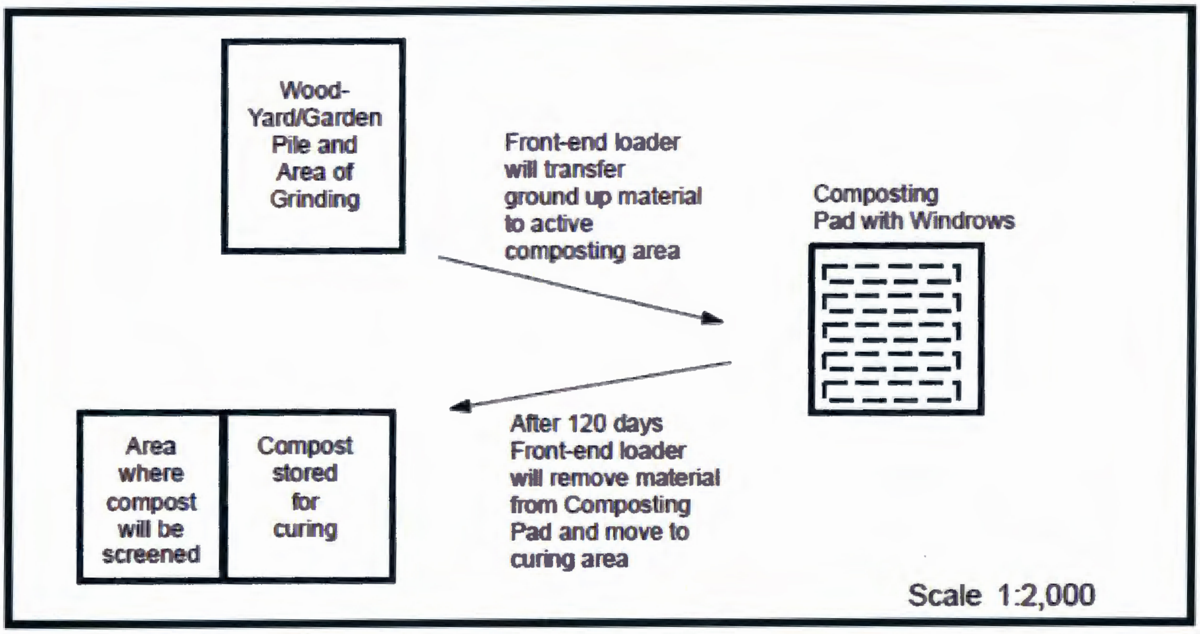
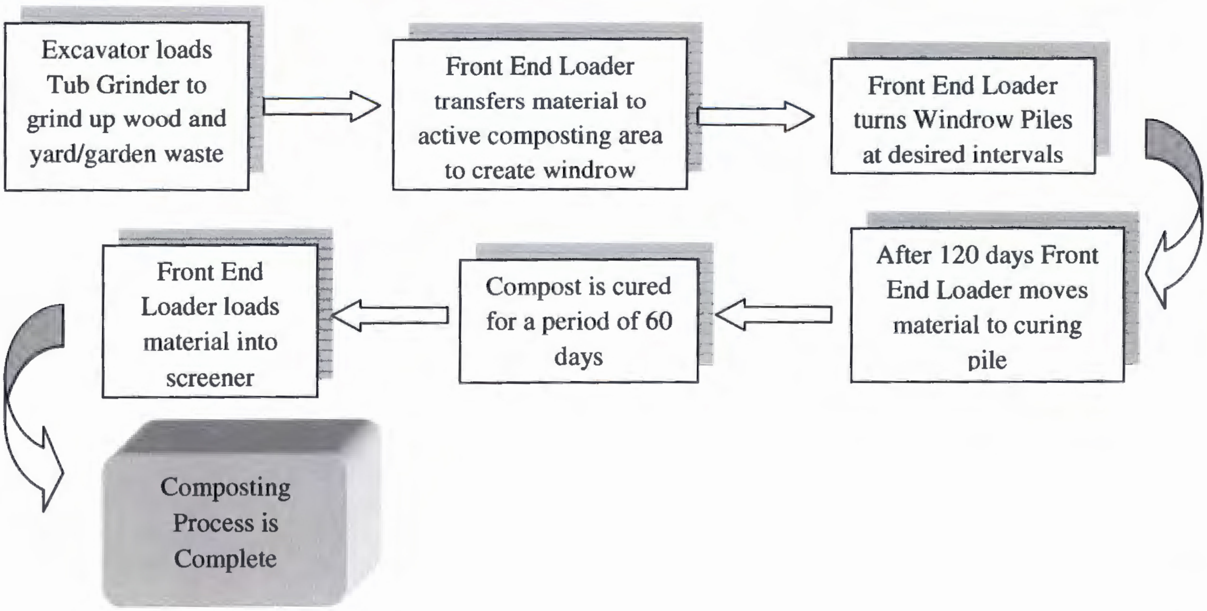


Figure 9: Wood and Yard/Garden Material Flow



If the assumption is made that wood and yard/garden waste will be delivered equally over a 7 month period (April-October) the volume equates to 533 m^3/month. As 533 m^3 is very close to the windrow volume of 527 m^3 one can say that the volume delivered to the landfill will equal one windrow per month. As the windrows will only be on the active composting site for 120 days (or 4 months) the maximum amount of windrows on the active composting site at any one time would be three as at the end of the fourth month when a new windrow would be ready to be created one windrow will be removed and taken to the curing pile. As the asphalt pad has to have sufficient room to turn the windrows it will be assumed an active composting pad that can accommodate 5 windrows will be required. This means an asphalt pad or PVC lined impermeable surface of 1600 m^2 (5 windrows × 8m width × 40m length) will be required. It should be noted that not all material delivered in a season will be composted (i.e. material delivered in October). This material will be retained onsite until the following season when the composting process can be completed.

Table 4 summarizes the parameters used for determining the amount of area required for the active composting. The reason for the difference between the initial input volume of 3736 m^3 and the output volume of 2242 m^3 is that during the composting process the volume of material shrinks while the raw feedstock is transformed into compost.

Table 4: Windrow Composting Design Parameters[1]

Composting Parameters	Value	Windrow Parameters	Value
Composting Period	120 days	Compost Windrow Length	38 m
Shrinkage during composting	30%	Base[2]	6.0 m
Shrinkage during curing	10%	Height[2]	3.5 m
Final Compost Volume	2242m ^{3}	Space between windrows	2.0 m
		Volume per windrow[3]	527 m^3
		Active Compost Pad	1600 m^2

[1] Table adapted from Addla Surender, A.R. (2008)
[2] Values from Art and Science of Composting (Cooperbrand, 2002). Compare closely with dimensions utilized at the Vancouver Landfill – Base: 25ft or 7.62m, Height: 13ft or 3.96m (N.Steglich email to author, Dec. 14, 2009).

[3] Formula used: Volume = Height × Width × Length × .66. Windrow shape is between an oval and trapezoid therefore use .66 as a factor. (Transform Compost Facility Operator Manual http://www.transformcompost.com/tf%20web%20other%20pdf/manual%20teaser.pdf

Capital and operational costs were calculated to determine a cost/tonne and cost/cubic meter. Three options are considered for windrow composting of wood and yard/garden waste. The cost differences between three options only impacts the amortized capital cost. The first option is for the construction of an asphalt pad where the active composting process will take place.

Figure 10: Example of Asphalt Pad

Photo Credit: http://cwmi.css.cornell.edu/compostfs6.pdf

The second option is to substitute the asphalt pad with a compacted gravel surface with an impermeable PVC liner buried in the gravel.

Figure 11: Example of Compost Pad with Liner

Photo Credit: http://cwmi.css.cornell.edu/compostfs6.pdf

The third option is to have the active composting site located on the landfill which is the least expensive as no special site preparation is required to control leachate as the design of the landfill already manages for leachate run-off. With the asphalt pad (Option #1) or the PVC liner (Option #2) additional earthwork is required to direct any leachate toward the leachate control system of the landfill. All three options will be utilising the same type of equipment: a grinder, a front end loader and a screen plant for the composting operation.

The cost/tonne is based on the incoming volume of feedstock while the cost/m³ is based on the final volume of compost produced. It will be assumed that operational costs will be the same for all three options.

Table 5 displays the initial purchase price and amortized capital cost of all the equipment, materials and improvements required for windrow composting of wood and yard/garden waste for all three options. A cost/tonne or cost/m³ is not tabulated for this table because Table 5 is just a summary of all the capital assets required for all three options.

Table 5: Amortized Capital Expenditures (Wood and Yard/Garden Composting)

Capital Asset	Purchase Price	Amortized Capital Cost[1]
Morbark 950 Tub Grinder[2]	$164,080.00	$16,408.00
McCloskey 412 Trommel Screener[3]	$123,853.00	$12,385.30
Asphalt Pad[4]	$64,000.00	$6,400.00
PVC 30 mil Liner[5]	$24,000.00	$2,400.00
Berm/Leachate Construction around Asphalt Pad[6]	$3167.00	$316.70
Installation/Berm/Leachate Construction for PVC Liner[7]	$7945.40	$794.54
Site Design / Engineering	$3500.00	$350.00

[1] Assume capital assets are amortized over a 10 yr period unless specified otherwise. Straight line amortization used as per RDKS procedures (RDKS, email to author, Feb. 10, 2009).

[2] Great West Equipment, email to author, Dec. 15, 2009

[3] Tyalta Industries, email to author, Feb 16, 2010.

[4] Assume cost of \$40/m² (\$40/m² x 1300m²). Cost is worst case scenario and includes grading, placement of 4-6" crush and 3" asphalt (personal communication, Terrace Paving, Dec. 2009).

[5] Assume cost of \$8/m². (Layfield Group, email to author, Dec. 14, 2009).

[6] Assume additional costs to construct berms around asphalt pad and ditch to direct leachate. Lump sum cost = \$3167.00. Cat 320 Excavator (\$158.35× 8hrs ×2.5 days). Excavator hourly rate based on 2009-2010 Blue Book Equipment Rental Rate Guide – BC Road Builders & Heavy Construction Association.

[7] Excavation, Placement of PVC Liner, Backfilling, Berm Construction, Ditches for Leachate. Lump sum cost = \$7945.40 .Cat 320 Excavator of (\$158.35 × 8hrs ×5.5 days) + Compactor (\$122.25 × 8hrs ×1 day). Compactor hourly rate based on 2009-2010 Blue Book Equipment Rental Rate Guide – BC Road Builders & Heavy Construction Association.

Table 6 is an extension of Table 5 by allocating the amortized capital costs that are applicable for each Option. For instance, each option utilises the same piece of machinery (i.e. tub grinder and trommel screener), but the difference between the options is with the type of composting pad used[17]. Option #1 uses an Asphalt Pad which is the most costly, while Option #3 is composting on the Landfill so it does not require a pad for leachate control which is why the only amortized capital costs allocated to it is for the equipment.

Table 6: Amortized Capital Expenditures per Option (Wood and Yard/Garden Composting)

Input: 1121 tonnes
Output: 2242 m³

Amortized Capital Expenditure	Option #1 Asphalt Pad	Option #2 PVC Liner	Option #3 On Landfill
Morbark 950 Tub Grinder	$16,408.00	$16,408.00	$16,408.00
McCloskey 412 Trommel Screener	$12,385.30	$12,385.30	$12,385.30
Asphalt Pad	$6,400.00	n/a	n/a
PVC 30 mil Liner	n/a	$2,400.00	n/a
Berm/Leachate Construction around Asphalt Pad	$316.70	n/a	n/a
Installation/Berm/Leachate Construction for PVC Liner	n/a	$794.54	n/a
Site Design / Engineering	$350.00	$350.00	n/a
Total ($):	**$35,860.00**	**$32,337.84**	**$28,793.30**
$/tonne	**31.99**	**28.85**	**25.69**
$/m³ (finished compost)	**15.99**	**14.42**	**12.84**

Table 7 summarizes all the operational expenditures that a windrow composting operation of wood and yard/garden waste is anticipated to incur. The general process is that an excavator is going to feed the tub grinder the raw feedstock (wood and yard/garden waste) which is going to be ground up. A front-end loader is then going to move the ground up material to create a windrow. On periodic intervals the front-end loader is going to turn the windrows and once the windrows have completed the active phase (assumed to be 120 days) the front-end loader is going to move and place the material in a pile for it to cure (minimum

[17] It is assumed that the life-span of each composting pad will be the same, although it is anticipated that the Asphalt Pad will need to be replaced earlier than the buried PVC Liner as the Asphalt Pad is in direct contact with the machinery.

60 days). Once the compost is cured the front-end loader is going to take the cured compost and place it through a screener to remove any oversized material or non-composted material (commonly referred to as 'overs' in the composting industry) and foreign objects (i.e. rocks). After the compost is screened it will be ready for sale or to be used as a final cover on the Thornhill Landfill. The exact physical location of each activity (i.e. drop-off site of feedstock, grinding site, active composting pad, curing pile) was not established, but it was assumed that each activity would be within 100-200 meters of each other. Once again it was assumed that the operational costs would be the same amongst the three options.

Table 7: Operational Expenditures (Wood and Yard/Garden Windrow Composting)

Input: 1121 tonnes
Output: 2242 m³

Operational Phase	Time	Rate	Total
Excavator to Load Morbark Tub Grinder[1]	198 hrs	$158.35/hr	$31,353.30
Tub Grinder (Fuel and Maintenance)[2]	198 hrs	$36/hr	$7128.00
Front End Loader to create Windrows[3]	75 hrs	$148.90/hr	$11,167.50
Turn Windrows[4]	27 hrs	$148.90/hr	$4,020.30
Move to Curing Area[5]	52 hrs	$148.90/hr	$7,742.80
Front end loader to load Trommel Screen[6]	56 hrs	$148.90/hr	$8338.40
Trommel Screen[7]	56 hrs	$11.00/hr	$616.00
Total ($):			**70,366.30**
$/tonne:			**62.77**
$/m³ (finished compost)			**31.39**

[1] Morbark 950 Tub Grinder can process 35-85 yd³/hr or 26.8-70 m³/hr. Assume midpoint 50 m³/hr.
http://www.palletenterprise.com/articledatabase/view.asp?articleID=307
Assume a 'loose' volume for wood of 3305m³ (assume bulk density of 330lbs/yd³ or 0.2 tonnes/m³) and 'loose' volume of yard/garden of 6571m³ (assume density of 125lbs/yd³ or 0.07 tonnes/m³).
http://www.epa.gov/waste/partnerships/wastewise/pubs/conversions.pdf.
Total volume is then 9876 m³ that once it will be shredded / ground up will be reduced to 3736 m³. Time = 198 hrs (9876 m³ ÷ 50 m³/hr). The excavator hourly rate is from 2009-2010 Blue Book Equipment Rental Rate Guide – BC Road Builders & Heavy Construction Association.

[2] Great West Equipment, email to author, March 10, 2010

[3] Average bucket capacity of 966 Cat Loader is 3.5 m³.
http://www.finning.ca/Products/Equipment/New_Equipment/Wheel_Loaders/966H_Wheel_Loader.aspx

Assume 4 min/cycle from grinding site to windrow pad. 3736 $m^3 \div 3.5$ m^3 = 1067 cycles × 0.07 hr/cycle = 75 hrs. Front End Loader hourly rate from 2009-2010 Blue Book.

[4] Total time of active composting is 24 weeks. Assume 1 turn each week for the first 4 weeks, and then 1 turn every 2 weeks thereafter equals a total of 14 turnings. As shrinkage during composting is assumed to be 30% therefore will use 85% of total initial volume to calculate the length of time for turnings. Assume 2 min/cycle (3176$m^3 \div$ 3.5m^3/bucket × 0.03 hr/cycle) = 27hrs.

[5] Volume to be moved is now 30% of initial volume. Assume 4 min/cycle for windrow pad to curing site. (2615$m^3 \div$ 3.5m^3/bucket × 0.07hr/cycle) = 52hrs

[6] Trommel screen production is 40 m^3/hr (Tyalta Industries, email to author, Feb16, 2010). Curing results in another 10% volume shrinkage. 2242 $m^3 \div$ 40 m^3/hr = 56 hrs.

[7] Trommel screen operational costs: (Tyalta Industries, email to author, Feb16, 2010).

Table 8 is a summary of the tabulated capital costs (Table 6) and tabulated operating costs (Table 7) for a wood and yard/garden composting operation. Summarized costs are presented with the three options.

Table 8: Summary of Costs for Wood and Yard/Garden Windrow Composting

Input: 1121 tonnes
Output: 2242 m^3

	Option #1 Asphalt Pad		**Option #2 PVC Liner**		**Option #3 On Landfill**	
Amortized Capital Expenditures	\$31.99/tonne	\$15.99/m^3	\$28.85/tonne	\$14.42/m^3	\$25.69/tonne	\$12.84/m^3
Operational Expenditures	\$62.77/tonne	\$31.39/m^3	\$62.77/tonne	\$31.39/m^3	\$62.77/tonne	\$31.39/m^3
Total	**\$94.76/tonne**	**\$47.38/m^3**	**\$91.62/tonne**	**\$45.81/m^3**	**\$88.46/tonne**	**\$44.23/m^3**

Food Waste Composting

The amount of food waste available for composting is 1377 m^3 (refer to Table 3). As food waste is high in nitrogen a bulking agent high in carbon (i.e. wood, yard/garden waste) needs to be added to arrive at an appropriate C:N ratio (Ripley and Mackenzie, 2008). Another requirement of the bulking agent is to lower the overall moisture percentage of the feedstock, due to the high moisture content of food waste. Compost managers often use judgement by the feel or look of the mixture to determine the appropriate ratio (Ripley and Mackenzie, 2008). It will be assumed that a 1:1 ratio of food waste to bulking agent will yield the appropriate mixture (ECS, email to author, Dec. 15, 2009). Given the total compostable volume is 5113 m^3 (Table 3) and 2754 m^3 (1377m^3 × 2) is directed toward food waste composting, means 2359 m^3 is remaining. It will be assumed that the residual volume (wood and yard/garden) will be windrow composted. Figure 12 provides a schematic of how a potential food waste operation would appear.

Figure 12: Schematic of Food Waste Compost Facility

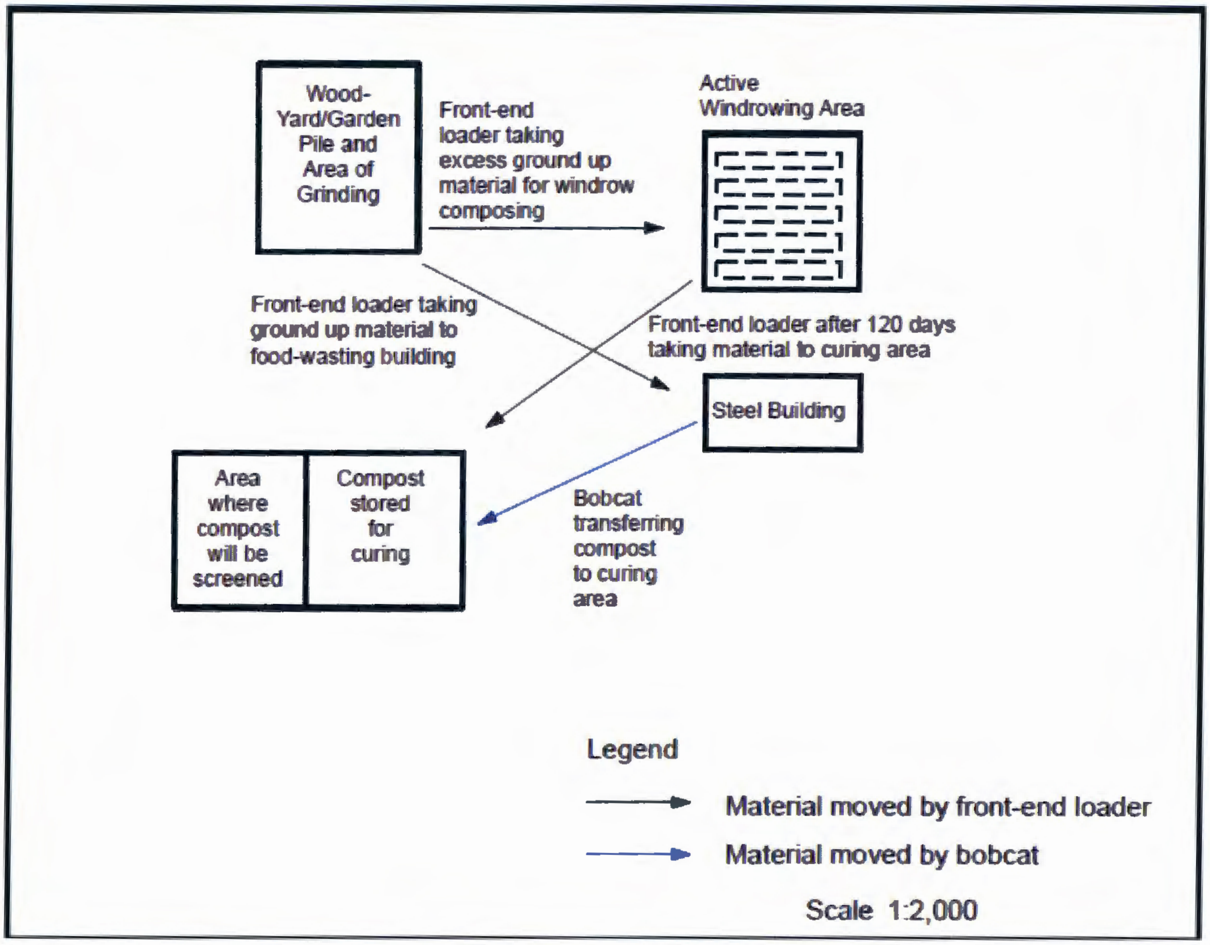
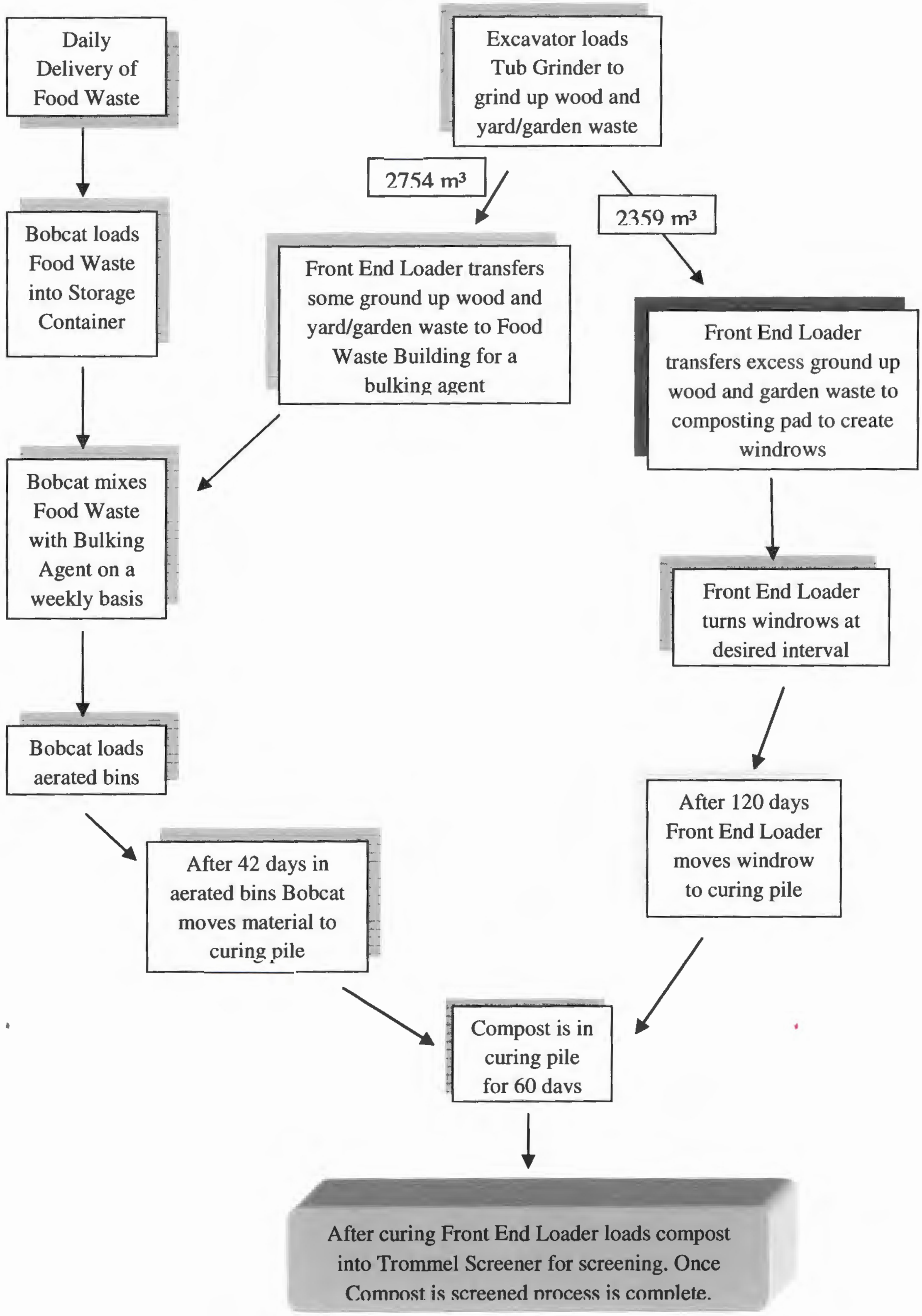


Figure 13: Material Flow of Food Waste Compost Facility



Food waste will be composted inside a facility utilizing aerated bins. A schematic of the facility is shown in Figure 14 and Figure 15 provides an example of approximately what the aerated bins would look like. The conceptual building is assumed to be a 20 m wide by 40 m long pre-fabricated steel building with a concrete foundation and a concrete running surface or floor. Figure 16 is an example of such a steel building. Inside the building there would be a storage container to store the food waste, a place to store the bulking agent (ground up wood and yard/garden waste), the mixer and 6 bins complete with an aeration system.

Figure 14: Diagram of Conceptual Compost Facility

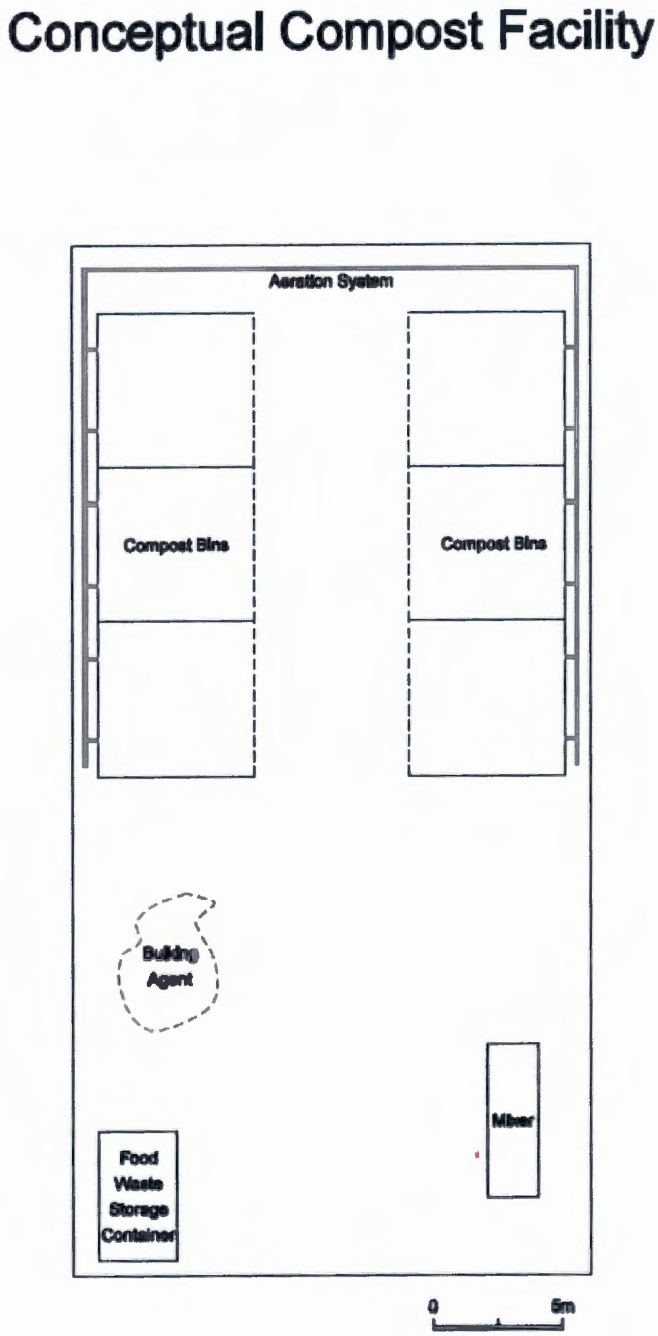


Figure 15: Examples of Aerated Bins

Photo Credit: http://www.transformcompost.com/Projects.htm

Photo Credit: http://www.o2compost.com/content/Bay_Systems_Sm.htm
Note: Aeration System on the right of the photo.

Figure 16: Example of Steel Building

Photo Credit: http://www.alliedbuildings.com/current-agricultural.html

The intent of the facility is to have it large enough so it can accommodate expansion. The use of lock blocks for the aerated bins allows for a 'temporary' bin and if needed, the dimensions of the bin can be modified. Also, it is relatively simple to add an extra bin if feedstock volume is more than estimated and /or 6 weeks is determined to be an inadequate length of time for the active composting process. Total annual capacity of the aerated bins is 4473 m^3.The assumption is that once a week a aerated bin will be filled up with a mixture of food waste and a bulking agent for a total of 52 m^3/week. This means that food waste will have to be stored in a container for approximately 4-5 days before being mixed with a bulking agent and placed in a bin for the composting cycle to start. The rationale for waiting 4-5 days is twofold: (1) do not want to put a portion of feedstock in the aerated bin each day as the composting process may start and (2) want to ensure that the aerated bins are full prior to starting the compost process. After six weeks (42 days) the aerated bins will be emptied and the compost will be taken outside for curing.

Table 9 summarizes the dimensions of the aerated bins, the amount of material to be composted on a weekly basis and the duration of the composting period.

Table 9: Aerated Bin Composting

Composting Parameters	**Value**	**Aerated Bin Parameters**	
Composting Period	42 days[1]	Width	6 m
Shrinkage during composting	30%	Length	5.25 m
Shrinkage during curing	10%	Height	2.25 m
Food waste input	26 m³/week[1]	No. of Bins[2]	6
Bulking Agent	26 m³/week[1]		

[1] Transform Compost, email to author, Dec 17, 2009

[2] 1377 m³ food waste ÷ 52 weeks

[3] 42 days composting/bin = 9 cycles/bin/year. Approx. volume/bin is 71m³ or each bin can process 639m³/yr.

Capital and operating costs were calculated to determine a cost/tonne and cost/cubic meter. The grinding costs were all attributed to the food waste composting phase as a bulking agent needs to be added to the food waste and it is immaterial whether all the grinding costs are in the food waste composting phase or only a portion with the remaining in the windrow composting phase (i.e. the overall expenditure will still be the same).

Table 10 is a summary of the capital expenditures anticipated with a food waste composting operation. Some expenditure, such as the tub grinder and trommel screen are the same as with the windrow composting operation of only wood and yard/garden waste (Tables 5 & 6) but the remaining capital expenditures are unique to a food waste composting operation. For example, a mixer is required to mix the food-waste with the bulking agent (wood and yard/garden waste). A Bobcat (small loader) is required to manoeuvre within the confines of the building to load the mixer and the aerated bins. As food waste composting is more involved than simply composting wood and yard/garden waste there is also a line item for training.

Table 10: Amortized Capital Expenditures (Food Waste)

Capital Expenditures	Initial Cost	Amortized Cost[1]
Steel Building [2]	$597,700	$29,885.00
Supreme EnviroProcessor 600 Mixer[3]	$62,650.00	$6,265.00
Lock-Block Bins[4]	$36,133.02	$3613.30
Computerized Control System with Aeration Unit[5]	$60,000	$6000.00
Bobcat[6]	$41,000	$3,430.00
Morbark 950 Tub Grinder[7]	$164,080.00	$16,408.00
McCloskey 412 Trommel Screener[8]	$123,853.00	$12,385.30
Food Waste Storage Bin	$2000.00	$200.00
Engineering / Site Design	$10,000.00	$1000.00
Training[9]	$4000.00	$400.00
Total:	**$1,094,716.00**	**$80,256.60**
$/tonne (input)[10]		**$62.02**
$/m³ (output)[11]		**$48.58**

[1] Costs for equipment will be amortized over a 10 yr period. Building will be amortized over 20 yr period. Amortization will the straight line method. (RDKS, email to author, Feb. 10, 2009).

[2] Steel building (800m² or 8608 ft²) complete with concrete foundation, prepared surface, lights and electric heat. McElhanney email to author Feb 15, 2010 estimated $84/sq.ft. AFJ Construction email to author Feb 18, 2010 estimated $55-60/sq.ft. Will use mid-point = $69.50/sq.ft.

[3] Transform, email to author, Feb 16, 2010.

[4] Lock-Block dimension 1.5m long × 0.75m wide. Need 33 Lock-Blocks per bin. 6 bins = 198 Lock-Blocks. Unit Cost = $162.49 (Skeena Concrete, personal communication, Feb 16, 2010). Added an additional $20/block to address delivery and installation ($4000 over 3 days) so total is $182.49.

[5] Transform, email to author, Feb 16, 2010.

[6] Williams Machinery, email to author, Feb 16,2010.

[7] Great West Equipment, email to author, Dec. 15, 2009

[8] Tyalta Industries, email to author, Feb 16, 2010.

[9] Transform Compost Course $495. Accommodation/Flight/Meals = $1500. Assume $2000.00/person.

[10] Tonnage input is 413 tonnes of wood or yard/garden waste and 881 tonnes of food waste for a total of 1294 tonnes.

[11] Volume output is 1652m³ from an input of 2754m³.

Table 11 summarizes the anticipated operational costs for operating a food waste composting facility. The general process is that food-waste will be dropped off at the facility on a daily basis in which the Bobcat will place the food waste into the storage container. At the end of the week the Bobcat will mix the food waste with the bulking agent and move the mixed material into one of the aerated bins to start the composting process. The bulking agent (wood and yard/garden waste) will have been ground up earlier with the tub grinder. The placing of the food waste into the storage container will occur on a daily basis and the mixing of the food waste and the bulking agent and transfer to the aerated bins will occur on a weekly basis. Once, the active composting process is complete (42 days) the Bobcat will empty out the aerated bin and transfer the compost to the curing area (assumed to be outside of the building, but in close proximity). Once the compost is cured (minimum 60 days) a front-end loader will take material from the cured pile and load it onto the trommel screen which will remove non-composted organic matter and foreign objects (i.e. plastic, bones). Once the compost is screened it will be ready for sale or to be used as a final cover on the Thornhill Landfill. The line item Administration refers to the involvement from RDKS staff in a food waste composting facility.

Table 11: Operational Expenditures (Food Waste)

Phase	Time	Rate	Total
Excavator to Load Morbark TubGrinder[1]	198 hrs	$158.35/hr	$31,353.30
Tub Grinder (Fuel and Maintenance)[2]	198 hrs	$36/hr	$7,128.00
Front End Loader transferring bulking agent to Food Waste Building[3]	27 hrs	$148.90/hr	$4020.30
Bobcat[4]	273 hrs	$78.60/hr	$21,457.80
Mixer[5]	52 hrs	$10.00/hr	$520.00
Bobcat moving Compost to Curing Area[6]	146 hrs	$78.60/hr	$11,476.00
Front end loader to load Screener[7]	41 hrs	$148.90/hr	$6104.90
Screening[8]	41 hrs	$11.00/hr	$451.00
Electricity (light/heat)[9]	325,000 kWh	$0.0769	$24,992.50
Administration[10]			$2500.00
Total ($)			**110,003.80**
$/tonne (input)[11]			**85.01**
$/m³ (output)[12]			**66.59**

[1] Morbark 950 Tub Grinder can process 35-85 yd³/hr or 26.8-70 m³/hr. Assume midpoint 50 m³/hr. http://www.palletenterprise.com/articledatabase/view.asp?articleID=307.
Assume a 'loose' volume for wood of 3305m³ (assume bulk density of 330lbs/yd³ or 0.2 tonnes/m³) and 'loose' volume of yard/garden of 6571m³ (assume density of 125lbs/yd³ or 0.07 tonnes/m³).
http://www.epa.gov/waste/partnerships/wastewise/pubs/conversions.pdf.
Total volume is then 9876 m³ that once it will be shredded / ground up will be reduced to 3736 m³. Time = 198 hrs (9876 m³ ÷ 50 m³/hr). The excavator hourly rate is from 2009-2010 Blue Book Equipment Rental Rate Guide – BC Road Builders & Heavy Construction Association.

[2] Great West Equipment, email to author, Feb. 12, 2010

[3] Require 26m³ of bulking agent/week to be mixed with the food waste. Yearly total will equal 26m³ × 52 weeks = 1352m³. Average bucket capacity of 966 Cat Loader is 3.5m³.
http://www.finning.ca/Products/Equipment/New_Equipment/Wheel_Loaders/966H_Wheel_Loader.aspx
Assume 4 min/cycle from grinding site to food waste building. 1352m³ ÷ 3.5 m³ = 386cycles × 0.07 hr/cycle = 27 hrs. Front End Loader hourly rate from 2009-2010 Blue Book.

[4] Assume .5 hr/day for Bobcat to load Storage Bin. (52weeks/yr × 5days/week × .5hrs/day = 130 hrs). Mixer production rate is 25-35 tonnes/hr (Transform, email to author, Feb 16, 2010) and Bobcat needs to load mixer. Weekly material to be mixed is 52m³ or 23.8 tonnes. Therefore, assume 1 hr/wk to load mixer × 52 weeks = 52 hrs. Bobcat Bucket is 32ft³ or 0.9m³ (Williams Machinery, email to author, Feb 16,2010) so 52m³/bin = 58 cycles/bin. Assume 2.0 min/cycle. 58cycles/bin × .03hrs/cycle = 1.75hrs × 52 weeks = 91hrs. Total Bobcat time for the year is: 130hrs + 52hrs + 91hrs = 273hrs. Hourly Rate for Bobcat is from 2009-2010 Blue Book Equipment.

[5] Mixer production rate is 25-35 tonnes/hr (Transform Compost, email to author, Feb 16, 2010). Weekly material to be mixed is 52m³ or 23.8 tonnes. Therefore, assume 1 hr/wk to load mixer × 52 weeks = 52hrs.

[6] Bobcat Bucket is 0.9m³ so 52m³/bin – 30% reduction in volume/bin = 40 cycles/bin. Assume 4.0 min/cycle. 40cycles/bin × .07hrs/cycle = 2.8hrs × 52 weeks = 146hrs.

[7] Screen production is 40 m³/hr (Tyalta Industries, email to author, Feb16, 2010). Curing results in another 10% volume shrinkage. 2754m³(orginal volume) × 0.6 (shrinkage factor) ÷ 40 m³/hr = 41hrs.

[8] Trommel screen operational costs: (Tyalta Industries, email to author, Feb16,2010).

[9] Average yearly electricity consumption = 325,000 kWh. Used City of Terrace Public Works Building 2007 consumption as reference (City of Terrace Corporate Energy & GHG Inventory, Sheltair Group, December 30, 2008). Average rate per kWh used = $0.0769 https://www.bchydro.com/youraccount/content/electric_tariff.jsp

[10] RDKS Administration. RDKS email, to author, Feb 16, 2010.

[11] Tonnage input is 413 tonnes of wood or yard/garden waste and 881 tonnes of food waste for a total of 1294 tonnes.

[12] Volume output is 1652m³ from an input of 2754m³.

It was assumed the remaining wood and yard/garden waste (2359 m³) would be composted on the landfill so no extra capital expenditures are required for leachate control. This assumption was made to minimize the overall capital expenditures, as the initial outflow of cash is quite substantial for the food waste composting phase.

Table 12 is a summary of the anticipated operational expenditures that will be incurred for windrow composting the excess wood and yard/garden waste that is not required to be used as a bulking agent for the food waste composting process. The process is very similar or even identical to the process discussed for Table 7, and hence will not be repeated.

Table 12: Operational Expenditures for the residual portion of the Wood and Yard/Garden Waste

Operational Phase	Time	Rate	Total
Front End Loader to create Windrows[1]	47 hrs	$148.90/hr	$6,998.30
Turn Windrows[2]	17 hrs	$148.90/hr	$2,531.30
Move to Curing Area[3]	33 hrs	$148.90/hr	$4,913.70
Front end loader to load Screener[4]	35 hrs	$148.90/hr	$5,211.50
Screening[5]	35 hrs	$11.00/hr	$385.00
Total ($):			**$20,039.80**
$/tonne (input)[6]			**28.30**
$/m³ (output)[7]			**14.16**

[1] Average bucket capacity of 966 Cat Loader is 3.5m³.
http://www.finning.ca/Products/Equipment/New_Equipment/Wheel_Loaders/966H_Wheel_Loader.aspx
Assume 4 min/cycle from grinding site to windrow pad. $2359m^3 \div 3.5\ m^3 = 674$cycles $\times$ 0.07 hr/cycle = 47 hrs. Front End Loader hourly rate from 2009-2010 Blue Book.

[2] Total of 24 weeks. Assume 1 turn each week for the first 4 weeks, and then 1 turn every 2 weeks thereafter equals a total of 14 turnings. As shrinkage during composting is assumed to be 30% therefore will use 85% of total initial volume to calculate the length of time for turnings. Assume 2 min/cycle ($2005m^3 \div 3.5m^3$/bucket $\times$ 0.03hr/cycle) = 17hrs

[3] Volume to be moved is now 30% of initial volume. Assume 4 min/cycle for windrow pad to curing site. ($1651m^3 \div 3.5m^3$/bucket $\times$ 0.07hr/cycle) = 33hrs

[4] Screen production is 40 m^3/hr. Curing results in another 10% volume shrinkage. $1415m^3 \div 40m^3$/hr = 35 hrs.

[5] Screen operational costs $11.00/hr

[6] $2359m^3$ input equates to 708 tonnes.

[7] Volume output equates to 1415 m^3.

Table 13 is a summary of the feedstock inputs (tonnes), compost output (volume) and the tabulated costs for a composting facility that incorporates food waste into the compost stream.

Table 13: Summary – Food Waste Composting

	Input Weight (tonnes)	**Output Volume (m^3)**	**$/tonne (input weight)**	**$/$m^3$ (output volume)**
Capital Expenditure (Food Waste Composting)	1294	1652	62.02	48.58
Operational Expenditure (Food Waste Composting)	1294	1652	85.01	66.59
Operational Expenditure (Windrow Composting remaining Waste)	708	1415	28.30	14.16

Since all the wood and yard/garden material is not required as a bulking agent when composting food waste it was assumed that the remaining volume is going to be windrow composted. So in actuality with a facility that composts food waste there is still some windrow composting occurring. As the costs differ between composing food waste and windrow composting wood and yard/garden to get an accurate representation of the costs of a food waste composting facility the costs of the two methodologies need to be prorated. Table 14 provides a summary of the prorated costs. Note: only the operational costs are prorated as it was assumed that there were no capital expenditures for the windrow composting portion at a food waste composting facility.

Table 14: Prorated Summary – Food Waste Composting

	Input Weight (tonnes)	**Output Volume (m^3)**	**\$/tonne (input weight)**	**\$/m^3 (output volume)**
Capital Expenditure (Food Waste Composting)	1294	1652	62.02	48.58
Operational Expenditure (Food Waste Composting)	1294	1652	55.26	35.96[3]
Operational Expenditure (Windrow Composting remaining Waste)	708	1415	9.91[2]	6.51[4]
Total (\$):			**127.19**	**91.05**

[1] Total input weight in tonnes = 2002. 1294 ÷ 2002 = 65%. Therefore multiply 85.01 × 0.65 = \$55.26
[2] Total input weight in tonnes = 2002. 708 ÷ 2002 = 35%. Therefore multiply 28.30 × 0.35 = \$9.91
[3] Total output in volume = 3067. 3067 ÷ 1652 = 54%. Therefore multiply 66.59 × 0.54 = \$35.96
[4] Total output in volume = 3067. 3067 ÷ 1415= 46%. Therefore multiply 14.16 × 0.46 = \$6.51

CHAPTER 6 – DISCUSSION

Limitations of Economic Review in the Literature

Although Renkow and Rubin (1998) and Steutville (1996) conducted their research more than twelve years ago, it is interesting to note the similarities in the issues experienced by me. Several private facilities that were contacted in the Lower Mainland never returned calls or were not interested in speaking to me, whereas all the public facilities were more than helpful. Moreover, one public facility that was contacted did not even really know what their cost/tonne is and are in the process of trying to quantify their costs by installing a set of weigh scales as a first step.

As previously noted obtaining composting costs for the different composting methodologies was a challenge. The lack of available data was one problem; however the greatest difficulty was trying to make an 'apple to apple' cost comparison for a given methodology. When trying to determine a cost for a composting methodology it is more beneficial to have costs from more than one facility so a range of costs can be provided. However, when the reported data is not based on the same parameters making a comparison between two costs can be difficult if not near impossible. It is speculated that the data in the literature is incomplete due to the absence of a need and the inherent variability of the industry.

For publicly owned facilities composting is possibly viewed more as a public good. The motivation or need for a municipality or regional district to compare or benchmark its costs with another is not present. Organic material is being diverted from the landfill and compost, with its many beneficial applications, is being created instead – so all is good. There is little incentive to report on costs.

Privately operated facilities likely consider their financial statements as proprietary. Private facilities charge a tipping fee for the municipal waste and then convert the input (yard/garden debris, food waste) into compost which they then can market and sell. As these private facilities are operating in the public realm, if their financials were made known and their profits are considered too high the facility could be pressured to lower its tipping fees.

The intention of researching the literature for the economics of different composting methodologies was to provide an indication which methodologies would be most applicable to the RDKS at the Thornhill and Forceman Ridge Landfills. For this purpose the literature was beneficial.

Economics

As expected composting only wood and yard/garden waste is less expensive than when food waste is incorporated into the composting process which is to be expected as the capital costs for a wood and yard/garden compost facility are less. The cost of windrow composting is more expensive than initially anticipated from the literature review. One of the reasons for this could be the frequency of turnings (14) used in the financial calculations. The windrow piles were turned at such a frequency to ensure the piles would remain aerobic (minimize odour) and that the composting process could be completed within 4 months.

Another potential reason for the higher than anticipated cost is, the low volume of material being windrow composted. The financial calculations of \$/tonne and \$/m^3 are predicated on dividing the total dollar value of the amortized capital costs and the annual operational costs by the input weight ($/tonne) and the output volume ($/m³). With an input volume of only 1121 tonnes and an output volume of 2242m³ (i.e. windrow composting wood and yard/garden only) the resultant calculation ($/tonne and $/m³) is very sensitive to the total dollar figure for the capital and operational costs. For example, for the input weight, every $1000 change in the capital and operational costs is going to adjust the $/tonne calculation by $0.89/tonne ($1000 ÷ 1121 tonnes). Using, as an example, Option #3 (Table 6) the amortized capital cost is $28,793.30 and the operational cost (Table 7) is $70,366.30 for a total of $99,159.60. A ten percent change in costs[18] is $9,915.96 or a change of $8.84/tonne ($9,915.96 ÷ 1121). Although the above example only pertains to Option #3 of windrow composting only wood and yard/garden waste, the principal is applicable to all the financial calculations. With such a small volume being composted no economies of scale are being realized.[19]

During the calculations two cost components were purposely omitted to keep costs down. The first was no accounting for a shelter or cover for the curing piles. It was assumed the RDKS would be able to cure compost without having to put it underneath a shelter or covering it. If it turns out the curing compost would need to be covered the least expensive option would be placing Compotex™ over the piles. Composting wood and yard/garden waste yields 2615 m³ of compost for curing while composting food waste yields 3580 m³.

[18] A ten percent change in costs is not that significant when costing out a project such as was done in Tables 5 to 7.

[19] It is beyond the scope of this paper to quantify the volume where economies of scale would be realized.

Compotex™ to cover 2615 m³ of compost would cost approximately \$5000.00[20] plus the time it took to place over the pile. For 3580 m³ the cost would increase to \$7000.00.

The second omission was not including the cost of a biofilter in the cost of the steel building. The hope is that the placement of 'overs' (residuals from the screening process) or wood chips on top of the compost pile in the aerated bins will address any potential odour issues.

During the financial calculations one item was noted that could have a substantial impact on the overall cost/tonne or cost/m³ and should be elaborated on. It is material/flow management.

Material/Flow Management

When discussing composting facilities and costs the literature describes the composting methodology being applied and the rationale for choosing the methodology. However no reference was found to the efficient design of a facility versus an inefficient design. A possible explanation is that for many facilities land may be a limiting factor so a facility just utilizes the area that it has to work with the best that it can. Any generic compost facility has the following processes: arrival of feedstock, converting feedstock to a useable form, composting and curing. If the location of these four phases is misaligned operational costs could increase substantially. For the RDKS cycle time calculations were used to determine the equipment time to complete a phase. For instance the cycle time from the shredding/grinding site to the windrow pad was assumed to be 4 min/cycle (composting only wood and yard/garden waste) resulting in a cost of \$11,167.50. If this cycle time was

[20] Compotex™ costs \$0.25/sq.ft. (Transform, email to author, Feb 16, 2010). Using the effective circumference equation (http://www.transformcompost.com/tf%20web%20other%20pdf/manual%20teaser.pdf) yields an area of 3789 sq.ft for each curing windrow.

increased to 6 min/cycle the equipment hours increases from 75 hrs to 106.7 hrs or an increase of $4,720.13[21]. With the RDKS processing a relatively small amount of compost 2242 m^3 or 1121 tonnes this results in an increase of $2.10/$m^3$ or $4.21/tonne. The above is an example from only one phase. If the locations of all the phases are misaligned the additional incurred costs could become substantial. Ideally, all the phases would be as close to each other as possible and appropriately aligned to minimize the distance and time for material movement.

<u>Thornhill Landfill versus Forceman Ridge</u>

Each site has its disadvantages and advantages. The Thornhill Landfill is closer to the communities of Terrace and Thornhill so there is less transportation expense for private or commercial haulers to deliver organic waste. However odours arising from the composting process could be an issue at Thornhill. The nearest group of houses is 1.5 km away from the dump but there is one residence very close to the landfill, 250m away.[22] As Forceman is located 26 km south of Terrace and not near any settled areas (Lakelse Lake is approximately 6.0 km to the north)[23] odour concerns are substantially less, though portions of the Onion Lake Ski Trails are located within 1.0 km of the proposed landfill. For food waste composting there is a higher likelihood for the need of a biofilter in a composting facility in Thornhill than at Forceman. As odours can be a composting facility's largest challenge (Forgie et al., 2004; Renkow and Rubin, 1998) Forceman would appear to be a better option, however the additional transportation costs cannot be overlooked. One potential end use of

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[21] A one minute increase in cycle time would result in an increase in $2069.71 or approximately $34.50/second.

[22] Google Earth, accessed February 15, 2010.

[23] Ibid

the compost is as a final cover on the closed Thornhill Landfill; however the cost to transport finished compost from Forceman to Thornhill is $64,336.22 (Appendix F). In essence raw material would be hauled out to Forceman, composted and then hauled back to Thornhill. Unless there are some extenuating circumstances, from a supply chain perspective such routing of material is illogical. Another potential end use of compost is compost sales to landscapers or residents. Once again the location of Forceman is at a disadvantage. Landscapers or residents may be more inclined to source the product locally rather than having to travel 26 km (one way) to purchase compost.

Economic Benefits from Composting

<u>Compost as Final Cover</u>

The Thornhill Landfill is projected to reach capacity by 2014 (Sperling Hansen Associates, 2008) when it will be closed. The most significant concern after closure is water percolating through the landfill, heavy metals or organics from material buried in the landfill attaching to the water molecules and then the contaminated water or leachate entering the water table. To prevent water from leaching through the landfill an impermeable layer is placed over the landfill. The final or top layer of this impermeable surface is 0.3m of top soil which is to act as a growing medium for new vegetation.[24] Dr. Tony Sperling confirmed (email to author, Dec. 13, 2009) that a 50/50 mix of compost and mineral soil would also suffice. For the final layer the RDKS has two options. It can purchase compost from a supplier or use the compost produced at the Thornhill Landfill (transporting it from Forceman Ridge would be cost prohibitive).

From Sperling Hansen Associates (2008) it was estimated that 4.159 ha or 41,590 m^2 of area requires an impermeable layer once the Thornhill Landfill is closed. Assuming a 50/50 blend of compost and mineral soil for the final 0.3m layer results in a 6239 m^3 of compost required. Suppliers of compost in the Terrace area were contacted and from the prices provided it appears as if it is more cost effective to purchase from a third party than for the RDKS to compost themselves.

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[24] Sperling Hansen Associates. Updated Cost Analysis of Regional Landfill Development at Thornhill, September 22, 1999. Report prepared for the Regional District of Kitimat-Stikine and inserted into Forgie (1999).

Table 15 illustrates the cost difference in compost purchased from a local supplier versus the RDKS producing compost from a windrow composting operation that is located on the landfill.

Table 15: Cost Comparison of Supplier and RDKS produced Compost

Volume = 6239 m^3

	Cost	Total
RDKS Windrow Composting at Thornhill	\$44.23/m^3	\$275,950.97
Local Supplier	\$28.13/m^3	\$175,503.07

[1] Cost based on finished product volume.
[2] Two local suppliers were contacted in December 2009 – Cypress Landscaping and J.L. Excavating. Price estimate given for delivery of screened ¾" topsoil was essentially the same.

It was not researched further why local suppliers were able to supply compost substantially cheaper than the RDKS being able to produce it at Thornhill. One possible explanation is that they utilize static pile composting which is cheaper than windrow composting.

Another issue with utilizing composting strictly made at Thornhill is the volume required for the final cover (6239 m^3). It is projected that a windrow only composting facility will produce 2242 m^3 and adding food waste will increase the compost output to 3067 m^3. Either way it will be several years before there is sufficient compost produced to meet the final cover requirements. It is questionable if the RDKS will want to wait several years or do the final cover in phases. It may be more cost effective (i.e. mobilization of equipment, planning and site engineering) to do the project all at once.

Compost Sales

Compost is a highly desired product by landscapers and the public. All the compost facility operators on the tour of the three facilities in the Lower Mainland stated that there was no issue in selling the compost. The Cinnamon Ridge Facility by Kamloops sells their compost for $27.60/m³ (City of Kamloops, email to author, Jan. 26, 2010) while the Vancouver Landfill sells their compost for $10.00/m³ (N.Steglich, email to author, Dec. 14, 2009). Ripley and Mackenzie (2008) reported that Olds Alberta charges $27.25/m³ for compost and the City of Kelowna sells compost for $18.96/m³ on bulk quantities >69 m³.

An assumption will be made that the RDKS will sell compost for $20.00/m³. If only composting wood and yard/garden waste (Option A) 2242 m³ of compost is produced, whereas if food waste is incorporated into the composting process (Option B) 3067 m³ is produced. Insufficient revenue is derived from compost sales to recover the costs incurred from composting.

Table 16 summarizes the net cost to the RDKS in producing compost once the revenue from the sale of compost is taken into account. For Table 16 the cost of producing compost (Option A) is taken from a windrow composting operation that is located on the landfill as such an operation has the lowest unit cost (refer to Table 8).

Table 16: Compost Sales

	Cost	**Sales**	**Residual Cost**
Option A	$44.23/m³	$20.00/m³	$24.23/m³
Option B	$91.05/m³	$20.00/m³	$71.05/m³

Greenhouse Gas Emissions

The literature has reported that for every tonne of organic waste composted versus landfilled results in the reduction of 0.2 tonnes of greenhouse gases (GHG) (CM Consulting, 2007). The composting of yard and garden waste will reduce greenhouse gas emissions by 224 tonnes (1121 tonnes × 0.2). When foodwaste is included in the composting stream GHG emissions are further reduced by 176 tonnes (881 tonnes × 0.2) for a total of 400 tonnes per year.

The Pacific Carbon Trust (PCT) is a British Columbia Crown Corporation that trades in carbon credits. It currently sells GHG off-sets for $25/tonne.[25] The price paid for offsets is based on a competitive bid process. Furthermore, purchase of off-sets by the PCT is based on a six step process and the GHG reduction must be validated and verified by an objective 3rd party. [26] By the RDKS diverting organics from the Thornhill or Forceman landfills the potential GHG savings is 400 tonnes. The potential revenue derived from these off-sets is small. Although it is extremely unlikely, but if an assumption was made that the offsets were purchased from the RDKS for $25/tonne the revenue generated would be $10,000. Subtract administration costs for the six-step process and 3rd party validation and verification and the monetary benefit is negligible. Actually when the PCT was contacted they indicated that the quantity of GHG savings required to 'breakeven' (i.e. the revenue derived from the credits minus the expense to validate and verify) would be approximately 5,000-10,000 tonnes in GHG savings per year (PCT, personal communication, March 5, 2010).

Leachate Control

Prior to initiating the project the hope was that the diversion of organics from the landfill would have substantial savings on the post closure costs of the Thornhill Landfill and the leachate treatment proposed for the Forceman Landfill.

As previously mentioned the Thornhill Landfill is projected to be closed in approximately 2014. It has been in operation since mid seventies (R.Tooms, email to author, Mar 3, 2010). Even in a hypothetical scenario, if organics were banned from the Thornhill landfill starting May 2010 a four year absence of organics in the landfill will have no impact

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[25] http://www.pacificcarbontrust.com/, accessed Feb 16, 2010.

[26] Ibid

in lessening the post closure leachate costs given that the landfill contains 35 years of buried organics and a host of other products that likely would not even make it to the landfill today (T.Sperling, email to author, Jan 26, 2010).

By the time the Forceman Landfill is operational it is possible the RDKS will have instituted a policy of no organics in the landfill. The Forceman Landfill, which currently is in the design phase, will have a leachate treatment facility. With no organics being landfilled it is conceivable that there could be capital and operational savings with the leachate treatment facility due to lower leachate concentration. For example, savings may occur from less aeration required in the leachate ponds. However trying to quantify the potential cost savings at this time is difficult as the design of the proposed landfill is still in progress (D.Forgie, email to author, Jan 28, 2010).

Landfill Extension

With the closure of the Thornhill Landfill approximately 4 years away an organic diversion strategy is going to have minimal impact in extending the lifespan of that landfill. From the Waste Composition Study, 18% of waste is compostable (RDKS, 2010). The current incoming annual tonnage to Thornhill is estimated to be 6698 tonnes/yr (Sperling Hansen and Associates, 2008), therefore 1206 tonnes/yr is organic. The cumulative volume after 4 years would be 4824 tonnes, however even this number is misleading. The Thornhill landfill already separates wood and yard/garden debris from the waste stream by placing it in a burn pile. Food waste is buried at the landfill, however this is only 519 tonnes/yr[27] or 2076

[27] 1206 tonnes/yr is organic. From the 2009 Waste Composition Study of the Compostable Materials 43% is food waste. 1206 tonnes/yr × .43 = 519 tonnes/yr.

tonnes after 4 years. Eliminating 2076 tonnes over 4 years is going to extend the lifespan of the landfill by approximately 4 months.[28]

The Forceman Landfill is expected to be constructed in several phases with a life expectancy of 50+ years. A life expectancy of 50 years equates to a capacity of 556,100 tonnes assuming the waste per year remains constant.[29] An organic diversion program would divert 2002 tonnes/yr or 18% of the assumed 11,122 tonnes/yr generated. By diverting 2002 tonnes/yr after 50 years the landfill will only contain 456,000 tonnes, or 100,100 tonnes below capacity which would extend the use of the landfill by approximately 11 years or 22%.[30] Trying to attach a monetary value to this extension in present dollars is difficult or impossible. It is unknown what constraints will be on the landbase in 50 years and what value the land would have.

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[28] 2076 tonnes ÷ 6698 tonnes/yr = .31 yrs. Multiply 0.31 yrs by 12 months/yr = 3.7 months.

[29] It is acknowledged by the author that the potential capacity of Forceman is much greater. Forgie (2000) indicated that ultimate capacity could be up to 1.5 million tonnes. The 50 year life expectancy is used to illustrate a point. http://rdks.bc.ca/pdf/brochures/info_forceman_ridge.pdf

[30] 11,122 tonnes/yr – 2002 tonnes/yr (diverted) = 9120 tonnes being landfilled. 100,100 tonnes ÷ 9120 tonnes/yr = 10.97 or approximately 11 years.

Cost/Benefit

The analysis clearly shows that from a strictly financial, dollars and cents view the costs incurred from composting outweigh the benefits. At the initiation of the project it was thought that utilizing the compost for a final cover layer would result in substantial enough cost savings to defray the expenditures incurred with composting. The contrary is true. It appears that it is actually more cost effective to source the final cover layer from an outside party. With the Thornhill landfill near capacity an organics diversion at this stage will have no impact on the post closure leachate treatment costs. Unfortunately the design for the proposed Forceman Landfill is still in the preliminary stages so a defensible estimate cannot be provided in the potential savings to the leachate treatment facility at that landfill. Once again with Thornhill near the end of its useful life the impact of diverting organics to extending the lifespan of the landfill is insignificant. An organic diversion strategy would benefit the Forceman Landfill by extending the life of that landfill but with a lifespan of 50+ years how significant is it now if one calculates that the life of the landfill could be extended by 11 years? Yes, it could mean an eventual smaller footprint[31] but currently, and none are foreseen, there are no constraints on land availability in that area. Organic diversion will lessen the release of GHG emitted from the landfill, however once again from a strictly monetary perspective it is difficult to argue (at the present time) that the gain from carbon credits is worth the effort to pursue the credits.

[31] The concept of a social license was beyond the scope of this paper.

Recommendation

Although a financial case cannot be made for composting, the benefits of composting will not be disputed. Reducing the amount of GHG emitted from a landfill is a good thing as so is reducing the footprint of future landfills. The current practice of burning clean wood and yard/garden waste although very cost effective seems somewhat of a waste in today's day and age. For example it was thought that if the wood and branches were ground up it could be utilized by the pellet industry. However when Pacific BioEnergy was contacted they expressed concern about the possibility of contamination (shredded yard/garden waste mixed with the shredded wood) of the feedstock (Pacific BioEnergy, email to author, Feb 15, 2010).

If the RDKS is serious in considering in diverting organics from its landfills it should consider two options. The first option is to promote decentralised composting (i.e. backyard composting). The second option is to implement a couple of composting pilot projects to replicate a centralised composting facility.

Decentralised composting is where individual homeowners in a community compost their own organic matter in their backyard. In terms of diverting organic matter from a landfill decentralised composting is the most cost effective, as there are no costs involved with curb-side pickup, transportation to the landfill and processing at the landfill. The challenge with backyard composting is giving homeowners a reason or motivation to compost. The RDKS could encourage decentralised composting by offering an incentitive program, where a portion of the purchase price of a backyard composter is paid for by the RDKS. Furthermore, for backyard composting to be successful it would require a significant amount of public education on how to compost, techniques in how to avoid wildlife conflicts and the benefits of compost. The key to such an educational initiative would be to instil buyin from the homeowner that the compost produced will have a beneficial use to the homeowner (i.e. nutrient supplement for the garden).

Focusing on centralised composting the first pilot project should involve composting wood and yard/garden waste at the Thornhill landfill. It is suggested that this would occur on an inactive portion of the landfill so no capital costs need to be incurred to manage leachate. It is not even necessary to compost all of the wood and yard/garden waste. No capital equipment expenditures would be required as a shredder/grinder and a screener could be rented from local vendors on an as needed basis. The cost would be similar to the Operational Expenditures in Table 7 ($31.39/m³) but the benefits from a learning perspective could be significant given the RDKS has no experience with centralized composting. A pilot project would provide valuable feedback in the appropriate or optimal windrow size, the frequency of turnings, the potential for odour issues, the need in covering the curing piles, the potential market for the finished product and provide baseline cost and productivity information.

The RDKS could also start working on a second pilot project for composting food waste. The scope of this pilot project would be more entailed than for wood and yard/garden waste as the project would have to incorporate residential pick-up. An example of such a pilot project is one that was conducted in the District of Kent in the Fraser Valley Regional District. In that 4 week pilot project 36 volunteer households and 5 elementary school classes separated food waste from their general garbage.[32] The purpose of the project was to determine the most appropriate collection and composting methods (Appendix G). The pilot

[32] http://www.transformcompost.com/pilot-household-organics-composting-project.htm

project found that it was estimated that garbage collection disposal costs would increase by 10% and result in a reduction of waste by 34%.[33]

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[33] Ibid

CHAPTER 7 – CONCLUSION

From a strictly monetary perspective the costs of composting exceed the benefits. This is consistent with the literature and the facilities visited where financials were always stated as a cost, not as a profit. The only instance in which composting could result in cost savings is if the alternative disposal option for organic wastes was more expensive. For the RDKS this is not the situation as there is no more cost effective method of disposal than current practice.

The research into the cost of the different composting methodologies is not suggested for other feasibility studies in composting. The financial information that is available is reported in so many different formats that attempting to make a comparison between two different facilities utilizing the same methodology can be a frustrating endeavour.

The methodology utilized in this research paper to calculate costs gives the RDKS an indication of the investment entailed to operate a composting facility. The calculation of the costs could have been improved upon if a detailed design (i.e. engineered drawings) of the layout and facilities was done first, however such detail was beyond the scope of this project.

The most significant variable for the calculation of composting costs is the amount of material that will be delivered to a facility. For this research the best available information was used, the 2009 Waste Composition Study. However that study only represents a snapshot in time and actual volumes may be more or less.

If the RDKS implements a zero organics ban at its landfills it will be a decision based on policy, not economics. It is beyond the scope of this paper to analyze the merits of an organics diversion strategy based on policy.

In preparation of a potential organic diversion policy the RDKS should promote backyard composting and implement a pilot project of windrow composting wood and yard/garden waste and food waste. The composting of yard/garden waste could occur immediately whereas a pilot project involving food waste would require more preparatory work.

Unless the pilot projects indicate that composting is not feasible at the Thornhill Landfill due to odour concerns any centralized facility should be established at Thornhill, not at Forceman as substantial savings can be incurred from transportation costs.

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APPENDIX A

A summary of the advantages and disadvantages of different composting methods from Ripley and Mackenzie 2008.

Composting Methodology	Advantages	Disadvantages
Static Pile	• Least costly and simplest method.	• Takes the longest time to produce compost and the final product is quite heterogeneous.
Windrow Composting	• Flexible process: can easily change the mixture of input materials, windrow size and turning frequency. • Not essential that input organic materials are completely mixed at the start of the composting process.	• Requires more space than other composting methods. • If not sufficiently turned there can be odor issues. • Limited organic input – food waste not suggested.
Aerated Static Piles	• Minimal on-going labor requirements once piles are formed, as no turning is required. • Good odor control due to minimal handling and movement of material.	• Mix and ration of organic feedstocks must be correct at the start of the process. • Large fluctuations in organic waste would require capability to store feedstocks until proper C:N ratio can be formed. • Higher capital cost than turned windrows. • Require power (electrical grid or generator) to supply the blower. • Issues with air channeling can arise (uneven distribution of oxygen throughout the pile resulting in anaerobic regions).
In-Vessel	• Requires the least amount of land. • Most rapid production of compost – highest control of composting parameters. • Odors can be controlled reasonably well as the composting process generally occurs inside a building.	• Most capital intensive. • Requires training (potentially extensive training) of personnel. • Higher maintenance and operational costs.

APPENDIX B

Table 1: Summary of the cost/tonne from 2002-2008 for the windrow composting facility at the Vancouver Landfill and the average arithmetic cost over the 7 year period.

Vancouver Landfill

Year	$/tonne	Volume (m^3)
2002	36.23	41,000
2003	45.48	36,500
2004	48.78	37,400
2005	47.39	39,200
2006	51.40*	42,952
2007	37.37**	41,996
2008	44.54	49,333
Average	**44.45**	**41,197**

* purchase of new grinding equipment
** civic strike

Table 2: Calculation to determine the cost/tonne of the windrow composting operation at the Glenmore Landfill from the information provided (Glenmore Landfill, email to author, January 25, 2010). To calculate a cost/tonne the capital and operating costs were added to together for a composting cost of $36.54/tonne.

Glenmore Landfill (Kelowna)
20,000 tonnes

Capital Equipment	Purchase Price ($)	Total Cost ($)	5 year amortization ($/tonne)	10 year amortization ($/tonne)
2008 Scarab Windrow Turner	418,000	*468,160	**4.68	**2.34

*Tax – assume 6% PST and 7% GST
**Amortization based on 20,000 tonnes

Phase	$	$/tonne
Grinding	500,000	
Turner Operation and Replacement	84,000	
Labour	85,000	
Other	15,000	
Total	684,000	34.20

Table 3: Summary of the information provided in the literature to calculate the cost/tonne of the windrow composting facility in Lehigh County Pennsylvannia. To be able to compare with the facility in Amherst New York separated costs out to show the costs with and without the DEP Grants

Lehigh County Pennsylvannia

2004 – 85,000 yd^3.

Assume bulk density of 0.175ton/yd^3 (USEPA, 2000) = 14,875 tons or 13,495 tonnes

	Not Including DEP Grants	Including DEP Grants
Main Site Costs	$ 392,069.00	$ 310,099.00
US $/tonne	29.05	22.98
CDN $/tonne	33.12	26.20*

*cost/tonne is more than Amherst New York – $26.20/tonne vs. $20.51/tonne.

Table 4: Summary of the information provided in the literature to calculate the cost/tonne of the windrow composting facility in Amherst New York.

Amherst New York

1991-2008 (cumulative) = 409,751 tons or 371,726 tonnes (1 ton = 0.9072 tonnes)

	1991-2008 (cumulative costs)	US $/ton	US $/tonne	CDN $/tonne
Labour Costs	4,758,547			
O+M Expenses*	5,686,573			
Material Sales	(2,814,244)			
Dump Fees	(943,339)			
Total:	6,687,537	16.32	17.99	20.51

*O+M Expenses include debt servicing costs of equipment purchases and original bonding of the site. However State of New York pays for 50% of all equipment purchased (grant) involved with processing of compost.

APPENDIX C

Summary of the Composting Facilities contacted for the Field Tour to the Lower Mainland December 1st-3rd, 2009. Facilities in green are the ones that were visited.

Organization	Location	Contact Information	Comments
Answer Garden Products	Abbotstford B.C.	604-856-6221	Windrow Composting. Do not conduct tours.
Ecowaste Industries Ltd.	Richmond B.C.	604-270-4185 info@ecowaste.com www.ecowaste.com	Would conduct tour however currently nothing to show. Switching over from windrow composting to aerated static pile composting.
Fisher Road Recycling	Cobble Hill B.C.	Dave Laing 250-883-1542	In Vessel composting of food waste. Would conduct tour however due to time constraints did not proceed.
Fraser Richmond Soil + Fibre Ltd.	Richmond B.C.	604-465-6254 info@fraserrichmond.ca www.fraserrichmond.ca	Windrow Composting Message left with receptionist – call never returned.
International Composting Facility (ICC)	Nanaimo B.C.	Dr. Brian Imber 250-722-4614	In Vessel composting of food waste. Would conduct tour however currently rebuilding facility.
Transform Compost Systems	Abbotsford B.C.	Dr. John Paul 604-856-8444 info@transformcompost.com www.transformcompost.com	Toured Kent Municipal Waste Water Treatment Plant where they compost biosolids using aerated piles in bins. Also viewed compost site under construction at the Vancouver Zoo in Aldergrove.
Vancouver Landfill	Delta B.C.	Nicole Steglich 604-940-3182 http://vancouver.ca/engsvcs/solidwaste/landfill/index.htm	Windrow Composting
Whistler Composting Facility	Whistler B.C.	Carney Waste Services 604-848-4750 www.carneyswaste.com	In Vessel composting of food waste and biosolids using the Wright Environmental System.

APPENDIX D

Summary of Suppliers, Manufacturers and Individuals Contacted for Cost Analysis

Location in Report	Individuals / Organizations	Method of Communication	Date	Reason
Composting Costs Windrow Composting	Gemaco Sales Ltd.	Email	Dec 15th, 2009	In email query for a the cost of a Duratech Grinder response from Gemaco discussed brokerage fees from importing machinery from the U.S.
Table 5, Table 10	Verna Wicke (Treasurer – RDKS)	Email	Feb 10th, 2009	Question regarding appropriate methodology for amortization of equipment.
Table 5, Table 10	Warren Palmer (Morbark Product Manager – Great West Equipment)	Email	Dec 15th, 2009	Quote for the purchase price of a new Morbark 950 Tub Grinder.
Table 5, Table 10	Tyalta Industries	Email	Feb 16th, 2010	Quote for the purchase price of a new McCloskey 412 Trommel Screener.
Table 5	Mirko Rutar (Terrace Paving)	Personal Communication	Dec 2009	Quote from Terrace Paving for site preparation and paving of asphalt pad.
Table 5	Cameron Martin (Business Manager, Layfield Group)	Email	Dec 14th, 2009	Quote for the cost of a PVC Liner.
Table 7, Table 11	Warren Palmer (Morbark Product Manager – Great West Equipment)	Email	Mar 10th, 2010	Estimate for hourly operating costs of Morbark 950 Tub Grinder.
Table 7, Table 11	Tyalta Industries	Email	Feb 16th, 2010	Trommel screen production and hourly operating costs.
Table 9	Dr.John Paul (President - Transform Compost Systems)	Email	Dec 17th, 2009	Question regarding composting period for an Aerated Bin System.
Table 10	Terry Myhr (McElhanney)	Email	Feb 15th, 2010	Estimate for Steel Building.
Table 10	Steve Maskell (Owner – AFJ Construction)	Email	Feb 16th, 2010	Estimate for Steel Building

Location in Report	**Individuals / Organizations**	**Method of Communication**	**Date**	**Reason**
Table 10, Table 11	Dr.John Paul (President - Transform Compost Systems)	Email	Feb 16th, 2010	Quote for Supreme EnviroProcessor 600 Mixer and Production Rates and Computerized Control System with Aeration Unit.
Table 10	Skeena Concrete	Personal Communication	Feb 16th, 2010	Quote for supply and delivery of Lock Blocks.
Table 10, Table 11	Paul Bergeron (Western Territory Sales Rep – Williams Machinery LP)	Email	Feb 16th, 2010	Quote for Bobcat which is to be used in Food Waste Composting Facility.
Table 11	Roger Tooms, (Manager Works & Services - RDKS)	Email	Feb 16th, 2010	Question regarding RDKS Administration Costs for a Food Waste Composting Facility.

APPENDIX E

Pictures of some of the equipment referred to in the report.

Morbark 950 Tub Grinder

Photo Credit: http://www.morbark.com/municipal/Municipal.htm

Photo Credit: http://www.morbark.com/equipment/SpecSheets/950.pdf

McCloskey 412 Trommel Screener

Photo Credit: http://www.mccloskeyinternational.com/products/3/trommel-screeners/412

Bobcat

Photo Credit: http://www.bobcat.com/loaders/skidsteer

Supreme EnviroProcessor Mixer

Photo Credit: http://www.transformcompost.com/Enviro-Processor.htm

APPENDIX F

Table 1: Cycle Time Calculation to illustrate the cost of transporting compost from Forceman Ridge to Thornhill if a composting facility is located at Forceman Ridge and the compost is going to be used as final cover at the Thornhill Landfill.

Cycle Time Calculation				
Section	Distance (km)	Empty (km/hr)	Loaded (km/hr)	Cycle Time (min)
Forceman Landfill - Hwy 37S	0.8	50	40	2.2
Hwy 37S - Old Lakesle Lake Road Turnoff	11.25	90	80	15.9
Old Lakesle Lake Road - Williams Creek	5.4	60	60	10.8
Through Jackpine Flats	2.4	50	50	5.8
Jackpine Flats - Thornhill Dump	4	75	70	6.6
				41.3
Add Load / Unload / Delay (min):				30
Total (min):				71.3
Trips / 8 hr day:				6.7334332
Gravel Truck Volume (m^3)				9.2
Volume/day				61.947585
Total Volume Compost Required (m3):				6239
Number of Days:				100.71418
Gravel Truck Rate[1]:				79.85
Total Hauling Cost (assume 8hrs/day):				$64336.215

[1] Gravel Truck Rate is from 2009-2010 Blue Book. Equipment Rental Guide. BC Road Builders and Heavy Construction Association.

APPENDIX G

District of Kent – Food Waste Pilot Project

Photo Credit: Transform Compost Systems[34]
Pick-up of residential food waste.

Photo Credit: Transform Compost Systems
Mixing of the organic waste.

Photo Credit: Transform Compost Systems
Temporary compost bins.

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[34] http://www.transformcompost.com/pilot-h-o-c-project_results_new2.htm

APPENDIX H

Summary of Individuals Contacted

Location in Report	Individuals / Organizations	Method of Communication	Date	Reason
Introduction	Roger Tooms, (Manager Works & Services - RDKS)	Personal Communication	Oct 9th, 2009	Query current practice of disposal of wood and yard/garden waste at the Thornhill Landfill.
Background	Roger Tooms (Manager Works & Services - RDKS)	Personal Communication	Aug 2009	Status of proposed Forceman Ridge Landfill.
Composting Techniques / Methods	Nicole Steglich EIT (Transfer and Landfill Operations)	Personal Communication	Dec 3rd, 2009	Frequency of turning windrow piles at the Vancouver Landfill Composting Facility/Operations.
Composting Costs Windrow	Gordon Light (Organics Supervisor)	Email	Jan 25th, 2010	Cost Information of Composting Operation at the Glenmore Landfill – City of Kelowna.
Composting Costs Aerated Static Piles	Mateo Ocejo (Director-Net Zero Waste)	Email	Oct 28th, 2009	Estimate for an Aerated Static Pile using GORE™ System for a composting operation.
Composting Costs In-Vessel and Conversion of Weight to Volume	Steve Diddy (Director of Business Development – Engineered Compost Systems)	Email	Dec 15th, 2010	Estimate for the CV Composter™ In-Vessel System.
Methodology Field Tour	Dave Forgie Associated Engineering	Personal Communication	Oct 27th, 2009	Discussion of Composting Facilities in the Lower Mainland.
Composting Yard and Garden Waste	Gordon Light (Organcis Supervisor)	Personal Communication	Jan 2010	Discussion of windrow composting operation at the Glenmore Landfill – City of Kelowna.
Table 4	Nicole Steglich EIT (Transfer and Landfill Operations)	Email	Dec 14th, 2009	Question regarding the dimensions of the windrow piles at the Vancouver Landfill Composting Facility/Operations.

Location in Report	Individuals / Organizations	Method of Communication	Date	Reason
Food Waste Composting	Steve Diddy (Director of Business Development – Engineered Compost Systems)	Email	Dec 15th, 2010	In providing cost estimate for CV Composter™ In-Vessel System discussed ratio of food waste to bulking agent.
Discussion - Economics	Dr.John Paul (President - Transform Compost Systems)	Email	Feb 16th, 2010	Quote for Compotex™
Economic Benefits from Composting – Compost as Final Cover	Dr. Tony Sperling (President-Sperling Hansen Associates)	Email	Dec 13th, 2009	Question pertaining to composition of final cover at the Thornhill Landfill.
Table 15	J.L. Excavating	Personal Communication	Dec 2009	Quote for supply of Compost Material.
Table 15	Cypress Landscaping	Personal Communication	Dec 2009	Quote for supply of Compost Material.
Economic Benefits from Composting – Compost Sales	Alex Bursac (Environment Technician – City of Kamloops)	Email	Jan 26, 2010	Question regarding Compost Sales.
Economic Benefits from Composting – Compost Sales	Nicole Steglich EIT (Transfer and Landfill Operations)	Email	Dec 14th, 2010	Question regarding Compost Sales.
Economic Benefits from Composting – Greenhouse Gas Emissions	Pacific Carbon Trust	Personal Communication	Mar 1st, 2010	Question regarding cost of validation/verification and quantity of greenhouse gas savings to make the credit program viable for a proponent.
Economic Benefits from Composting – Leachate Control	Roger Tooms, (Manager Works & Services - RDKS)	Email	Mar 3rd, 2010	Question regarding the start of the Thornhill Landfill.
Economic Benefits from Composting – Leachate Control	Dr. Tony Sperling (President-Sperling Hansen Associates)	Email	Jan 26th, 2010	Question pertaining to post closure leachate treatment costs at the Thornhill Landfill.

Location in Report	**Individuals / Organizations**	**Method of Communication**	**Date**	**Reason**
Economic Benefits from Composting – Leachate Control	Dr. Dave Forgie (Associated Engineering)	Email	Jan 28th, 2010	Question pertaining to leachate treatment costs at the Forceman Ridge Landfill.
Recommendation	Pacific BioEnergy	Email	Feb 15, 2010	Question pertaining to the feasibility of using wood and yard/garden waste as feedstock for a pellet plant.

APPENDIX I

List of Supplemental Information Sources (all websites accessed April 19, 2010):

Source	Rationale
http://www.rdks.bc.ca/content/about-us?q=node/15	Information on RDKS Zero Waste Initiative.
http://www.rdks.bc.ca/content/about-us	Background Information on RDKS.
http://www.bankofcanada.ca/pdf/nraa09.pdf	Conversion of US Dollar to CDN Dollar.
http://www.rdn.bc.ca/cms.asp?wpID=942	Information on % of Compostable Material from Naniamo Waste Composition Study.
www.climate.weatheroffice.gc.ca	Determine Terrace B.C. Historical Weather.
General Measurement Standards and Reporting Guidelines http://www.ecy.wa.gov/programs/swfa/grants/docs/OutcomeMeasureConvSht.pdf	Determine Bulk Density of Wood and Yard/Garden after Shredding.
National Recycling Coalition Measurement Standards and Reporting Guidelines; EPA; FEECO and CIWMB 2006. Footprint Environmental, email to author, February 13, 2010 http://www.footprintbc.com/	Determine Bulk Density of Food Waste.
BC Stats: Census 2006. http://www.bcstats.gov.bc.ca/	Determine Population of Terrace
BC Municipal Solid Waste Tracking Report 2006. www.env.gov.bc.ca/epd/epdpa/mpp/pdfs/tracking-rpt2006.pdf	Determine waste generation per capita.
Transform Compost Facility Operator Manual http://www.transformcompost.com/tf%20web%20other%20pdf/manual%20teaser.pdf	Calculate Volume of Windrow and Quantity of Compotex™
2009-2010 *Blue Book Equipment Rental Rate Guide* – BC Road Builders & Heavy Construction Association. http://www.roadbuilders.bc.ca/bluebook.php Information provided to author by Brian Ness, Ministry of Forests and Range – Kalum Forest District.	Equipment Rates
http://www.palletenterprise.com/articledatabase/view.asp?articleID=307.	Production of Morbark 950 Tub Grinder

Source	Rationale
Standard Volume to Weight Conversion Factors http://www.epa.gov/waste/partnerships/wastewise/pubs/conversions.pdf	Loose volume of wood and yard/garden.
http://www.finning.ca/Products/Equipment/New_Equipment/Wheel_Loaders/966H_Wheel_Loader.aspx	Average bucket capacity of Front-End Loader.
City of Terrace Corporate Energy & GHG Inventory, Sheltair Group, December 30, 2008 Copy available from the City of Terrace http://www.terrace.ca/ (Contact: Tara Irwin, Sustainability Co-ordinator)	Reference for Electricity Consumption
https://www.bchydro.com/youraccount/content/electric_tariff.jsp	Average kWh rate.
http://www.pacificcarbontrust.com/	Background information on Carbon Credits.
http://www.rdks.bc.ca/content/downloads	Estimated lifespan of Forceman Ridge Landfill.
http://www.transformcompost.com/pilot-household-organics-composting-project.htm	District of Kent Food Waste Composting Pilot Project.