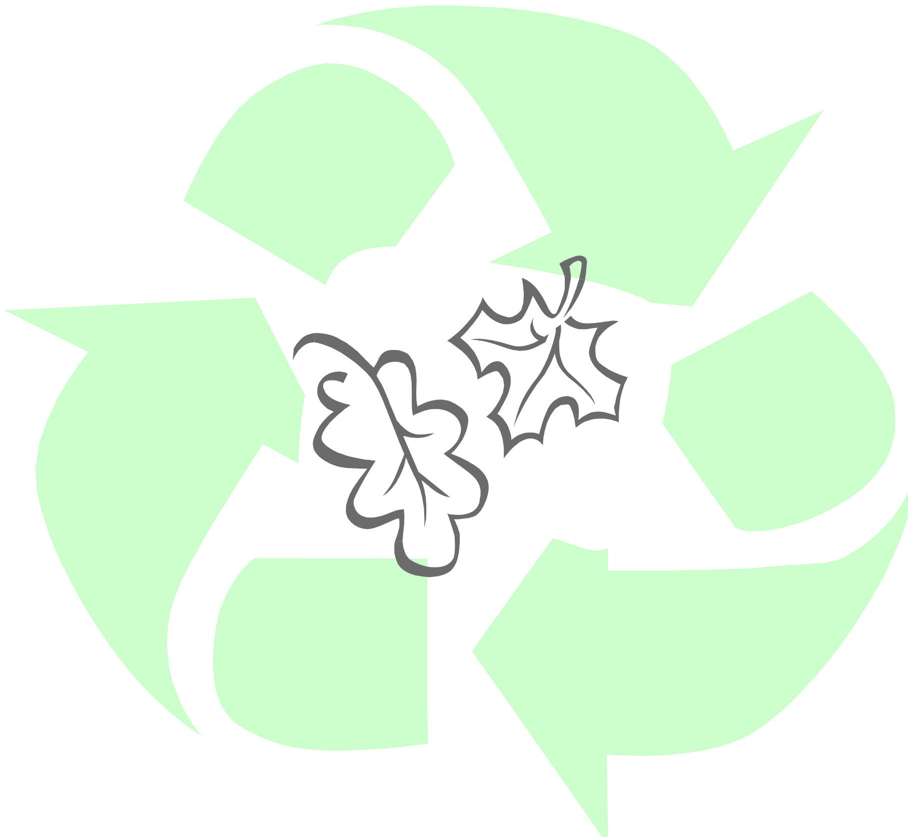
Measuring the benefits of composting source separated organics in the Region of Niagara



Prepared for: The Region of Niagara
By: CM Consulting

December 2007

Executive Summary

Assessing the value of various management options for organic waste (leaf & yard, brush and food waste) in the Region of Niagara requires an understanding of the environmental and human health implications at each stage of each option; from collection to processing to end-use applications.

The following report provides the 'true costs' or 'full cost accounting' associated with the environmental and human health impacts of composting, landfill and energy from waste (EFW) for 47,178 tonnes of organic waste projected to be managed in the Region of Niagara.

More specifically, the 'true costs' provided in this study represent the cost of operations off-set by the economic environmental benefit of each option.

$ True Cost = $ Net Cost of operations – $ Environmental cost benefit

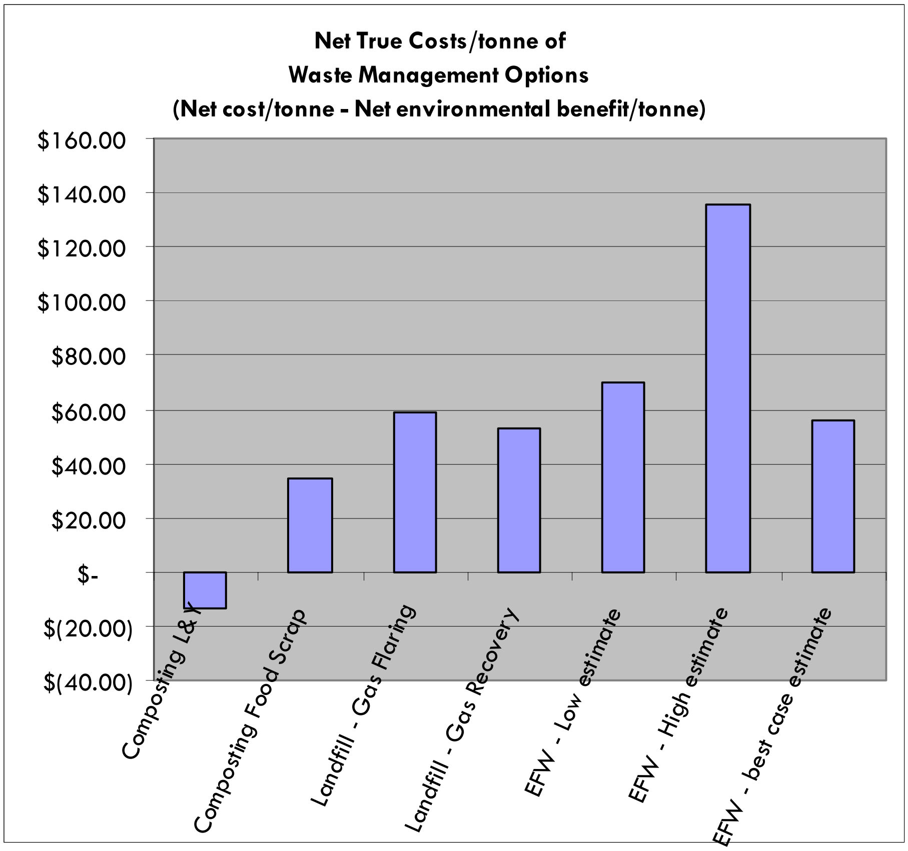
This environmental benefit or cost is the sum of the monetized value of various pollutants, like greenhouse gas emissions (eCO2); human health particulates (ePM2.5); human health toxics (eToluene); human health carcinogens (eBenzene); Eutrophication (eN); Acidification (eSO2); and Ecosystems Toxicity (e2,4-D).

The environmental benefit also includes the monetized value of avoided pollutants as a result of finished compost replacing pesticides and synthetic fertilizers. In addition, the environmental benefit includes the avoided pollution associated with substituting natural gas with electricity produced in an EFW facility. Because the pollution of the substituted natural gas is not created, it is therefore considered as "avoided" and an environmental benefit of EFW. Finally, any carbon sequestration (absorption) that occurs in landfill and compost is also considered as an environmental benefit.

The results show that in the case of the Region of Niagara, the 'True Costs' associated with managing organics are $(15.76) and $32.18 per tonne for composting leaf, yard and brush waste, and food waste respectively, $75.14 per tonne for landfill with gas flaring, 49.37 per tonne for landfill with gas recovery for electricity generation, and from $62.72 - $142.72 per tonne for EFW.

	Composting L&Y& Brush	Composting Food Waste	Landfill - LRG Flaring	Landfill LGR - electricity generation	EFW - low estimate	EFW - High estimate	EFW - best case estimate
Operations Cost per tonne	$ 33.83	$ 81.77	$ 82.93	$ 69.00	$ 102.00	$ 168.00	$ 88.00
Environmental Benefit per tonne	$ 49.59	$ 49.59	$ 7.79	$ 19.63	$ 25.28	$ 25.28	$ 25.28
True cost per tonne	**$ (15.76)**	**$ 32.18**	**$ 75.14**	**$ 49.37**	**$ 76.72**	**$ 142.72**	**$ 62.72**

Costs associated with managing organic waste in the Region of Niagara



In addition, the net economic benefit of composting organics instead of landfill or EFW represents a net economic benefit of between $1.4 million to $5.8 million per annum.

True costs associated with managing organic waste in the Region of Niagara

	Composting (L&Y&B and Food waste)	Landfill - LRG Flaring	Landfill LGR - electricity generation	EFW - low estimate	EFW - High estimate	EFW - best case estimate
Net True Cost	$ 927,746	$ 3,545,130	$ 2,329,162	$ 3,619,527	$ 6,733,275	$ 2,959,035
True cost per tonne	$ 19.66	$ 75.14	$ 49.37	$ 76.72	$ 142.72	$ 62.72

Note: The costs associated with organics (leaf/yard/brush and food waste) were aggregated and divided by the amount of tonnes in order to present one "true cost" for composting.

Special Thanks

Dr. Jeffrey Morris of Sound Resource Management based in Olympia, Washington, USA, is responsible compiling the necessary data and building a user-friendly excel-based model, which he graciously provided to CM Consulting to utilize for this study.

Thanks to Dr. Morris' work, today decision makers can be better informed when making choices about their waste management options, which can lead to a less harm on the environment and human health.

Derek Ali, MBA, P.Eng and President of DFA Infrastructure International Inc. graciously peer reviewed this study. This process has ensured that the work meets acceptable standards and assures prevention of unwarranted claims, unacceptable interpretations, or personal views.

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Tables and Charts

Part 1: Methodology

A cost benefit analysis is a technique designed to determine the feasibility of a project by quantifying its costs and benefits. Ideally, these costs and benefits are measured for the life cycle of the project, which provides a more robust or "full cost accounting" profile. This requires identifying, quantifying and allocating the direct and indirect environmental costs of the project.

Measuring the benefits of source separating organics from the waste stream for composting against other waste management options like landfill or energy-from-waste (EFW) is a complex process. The process of composting and the use of the finished compost offer many environmental, economic and social benefits often unaccounted for in general costing exercises. At the same time, landfills have carbon sequestration properties, which can be beneficial in terms of improving its carbon footprint, and EFW systems can produce energy, which will offset other carbon-based energy sources.

The following five steps provides a summary of the approach taken in this report to undertake a cost benefit analysis of the various waste management options for organics for the Region of Niagara.

1.1 Apply existing models to determine GHG impact

Comparing the net environmental impact of various waste management options in terms of net greenhouse gas (GHG) emissions from collection, carbon sequestration, and processing has been extensively examined and modeled by both Environment Canada[1] and the United States Environmental Protection Agency (US EPA)[2]. For the purpose of this study, the net GHG data for composting, landfill and EFW from the US EPA's most recent updated model was utilized, as this is the data utilized within the Morris calculator.

1.2 Use existing RTI model to determine other pollution impacts on the environment and human health

More recently, work has been undertaken by the Research Triangle Institute (RTI) for the US EPA[3] to account not only for GHG emissions, but other associated pollutants from waste management that can impact human health and the environment. These pollutants originate from the various stages of waste management operations, including transportation, combustion, energy use, effluent etc. There are over 900 different pollutants which have been aggregated into various environmental impact categories as categorized in Table 1.2. The methodology for aggregating pollution emissions into the impact categories is explained in the documentation of the US EPA's TRACI model.[4] The following provides a synopsis of the methodology for aggregating pollutants.

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[1] *Determination of the impacts of waste management activities on greenhouse gas emissions – final report 2001* & 2005 update, ICF Consulting, for Environment Canada and Natural Resources Canada

[2] *Solid Waste Management and Greenhouse Gases – A Life-Cycle Assessment of Emissions and Sinks*, 3rd. edition, October 2006.

[3] Research Triangle Institute, *"Municipal Solid Waste Life-Cycle Database*, 2003

[4] *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)*, US EPA

During the development of TRACI, impact categories were selected based on their level of commonality with the existing literature in this area, their consistency with EPA regulations and policies, their current state of development, and their perceived societal value. The traditional pollution categories of ozone depletion, global warming, human toxicology, ecotoxicology, smog formation, acidification, and eutrophication were included within TRACI because EPA programs and regulations recognize the value of minimizing effects from these categories. Human health was subdivided into cancer, non-cancer, and criteria air pollutants (with an initial focus on particulates) to better reflect the focus of EPA regulations and to allow methodology development consistent with the regulations, handbooks, and guidelines (e.g., EPA Risk Assessment Guidelines (RAGs), and Human Exposure Factor Handbook). Smog formation effects were maintained independently and not further aggregated with other human health impacts because environmental effects related to smog formation would have become lost in the process of aggregation. Criteria pollutants were preserved as a separate human health impact category to allow a modeling approach that could take advantage of the extensive epidemiological data associated with the impacts of criteria pollutants. (US EPA, 1999, Levy, et al, 2000, Nishioka, et al 2000, Nishioka, et al, 2002),

From: Jane C. Bare, Systems Analysis Branch, Sustainable Technology Division, National Risk Management Research Laboratory, US Environmental Protection Agency

Table 1.2: **Categorization of associated pollutants from composting, landfill and EFW operations**

POLLUTANT	IMPACT	IMPACT DEFINED
Carbon dioxide equivalent (eCO2)	**Climate change**	The temperature on Earth is regulated by a system known as the "greenhouse effect". Greenhouse gases primarily water vapour, carbon dioxide, methane, and nitrous oxide trap the heat of the sun, preventing radiation from dissipating into space. Around the world, climate change is projected to: • threaten the world's boreal forests with an increased fire risk because of the drying climate; • cause water needs to outstrip supply; • cause severe water loss due to changes in evaporation and precipitation patterns; • cause flood damage to low-lying countries and island states, including loss of coastal land to rising sea levels; • encourage the movement of tropical diseases such as malaria northward, where populations have little or no immunity; and • affect international trade patterns. Source: http://www.ec.gc.ca/climate/overview_science-e.html
Particulate matter less than 2.5 micron equivalent (ePM2.5)	**Human Health**	Particulate matter (PM) consists of airborne particles in solid or liquid form. PM may be classified as primary or secondary, depending on the compounds and processes involved during its formation. Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: • increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; • decreased lung function; • aggravated asthma; • development of chronic bronchitis; • irregular heartbeat; • nonfatal heart attacks; and • premature death in people with heart or lung disease. People with heart or lung diseases, children and older adults are the most likely to be affected by particle pollution exposure. Source: http://www.epa.gov/air/particlepollution/health.html
Toluene equivalents (eToluene)	**Human health**	Toluene diamine is toxic to wildlife as well as humans, in particular water-dwelling organisms may be at risk from spills or releases in effluent. It will biodegrade slowly in water and soils. TDA is broken down rapidly in the atmosphere (hours-days). Diaminotoluene may cause cancer and genetic damage. Excessive exposure may affect the blood, eye, liver, lung and skin. Source: www.environment-agency.gov.uk
Benzene equivalents (eBenzene)	**Human Health**	Benzene slows down nerve transmission, depresses the central nervous system, lowers the capacity of blood hemoglobin to hold oxygen, and reduces the ability of cells to bind molecules involved in the hormone system. Laboratory rats and mice exposed to benzene have developed cancer. Source: http://www.ec.gc.ca/ceqg-rcqe/English/Html/GAAG_BenzeneSoil_e.cfm

POLLUTANT	IMPACT	IMPACT DEFINED
Nitrogen equivalents	**Eutrophication:**	Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. (Source: www.toxics.usgs.gov/definitions/eutrophication.html)
Sulfur dioxide equivalents (eSO2)	**Acidification:**	When the environment cannot neutralize acid rain, damage occurs to forests, crops, lakes, and fish. Toxic metals such as copper and lead can also be leached from water pipes into drinking water. The interactions between living organisms and the chemistry of their aquatic habitats are extremely complex. If the number of one species or group of species changes in response to acidification, then the ecosystem of the entire water body is likely to be affected through the predator-prey relationships of the food web. At first, the effects of acid deposition may be almost imperceptible, but as acidity increases, more and more species of plants and animals decline or disappear. Source: http://www.atl.ec.gc.ca/msc/as/acidfaq.html
Herbicide 2,4-D equivalents (e2-4-D)	**Ecosystem toxicity:**	Despite industry efforts claiming the safety of this chemical, there is a large body of evidence (Sierra Club of Canada) indicating major health effects, from cancer to immunosuppression, reproductive damage to neurotoxicity. Environmental contamination, particularly in wetlands has also been demonstrated, in direction infringement of the *Fisheries Act* R.S., c. F-14, s. 36. Source: Sierra Club Canada, Jan 2005

Applying the RTI model to determine the environmental impact of waste management options provides a series of pollution values, each with its own set of unique impact properties. While this data may be informative, it is difficult to use it to compare the various options against each other. For example, the human health impacts of one tonne of particulates (e2.5PM) are far more severe than one tonne of Toluene equivalents (eToluene), both of which are far worse to human health than the environmental damage caused by one tonne of Nitrogen equivalents (eN).

1.3 "Monetize" or "valuate" pollution impacts

To help overcome the barrier associated with trying to compare impacts of various pollutants, more recent work provided by Dr. Jeffrey Morris of Sound Resource Management, presents a model or calculator with monetary values for each pollutant as a method to evaluate the various trade-offs within each pollution category for an "apples-to-apples" comparison of the waste management options.

Dr. Morris' calculator uses pre-existing impact data from the US EPA related to various waste management practices and applies monetary values associated with its related pollution. The monetary value of each pollutant is based either on the estimated real financial costs to society in terms of environmental degradation and human health, or the actual market value of the pollutant's emissions established through trading schemes such as the US EPA's sulfur dioxide emission permits under the Clean Air Act provisions for controlling acid rain.

These values represent the environmental and human health damage caused by these pollutants. Simply put, these values answer the question, what does a ton[5] of a particular

[5] A "ton" is a US short ton, which is equal to 0.91 metric tonnes. A short ton is slightly smaller than a metric tonne, and is used in this study because all of the values provided by the US EPA and other US sources are presented in imperial tons.

pollutant end-up costing society? The monetary values for the listed pollutants are provided in the table 1.3.

The table lists a value of $36 per ton for one ton of carbon dioxide equivalent (eCO2) based on GHG offset valuation used by Seattle City Light. The value of a ton of carbon dioxide varies in the North American (unregulated) marketplace, from $1 to $4 (US$) per ton with values exceeding $100 per ton in jurisdictions where carbon trading is regulated. The recently completed Stern Review[6] on the economics of climate change estimates the environmental cost of a metric tonne of CO2 emissions at $85 (US$). Therefore, a value of $36 can be considered as conservative. (Note: Part 8 of this report presents a sensitivity analysis with CO2 values of $4 and $85).

Sulfur Dioxide (SO2) is monetized with a cost of $661 per ton, and is based on a rolling average of spot prices for SO2 emission permits in the US EPA's annual acid rain allowance auction 2005 ($690); 2006 ($860); 2007 ($433)[7].

Other monetized pollutants are based on scientific and peer reviewed studies on the health and ecological costs of these environmental impacts. For example, human health costs of "toxics" is based on a Harvard University Centre for Risk Analysis study on the health costs of mercury emissions, while the cost to ecosystems of ecologically toxic emissions is based on an Ohio State University Integrated Pest Management Program Study on putting a price on pesticide use. Each of these studies and studies referenced therein provides detailed methodologies for full-cost accounting of the damage caused by pollutants on the eco-system and/or human health.

The value of $10,000 per ton for particulates (ePM2.5) and $3,030 per ton for carcinogens (eBenzene) are based on a study by Eastern Research Group (2006)[8]. The value of $118 per ton for Toluene equivalents (eToluene), $4 per ton for nitrogen equivalents (eN), and $3,280 per ton for Herbicide 2,4-D equivalents (e2,4-D) are based a study by Morris and Bagby (2007)[9]

Table 1.3: **Value of Environmental Impact Category Emissions Reductions Per Ton**

Value of Environmental Impact Category Emissions Reductions Per Ton						
Climate Change	**Human Health - Particulates**	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophication**	**Acidification**	**Ecosystems Toxicity**
eCO2	**ePM2.5**	**eToluene**	**eBenzene**	**eN**	**eSO2**	**e2,4-D**
$36	$10,000	$118	$3,030	$4	$661	$3,280

[6] *Stern Review Report on the Economics of Climate Change*: www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change
[7] For auction results by year go to. http://www.epa.gov/AIRMARKET/trading/auction.html
[8] Eastern Research Group (2006), *Draft Report: Cost Benefit Analysis for Six 'Pure" Methods for Managing Leftover Latex Paint* – Data Assumptions and Methods, Prepared for the Paint Stewardship Initiative
[9] Morris, Jeffery and Jennifer Bagby (2007), *Measuring Environmental Value for Natural Lawn and Garden Care Practices*. Published and peer reviewed by; International Journal of Life Cycle Assessment

1.4 Calculate the upstream pollution prevention benefits associated with compost end-use

Composting organic waste is not simply about diversion from landfill or EFW. Recycled organics in the form of usable compost offer a variety of benefits to soils, plants and the environment.

For example, using compost in landscaped parts of roads, cycle ways and parks:

- reduces irrigation requirements;
- retains water and reduces leaching loss for plants;
- reduces soil erosion and runoff; and
- suppresses weeds and herbicide requirements.[10]

Using compost as top dressing on playing field surfaces:

- requires less water;
- maintains good turf growth under stressful conditions;
- improves soil structure, water infiltration, and water holding capacity of the soil;
- slowly releases essential macro and micro-nutrients to turf growth, reducing the need for mineral fertilizers and making these fertilizers more effective;
- supplies nitrogen and iron for long-term greening; and
- can suppress grass diseases and reduce the need for regular pesticides application.[11]

The benefits of compost use vary depending on local conditions such as soil type and characteristics, plant varieties, and local environmental conditions.

Attaining a complete profile of the environmental and human health impact benefits associated with the end-use of the finished compost have been determined as well. More specifically, because compost produced from yard waste and food scraps will substantially reduce the use of pesticides and synthetic fertilizers on lawns and other applications, their avoided impacts can be measured as an environmental benefit associated with composting.

However, quantifying the environmental benefits associated with pesticide and synthetic fertilizer reduction is problematic. *Curbside Recycling in King County: Valuation of environmental Benefits,* Morris (2007), states:

"There are as yet no systematic empirical data on the average amount of pesticide and fertilizer use reductions associated with home lawn and garden compost applications. However, one can make a reasonable argument that compost use on lawn and gardens may be associated with a 50% or more reduction in pesticides and synthetic fertilizer use."

For the purposes of this report, this assumption is supported as applied in the Morris study undertaken for King County, CA – August 2007. (Note: Part 8 of this report presents a sensitivity analysis where the compost substitution rate is 25% versus 50%)

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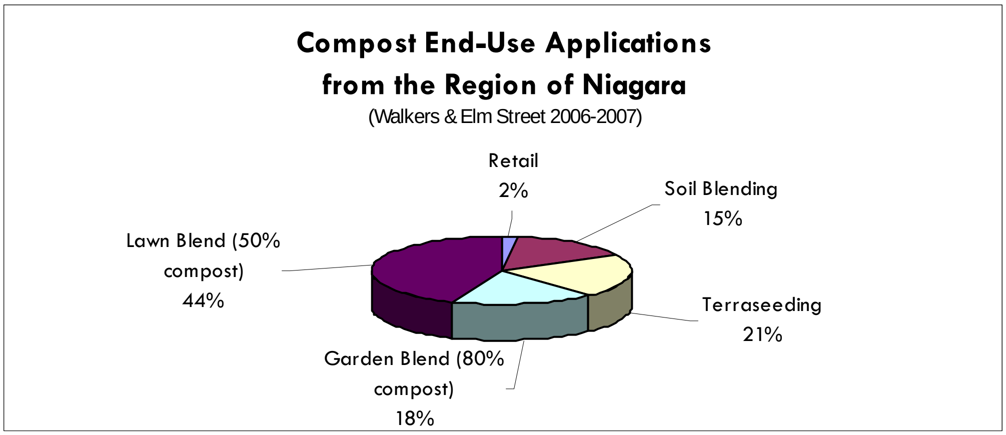
[10] *Cost/Benefit of Using Recycled Organics in Council Parks and Gardens operations in NSW*, December 2005, Department of Environment and Conservation , NSW.
[11] Ibid.,

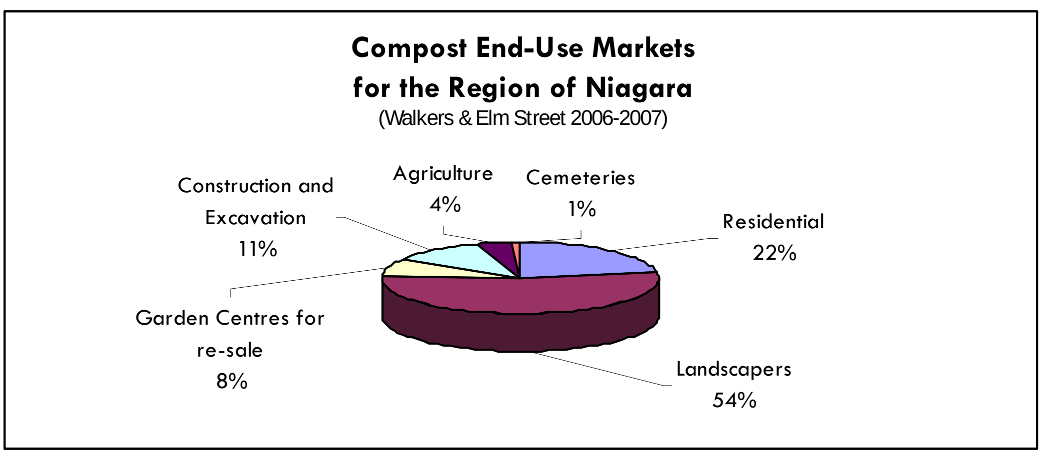
In Niagara Region, based on available information[12], compost is used primary in soil and high grade blending agents. (See Char below for applications).

Chart 1.4a: **Compost end-use applications from the Region of Niagara**



The markets[13] for finished compost include: residential, landscaping, agriculture, cemeteries, and construction & excavation projects. Note, these end-markets are not likely to change, given that the composting technology used in the Region will remain the same.

Chart 1.4b: **Markets using the Region of Niagara's finished compost**



[12] Compost applications provided by Region of Niagara
[13] Compost markets provided by Region of Niagara.

1.5 Calculate the "true cost" by off-setting actual costs of operations with the monetized environmental benefit

The final step in a cost benefit analysis applies existing real cost of operations against the monetized environmental benefit. These results provide a true socio-economic picture of the costs associated with each option.

$ True Cost = $ Net Cost of operations – $ Monetized environmental cost benefit

Part 2: Data Inputs and Assumptions

2.1 Tonnes of organic waste generated in the Region of Niagara

The amount of organic waste used as the base data in this report was 47,178 tonnes. This estimate is based on the Region of Niagara's projected 2009 organic waste forecast indicated in the table 2.1a below.[14]

The 2009 processing rate for the Niagara Region facilities is projected, based on the volumes processed in 2006, a medium level of participation and capture rate; with a CPI adjustment added. This rate is a combined rate for processing the leaf & yard waste, as well as chipping the brush. Tonnages are based on projected 2007 incoming figures and escalated to 2009 levels, based on growth projections for each year. Leaf & yard waste is based on Organic Diversion Strategy for a fully-mature program.

For the purposes of this study, source separated organics is broken down into "food waste" and "leaf, yard and brush waste" material. The breakdown is based on a medium success rate in terms of food waste participation, and capture rate of 70% and 70% respectively. Food waste generation data is derived from aggregate weights using 2006 waste audits conducted in Niagara Region by Stewardship Ontario and the Organic Diversion Strategy.

Table 2.1a: **Projected Niagara Region Organic Tonnages for 2009**

	2009 Forecasted Organics Tonnage		
Leaf & Yard Waste, Brush N/R Facilities	**Tonnes**	**Rate per tonne**	**Total**
Niagara Road 12 - Leaf & Yard Waste, Brush	1,599	Proprietary	Proprietary
Bridge Street - Leaf & Yard Waste, Brush (4)	2,458	Proprietary	Proprietary
Humberstone – Brush (1)	2,819	Proprietary	Proprietary
TOTAL	6,875		
Leaf & Yard Waste, Brush, New Facility			
Leaf & Yard Waste, Brush	5,440	Proprietary	Proprietary
Total Leaf, yard and brush (rate per tonne is an aggregated amount)	**12,315**	**$33.83**	$416,673
SS Organics (includes leaf, yard, brush and food waste) - New Facility			
SS Organics, based on 70% Capture & 70% Participation SFD	29,700	Proprietary	Proprietary
SS Organics, based on 70% Capture & 70% Participation SFD (above 29,700 tonne limit)	5,163	Proprietary	Proprietary
Total source separated organics (rate per tonne is an aggregated amount) Estimated 14,861 food waste and 20,002 leaf, yard and brush waste.	**34,863**	**$ 81.77**	$2,850,692
TOTAL (rate per tonne is an aggregated amount)	**47,178**	**$ 69.26**	**3,267,365**

[14] Provided by the Region of Niagara. Rate per tonne information is proprietary. Aggregated totals are provided based on actual costs for the leaf, yard and brush; and SSO organics categories.

Table 2.1b: **Summary of organics projected for 2009 by type**

	Metric Tonnes	Short Tons
Food Waste	14,861	16,381
Leaf & Yard Waste and Brush	32,317	35,623
Total	**47,178**	**52,004**

2.2 GHG Impact of Composting, Landfill and EFW:

The following section provides a summary of the greenhouse gas (GHG) impacts of composting, landfill and EFW management options. These data are derived using the following assumptions:

Composting:
Source: US EPA, Solid *Waste Management and greenhouse Gases: A Life Cycle assessment of Emissions and Sinks*, 3rd. Edition, September 2006., Tables: B-5

- Aerobic composting technology;
- Includes impacts from: composting and carbon sequestration;
- Includes a collection, hauling and facility operations impact of 0.043 eCO2/tonne; and
- Does not include biogenic carbon emissions.

Landfilling – Gas Flaring:
Source: US EPA, Solid *Waste Management and greenhouse Gases: A Life Cycle assessment of Emissions and Sinks*, 3rd. Edition, September 2006., Tables: 6-6, 6-8.

- Includes GHG emissions from CH4 generation (Methane);
- Includes impacts from: transportation, landfilling, and carbon sequestration[15];
- Assumes landfill gas recovery and flaring;
- Includes a collection, hauling and landfill operations impact of 0.043 eCO2/tonne; and
- Does not include biogenic carbon emissions.

Landfilling – Gas recovery with electricity generation:
Source: US EPA, Solid *Waste Management and greenhouse Gases: A Life Cycle assessment of Emissions and Sinks*, 3rd. Edition, September 2006., Tables: 6-6, 6-8.

- Includes GHG emissions from CH4 generation (Methane);
- Includes impacts from: transportation, landfilling, and carbon sequestration;
- Assumes landfill gas recovery (75% gas recovery rate) and electricity generation ;

[15] Carbon sequestration means the uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide, release the oxygen and store the carbon. Landfills are built to prevent degradation, and therefore when leaf, yard and brush material is landfilled, this carbon is not released immediately. As such, Landfilling leaf and yard waste is reported as carbon negative (i.e. sequestration)

- Includes a collection, hauling and landfill operations impact of 0.043 eCO_2/tonne;
- Does not include biogenic carbon emissions.

EFW:
Source: US EPA, Solid *Waste Management and greenhouse Gases: A Life Cycle assessment of Emissions and Sinks*, 3rd. Edition, September 2006., Tables: 5-1,

- Assumes energy off-set based on replacement of natural gas turbine power;
- Includes impact from: transportation, and combustion (N_2O emissions);
- Includes a collection, hauling and EFW operations impact of 0.032 eCO_2/tonne; a
- Does not include biogenic carbon emissions.

Biogenic emissions represent the carbon emitted from paper, grass trimmings and other organic material like food waste during composting, landfilling or EFW (combustion). Biogenic carbon emissions were originally removed from the atmosphere by photosynthesis, and under natural conditions. This carbon will eventually cycle back to the atmosphere as CO_2 due to degradation processes.

In general, when assessing the GHG impact of a system, anthropogenic emissions (emissions resulting from human activities which are subject to human control), are measured on their own. Scientists have chosen this standard because it is these emissions that have the potential to alter the climate by disrupting the natural balances in carbon's biogeochemical cycle, and altering the atmosphere's heat-trapping ability. That said, most models have the ability to measure the GHG impact with and without the biogenic emissions.

It is important to note that omitting GHG releases from biogenic sources is premised on the assumption that the materials are grown on a sustainable basis. In this case, those emissions are considered to simply close the loop in the natural carbon cycle. For the purposes of this report the assumption is made that community generated leaf, yard and brush waste, and food waste are being sustainable re-harvested.

The following summarizes the climate change impacts of composting, landfill and EFW represented as tons of carbon dioxide (eCO_2) per tonne of material.

Table 2.2: **GHG emissions from waste management options including carbon sinks/sequestration**

GHG Emissions from MSW Management Options (tons eCO2/ton) including carbon sinks/sequestration				
	Composting	**EFW**	**Landfill (LFG recovery flaring)**	**Landfill (LFG recovery & electricity generation)**
Food waste	-0.20	0.047	0.33	0.25
Leaf, yard & brush waste	-0.20	-0.067	-0.44	-0.49

2.3 Pollution impacts on the environment and human health of composting EFW and landfill

The following section summarizes the pollution impacts on the environment and human health of composting, landfill and EFW. These data are derived using the same assumptions stated in 2.2 for GHGs.

Table 2.3: **Emissions (pounds) of pollutants per ton or organics managed**

Pounds of Emissions Reductions/(Increase) Per Ton of Organic Waste Managed[16]						
	Human Health - Particulates	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophication**	**Acidification**	**Ecosystems Toxicity**
	(ePM2.5)	**(eToluene)**	**(eBenzene)**	**(eN)**	**(eSO2)**	**(e2,4-D)**
COMPOSTING	-6.16E-02	-4.89E+01	-7.61E-04	-1.67E-01	-4.35E-01	-8.87E-01
LANDFILL - LGR - Flaring	-7.82E-02	-3.44E+00	-1.78E-04	-1.28E-01	-2.96E-01	-1.03E-01
LANDFILL - LGR Electricity	8.24E-01	3.68E+01	7.97E-04	-8.73E-02	2.77E+00	5.97E-03
EFW	2.86E+00	5.51E+01	1.18E-03	2.95E-02	8.06E+00	-3.99E-02

2.4 Cost of operations for composting, landfill, and EFW of organic waste

Providing the complete socio-economic cost or the "true cost" of the various waste management options necessitates off-setting the economic environmental impact of an option with its associated net costs to operate (i.e. the cost of collection, and processing plus associated revenues per tonne.)

$ True Cost = $ Net Cost of operations – $ Monetized environmental cost benefit

The following waste management costs[17] per tonne (not including collection) are used in this economic analysis:

Table 2.4: **Cost of operations: composting, landfill and EFW per tonne**

Waste Management Option	**Low estimate per tonne**	**High estimate per tonne**	**"Best case" estimate per tonne**	**Cost per tonne**
Compost – Food Waste				$81.77
Compost - Leaf and Yard				$33.83
Landfill – LGR Flaring				$82.93
Landfill – LGR electricity generation			$69.00	
EFW	$102.00	$168.00	$88.00	n/a

[16] Research Triangle Institute, *Municipal Solid Waste Life-Cycle Database*, prepared for Atmospheric Protection Branch, National Risk Management Research Laboratory, US EPA
[17] Provided by The Region of Niagara

"Costs per tonne" represent the cost of operating the waste management option (not including transportation).

1. Composting cost of food waste is $81.77 per tonne. This is an aggregated rate based on the actual forecasted contract price per tonne before and after the minimum threshold is met. These two figures cannot be disclosed at this time, as the contract negotiations are still underway.
2. Composting cost for leaf, yard waste and brush material is $33.83 per tonne. This is an aggregated rate based on the actual forecasted contract rate for leaf and year waste after a minimum threshold is met. This figure also includes the current cost for managing this material at Niagara Road 12; Bridge Street; and Humberstone locations.
3. Landfilling LGR – flaring is $82.93, and is based on current landfill cost projections for 2009. NPV (Net present value) on an annual basis minus collection costs divided by the tonnage projected for 2009.
4. Landfilling LGR – recovery and electricity generation is $69.00 and is based on data generated from "Improved Assumptions" applied for sensitivity analysis - *Reasonable Cost per tonne, contained in "Alternatives To" and Selection of a Preferred Disposal System,* DRAFT, July 20, 2007). Page 5-41
5. EFW cost projections are various scenarios, including low and high estimates of $102 and $168 per tonne.
6. Further, EFW provides a third cost projection called "best case" of $88.00 per tonne. This estimate is subject to various scenario assumptions (details provided in the report). All EFW estimates are listed in *"Alternatives To" and Selection of a Preferred Disposal System,* DRAFT, July 20, 2007). Page 5-41

   The assumptions for the best case scenario include:

   - More efficient recovery of energy from waste, based on the recovery of both electricity and heat (i.e. combined heat and power), assuming that a heat-load or other user of the heat;
   - Processing of the bottom ash to produce granular material to be marketed for construction applications;
   - 18.5% net electrical efficiency used (i.e. the facility would recover about 600 kwh electrical per tonne processed);
   - 1200 kwh thermal energy recovered per tonne of waste processed, hot water 40% of the time;
   - Assumed current standard market price for electricity @ $70 /MWh
   - Assumed heat sold at $44 /MWh

Using imperial tons instead of metric tonnes

The majority of the data provided in this report is presented as imperial tons (short tons) and imperial pounds, because each study and model referenced and used uses imperial weights.

For the purpose of consistency and transparency in referencing data, imperial measurements are presented throughout the report, except in the final results, where they are presented on a metric tonne basis.

Using US currency ($US)

This report provides all monetization and true cost calculations in $US currency, as each study and model referenced and used presents US currency ($US) only.

Once again, for the purpose of consistency and transparency in referencing data $US are presented throughout the report, except in the final results, where they are presented in $CAN using a conversion factor of:

1 US Dollar = 1.01730 Canadian Dollar
Source: http://www.xe.com/ucc/convert.cgi
Based on Friday, December 14, 2007

Part 3: Measuring the Waste Management Options based on GHG impact

By applying existing greenhouse gas (GHG) impact models to the Region of Niagara's compostable waste stream, it is possible to determine what the greenhouse gas impact is for composting, EFW and landfilling organic waste.

Table 3a and Chart 3b summarizes the GHG impact of the various waste management options for The Region of Niagara organics management. Each case suggests that there is a net CO2 decrease, which arises for the following reasons:

1) For **composting**, the CO2 sequestration when composting outweighs the amount of CO2 released from collection and processing operations. It should also be noted that the natural release of CO2 for organic materials being composted is not counted as it is considered a biogenic source of CO2 (see explanation on page 16). As such, for the organic material from the Region of Niagara, aerobic composting will result in a net decrease of 10,401 tons of CO2 per annum.

2) For **EFW**, there is a net CO2 decrease primarily because the release of CO2 during combustion of organic waste is not counted because it is biogenic in nature. The CO2 off-set comes from the avoided CO2 generated by replacing natural gas (turbine power) with energy from the EFW facility. As such, for the organic material from the Region of Niagara, EFW will result in a net decrease of 1,617 tons of CO2 per annum.

3) For **landfill with flaring**, there is a net CO2 decrease, primarily because in the case of leaf and yard waste landfilled (which makes up more than 69% of the total) more CO2 is sequestered in the landfill than released during collection and landfilling. Because the captured methane is being flared (as is being done at Niagara's landfill), there is no energy off-set, as there is with EFW. As such, for the organic material from the Region of Niagara, Landfilling with flaring will result in a net decrease of 10,268 tons of CO2 per annum.

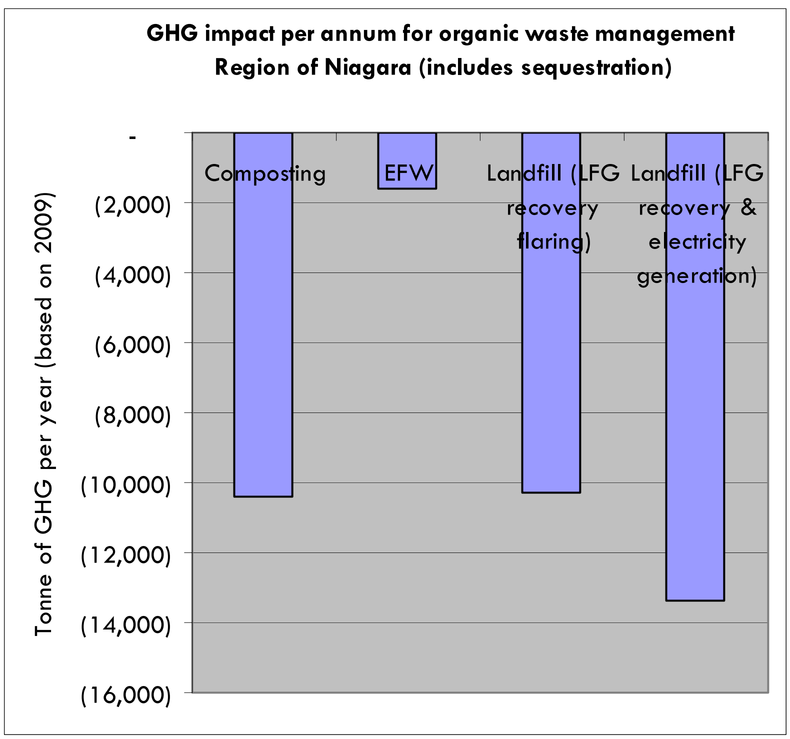
4) For **landfill with gas recovery for electricity generation**, there is a greater net CO2 decrease, because of the additional energy off-set which comes from the avoided CO2 generated by replacing natural gas (turbine power) with electricity form the landfill gas. As such, for the organic material from the Region of Niagara, landfilling with energy recovery will result in a net decrease of 13,360 tons of CO2

Table 3a: **GHG Emissions from waste management options (tons eCO2 including carbon sinks/sequestration)**

These figures are obtained by multiplying the Niagara organic tonnages by the GHG emissions factors in table 2.2

GHG Emissions from MSW Management Options (tons of eCO2 including carbon sinks/sequestration)				
	Composting	**EFW**	**Landfill (LFG recovery flaring)**	**Landfill (LFG recovery & electricity generation)**
Food waste	(3,276)	770	5,406	4,095
Leaf, yard & brush waste	(7,125)	(2,387)	(15,674)	(17,455)
TOTAL	**(10,401)**	**(1,617)**	**(10,268)**	**(13,360)**

Chart 3b: **GHG impact per annum for organic waste management for the Region of Niagara**



Part 4: Measuring the monetized value of the pollution impacts on the environment and human health

By applying pollution and human health impacts to the Region of Niagara's compostable waste stream, it is possible to determine what the associated pollution impact is for composting, EFW and landfilling organic waste.

Table 4 presents the pollution impact associated with composting, EFW and landfilling of organic waste.

As was previously explained, the cause for a decrease in pollution in the case of EFW, occurs as a result of the energy off-set for natural gas.

Table 4: **Pollution impact associated with composting, landfilling (flaring and electricity generation) and EFW of organic waste**

Pounds of Emissions Reductions/(Increase) Per Ton of Organic Waste Managed **Source: Research Triangle Institute, *Municipal Solid Waste Life-Cycle Database*, prepared for Atmospheric Protection Branch, National Risk Management Research Laboratory, US EPA**						
	Human Health - Particulates	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophication**	**Acidification**	**Ecosystems Toxicity**
	(ePM2.5)	**(eToluene)**	**(eBenzene)**	**(eN)**	**(eSO2)**	**(e2,4-D)**
COMPOSTING	-6.16E-02	-4.89E+01	-7.61E-04	-1.67E-01	-4.35E-01	-8.87E-01
LANDFILL - LGR - Flaring	-7.82E-02	-3.44E+00	-1.78E-04	-1.28E-01	-2.96E-01	-1.03E-01
LANDFILL - LGR Electricity Generation	8.24E-01	3.68E+01	7.97E-04	-8.73E-02	2.77E+00	5.97E-03
EFW	2.86E+00	5.51E+01	1.18E-03	2.95E-02	8.06E+00	-3.99E-02

Part 5: A calculation of the upstream pollution prevention benefits associated with compost end-use

Research into end-use applications of compost shows that is can significantly reduce the use of pesticides and synthetic fertilizers on lawns and gardens. Using a basic assumption that compost use may be associated with a 50% or more reduction in pesticides and synthetic fertilizer use, the following pollution reduction data is associated with every ton of waste organics composted. Note: The associated pollutants in the table do not include: exposure to persons or wildlife at time of pesticide application; and release / impacts from disposal of pesticides in the garbage.

Rational for 50% compost to fertilizer/pesticide substitution rate is further explained in Part 8 – on sensitivity analysis. In addition, Part 8 offer a sensitivity analysis which shows the impact if the 50% reduction assumption is reduced to 25% reduction.

Table 5: **Estimated upstream and use phase emissions reductions per ton composted**

Estimated Upstream and Use Phase Emissions Reductions per Ton Composted[18] (pounds of emissions reductions per ton composted)							
	Climate Change	**Human Health - Particulates**	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophica-tion**	**Acidification**	**Ecosystems Toxicity**
-	**(eCO2)**	**ePM2.5**	**eToluene**	**eBenzene**	**eN**	**eSO2**	**e2,4-D**
Avoided Pesticide Production	54.02	0.09	112.42	0.06		0.45	0.89
Avoided Pesticide Use			27.77	0.00			1.74
Avoided Fertilizer Production	1018.31	0.41	146.82	0.25		1.86	2.28
Avoided Fertilizer Use					5.36		
Total	**1072.33**	**0.51**	**287.00**	**0.31**	**5.36**	**2.31**	**4.92**

[18] As per *Curbside Recycling in King County: Valuation of Environmental Benefits Draft,* Dr. Jeffrey Morris, Sound Resource Management, August 22, 2007, page 9, : "Estimates of emissions from production and use of pesticides and synthetic fertilizers are based on Morris and Bagby (2007), Morris *et al* (2007) and the CEI model, and the Carnegie Mellon Economic Input Output – Life Cycle Analysis model described in Cicas *et al* (2006) and available on the Internet at www.eiolca.net"

Part 6: A Calculation and monetization of the pollution impacts from waste management options and the upstream impact of compost use

Utilizing all previously stated data on the environmental and human health impacts associated with composting, EFW, landfill and compost end-use, a summary of net environmental impact or benefit can be obtained. Table 6a provides a summary of the net environmental benefits per ton. Unlike calculating the net benefit of EFW and landfill, the composting net benefit requires subtracting the landfill benefit (as composting is replacing the landfill option) and further adding the benefit of compost use. (Appendix A provides the detailed calculation).

Table 6a: **Summary of the net environmental benefits of composting, landfill (flaring and electricity generation), and EFW of organics**

		Pounds of Emissions Reductions/(Increase) Per Ton Recycled/Composted						
		Climate Change	**Human Health - Particulates**	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophica-tion**	**Acidification**	**Ecosystems Toxicity**
		(eCO2)	**(ePM2.5)**	**(eToluene)**	**(eBenzene)**	**(eN)**	**(eSO2)**	**(e2,4-D)**
COMPOSTING	L&Y&Brush	542.31	0.52	241.54	0.31	5.32	2.17	4.13
	Food scrap	2247.95	0.52	241.54	0.31	5.32	2.17	4.13
LANDFILL - LGR Flaring	L&Y&Brush	970.77	(0.08)	(3.44)	(0.00)	(0.13)	(0.30)	(0.10)
	Food scrap	(734.87)	(0.08)	(3.44)	(0.00)	(0.13)	(0.30)	(0.10)
LANDFILL LGR Electricity generation	L&Y&Brush	1083.94	0.82	36.77	0.00	(0.09)	2.77	0.01
	Food scrap	(540.87)	0.82	36.77	0.00	(0.09)	2.77	0.01
EFW	L&Y&Brush	148.47	2.86	55.14	0.00	0.03	8.06	(0.04)
	Food scrap	103.10	2.86	55.14	0.00	0.03	8.06	(0.04)

Applying the monetized values associated with the various pollutants, listed above provides a new indicator; a "dollar value" of the impact of the associated pollution.

Once again, the following table provides the per ton monetized value of each pollutant.

Value of Environmental Impact Category Emissions Reductions Per Ton

Value of Environmental Impact Category Emissions Reductions Per Ton						
Climate Change	**Human Health - Particulates**	**Human Health - Toxics**	**Human Health- Carcinogens**	**Eutrophica-tion**	**Acidification**	**Ecosystems Toxicity**
eCO2	**ePM2.5**	**eToluene**	**eBenzene**	**eN**	**eSO2**	**e2,4-D**
$36	$10,000	$118	$3,030	$4	$661	$3,280

The monetized values for composting, landfilling and EFW for the Region of Niagara's organic waste are presented in table 6b. These values represent the monetized value of the pollutant times the amount of the pollutant. For example, to calculate the eCO2 benefit for composting leaf,yard & brush waste:

*Pounds of eCO2 per ton composted: 542.31 * value of eCO2 per ton: $36 divided by 2000 (converting lbs to tons) = $9.76 per ton.*

Table 6b: **Monetized value of pollution impacts from composting, landfill and EFW of organics**

		Value of Emissions Reductions Per Ton Recycled/Composted							Total per ton
Climate Change	**Human Health - Particulates**	**Human Health – Toxics**	**Human Health- Carcinogens**	**Eutrophica-tion**	**Acidification**	**Ecosystems Toxicity**	**Climate Change**	**Human Health - Particulates**	**Human Health – Toxics**
(eCO2)	**(ePM2.5)**	**(eToluene)**	**(eBenzene)**	**(eN)**	**(eSO2)**	**(e2,4-D)**	**(eCO2)**	**(ePM2.5)**	**(eToluene)**
COMPOSTING	L&Y&Brush	$9.76	$2.62	$14.19	$0.48	$0.01	$0.72	$6.78	**$ 34.55**
	Food waste	$40.46	$2.62	$14.19	$0.48	$0.01	$0.72	$6.78	**$ 65.25**
LANDFILL - LGR Flaring	L&Y&Brush	$17.47	-$0.39	-$0.20	$0.00	$0.00	-$0.10	-$0.17	**$ 16.61**
	Food waste	-$13.23	-$0.39	-$0.20	$0.00	$0.00	-$0.10	-$0.17	**$ (14.09)**
LANDFILL LGR Electricity generation	L&Y&Brush	$19.51	$4.12	$2.16	$0.00	$0.00	$0.91	$0.01	**$ 26.72**
	Food waste	-$9.74	$4.12	$2.16	$0.00	$0.00	$0.91	$0.01	**$ (2.53)**
EFW	L&Y&Brush	$2.67	$14.29	$3.24	$0.00	$0.00	$2.66	-$0.07	**$ 22.80**
	Food waste	$1.86	$14.29	$3.24	$0.00	$0.00	$2.66	-$0.07	**$ 21.98**

For the Region of Niagara's tonnage of 14,861 tonnes of food waste (16,381 short tons); 32,317 tonnes of leaf & yard waste and brush (totaling 35,623 short tons), the monetized value of the economic benefit or (impact) is provided in Table 6c, 6d, and chart 6c and 6d.

Table 6c: **Monetized value of environmental benefit of composting, landfill and EFW of the Region of Niagara's organics in US$.**

$ Value of Environmental Benefit (Impact) in $US							
	Tons of organics	**Composting (L&YLBrush & Food waste)**	**Landfill - LRG Flaring**	**Landfill LGR - electricity generation**	**EFW - low estimate**	**EFW - High estimate**	**EFW - best case estimate**
L&Y&Brush	35,623	$ 1,230,891	$ 591,856	$ 951,786	$ 812,228	$ 812,228	$ 812,228
Foods Waste	16,381	$ 1,068,940	$(230,762)	$ (41,415)	$ 360,120	$ 360,120	$ 360,120
$ TOTAL	52,004	**$ 2,299,831**	**$ 361,094**	**$ 910,371**	**$ 1,172,348**	**$ 1,172,348**	**$ 1,172,348**

Table 6d: **Monetized environmental benefit of composting, landfill and EFW of the Region of Niagara's organics in Canadian dollars.**

	Composting (L&YLBrsh & Food waste)	**Landfill - LRG Flaring**	**Landfill LGR - electricity generation**	**EFW - low estimate**	**EFW - High estimate**	**EFW - best case estimate**
$ TOTAL costs Environmental Benefit $CAN)	**$2,339,618**	**$367,341**	**$ 926,120**	**$1,192,629**	**$1,192,629**	**$1,192,629**
Average benefit per tonne (Can$)	**$ 49.59**	**$ 7.79**	**$ 19.63**	**$ 25.28**	**$ 25.28**	**$ 25.28**

Chart 6e: **Value of Monetized Environmental Benefit of Waste Management Options for Organics**

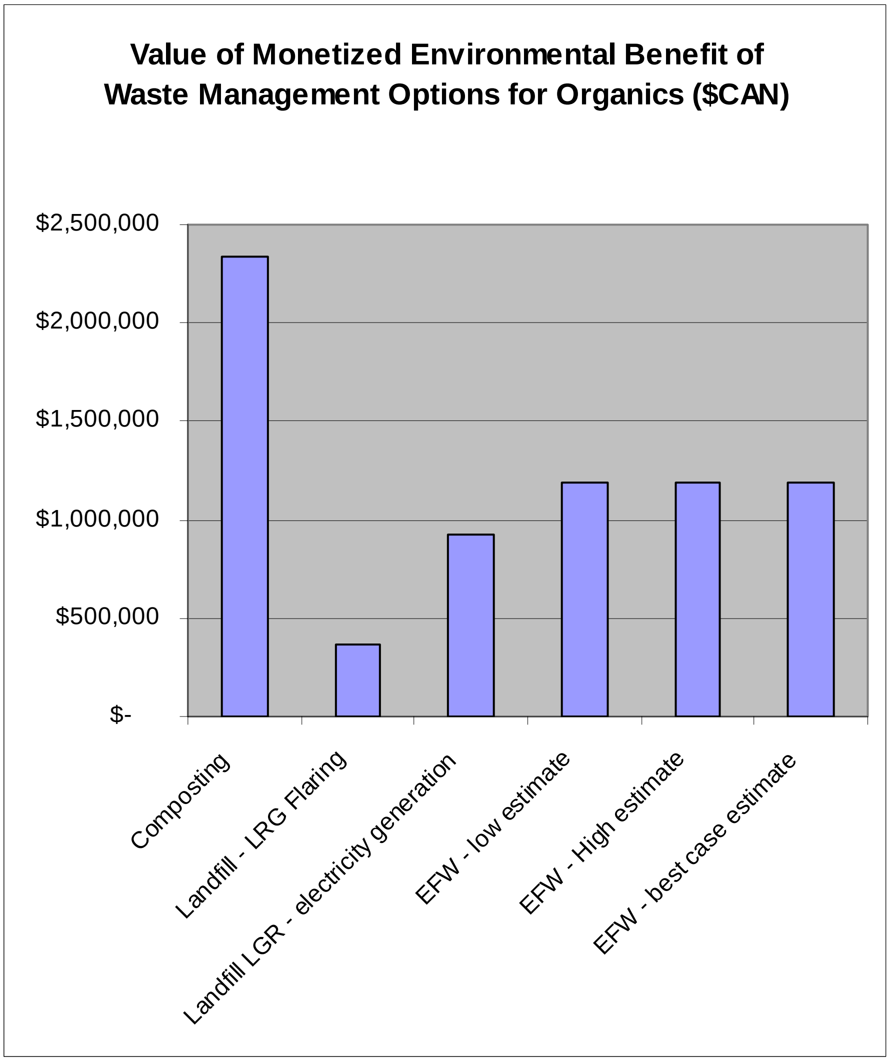
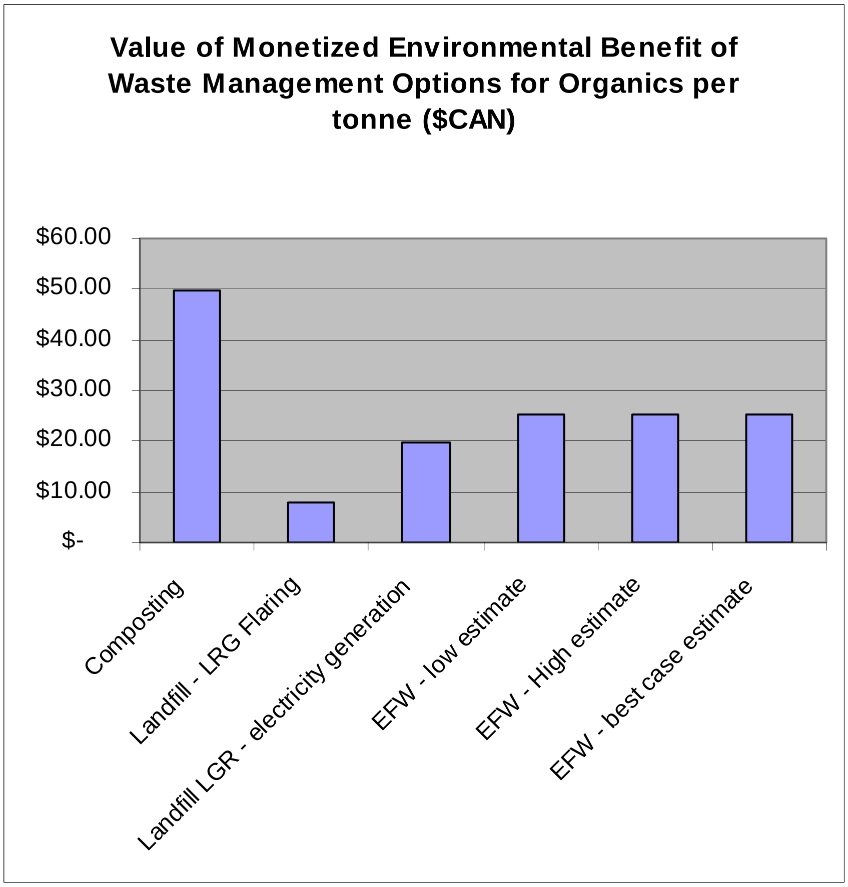


Chart 6f: **Value of Monetized Environmental Benefit of Waste Management Options for Organics per tonne**



Part 7: A calculation the "true cost" of waste management options by off-setting actual costs of operations with the monetized environmental benefit

For a "true cost" estimate of each waste management option, the monetized environmental benefit is subtracted from the actual cost of operations per tonne.

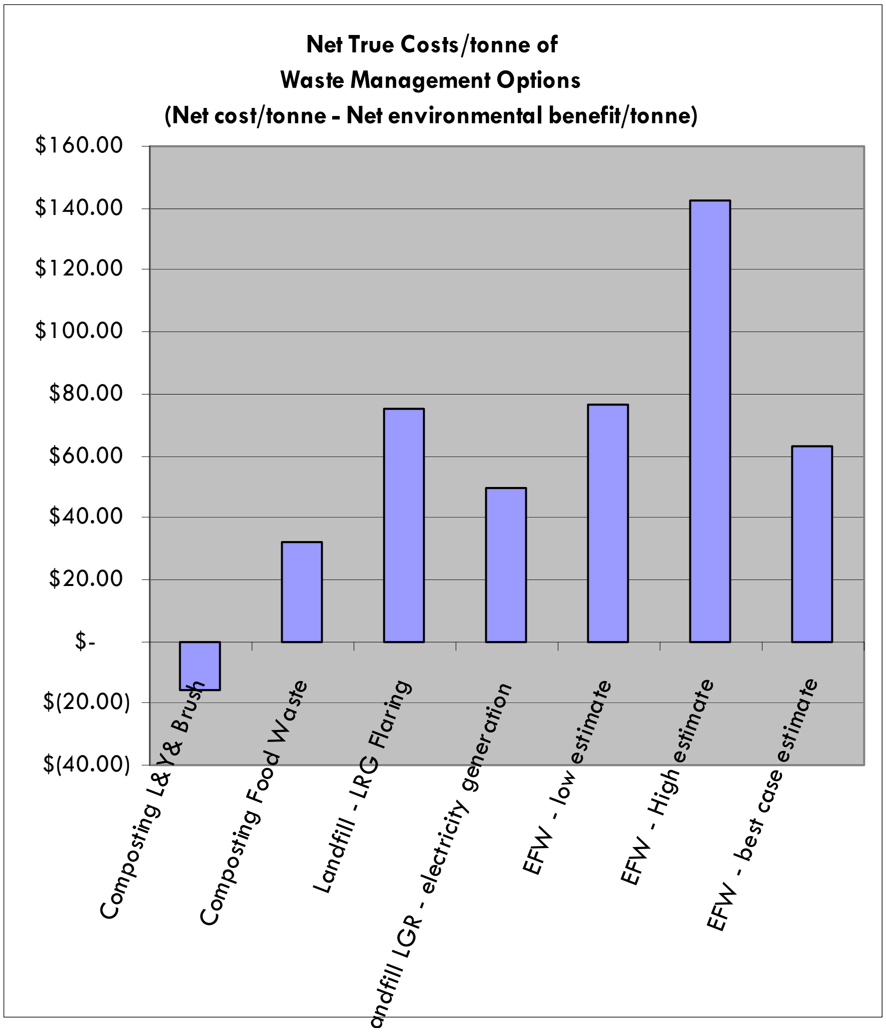
$ True Cost = $ Net Cost of operations – $ Monetized environmental cost benefit

In the case of the Region of Niagara, the 'True Costs' associated with managing organics are $(15.76) and $32.18 per tonne for composting L&Y and brush, and food waste respectively, $75.14 per tonne for landfill with gas flaring, $49.37 per tonne for landfill with gas recovery for electricity generation, and from $62.72 -$142.72 per tonne for EFW.

Table 7a: **True costs associated with managing organic waste in the Region of Niagara**

	Composting L&Y& Brush	**Composting Food Waste**	**Landfill - LRG Flaring**	**Landfill LGR - electricity generation**	**EFW - low estimate**	**EFW - High estimate**	**EFW - best case estimate**
Operations Cost per tonne	$ 33.83	$ 81.77	$ 82.93	$ 69.00	$ 102.00	$ 168.00	$ 88.00
Environmental Benefit per tonne	$ 49.59	$ 49.59	$ 7.79	$ 19.63	$ 25.28	$ 25.28	$ 25.28
True cost per tonne	**$ (15.76)**	**$ 32.18**	**$ 75.14**	**$ 49.37**	**$ 76.72**	**$ 142.72**	**$ 62.72**

Chart 7b: **True costs/tonne of waste management options**



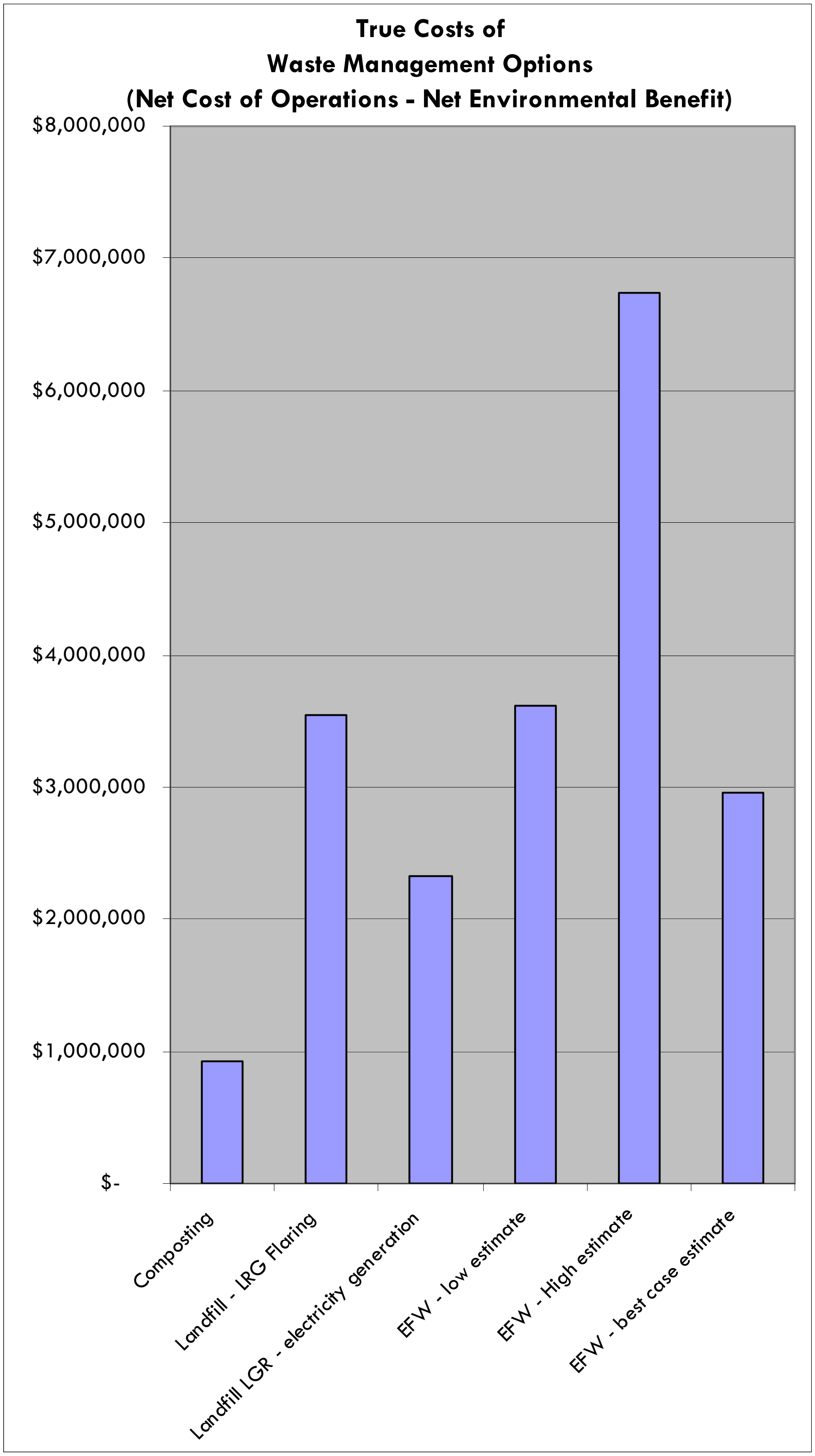
In addition, the net economic benefit of composting organics instead of landfill or EFW represents a net economic benefit of between $1.4 million to $5.8 million per annum.

Table 7c **True costs associated with managing organic waste in the Region of Niagara**

	Composting (L&Y&B and Food waste)	Landfill - LRG Flaring	Landfill LGR - electricity generation	EFW - low estimate	EFW - High estimate	EFW - best case estimate
Net True Cost	$ 927,746	$ 3,545,130	$ 2,329,162	$ 3,619,527	$ 6,733,275	$ 2,959,035
True cost per tonne	$ 19.66	$ 75.14	$ 49.37	$ 76.72	$ 142.72	$ 62.72

Note: The costs associated with organics (leaf/yard/brush and food waste) were aggregated and divided by the amount of tonnes in order to present one "true cost" for composting.

Chart 7d: **True Costs of Waste Management Options**



Part 8: Applying a sensitivity analysis

A sensitivity analysis investigates how projected performance varies with changes in the key assumptions on which the projections are based. Sensitivity analysis illustrates how a model output varies with changes in model inputs.

A model is said to be sensitive to an input if changing that input variable changes the model output. This output variability (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation in the inputs.

The following sensitivity analyses will investigate changes in two basic input assumptions.

1) *Compost-use will result in a 50% reduction of pesticide and synthetic fertilizer use.*

will be replaced with:

Compost-use will result in a 25% reduction of pesticide and synthetic fertilizer use.

2) The value of carbon dioxide is worth about $36 per ton (US$)

will be replaced with:

- *The value of carbon dioxide is worth about $4 per ton (US$); and*
- *The value of carbon dioxide is worth about $85 per ton (US$)*

8.1 Compost-use replacing synthetic fertilizers and pesticides

Understanding the basic assumption:
Compost-use will result in a 50% reduction of pesticide and synthetic fertilizer use.

This assumption is premised on the fact that buyers of compost for their lawn and garden, are purchasing them in place of fertilizers with herbicides. They are likely to be more conscientious about the environmental and human health impacts of pesticides (herbicides, insecticides, fungicides) etc. In addition, from an economic perspective, people who buy compost are not going to buy the same amount of fertilizers as they did before they became aware of compost as a soil amendment.

Finally, the impact assumption of a 50% reduction in pesticide and synthetic fertilizer use does not include exposure to persons or wildlife at time of pesticide application, nor does it include impacts from the release and no release/impacts from disposal of pesticides in the garbage).

While this assumption may seem conservative, it is reasonable to reduce the assumption to a 25% substitution rate in order to test the sensitivity of composting versus other waste management options.

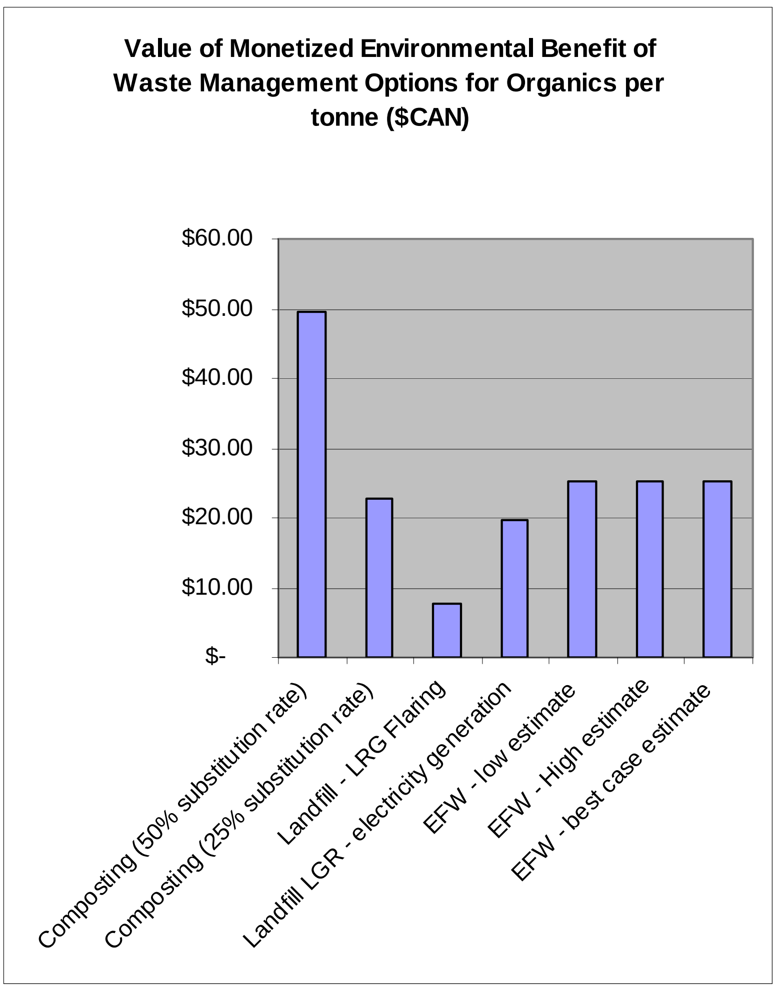
The results:

By reducing the compost to fertilizer/pesticide substitution rate from 50% to 25%, the environmental benefit reduces from $49.59 per tonne to $22.67 per tonne for a mix of organics (35,623 tons of leaf/yard/brush and 16,381 tons of food waste).

Table 8.1a: Impact on the environmental benefit of 25% compost to pesticide/fertilizer substitution rate

	$ Value of Environmental Benefit (Impact) in $US						
	Composting (50% substitution rate)	Composting (25% substitution rate)	Landfill - LRG Flaring	Landfill LGR - electricity generation	EFW - low estimate	EFW - High estimate	EFW - best case estimate
Environmental Benefit ($CAN)	$ 2,339,618	$ 1,069,601	$ 367,341	$ 926,120	$ 1,192,629	$ 1,192,629	$1,192,629
Average benefit per tonne (Can$)	$ 49.59	$ 22.67	$ 7.79	$ 19.63	$ 25.28	$ 25.28	$ 25.28

Chart 8.1b: Impact on the environmental benefit of 25% compost to pesticide/fertilizer substitution rate



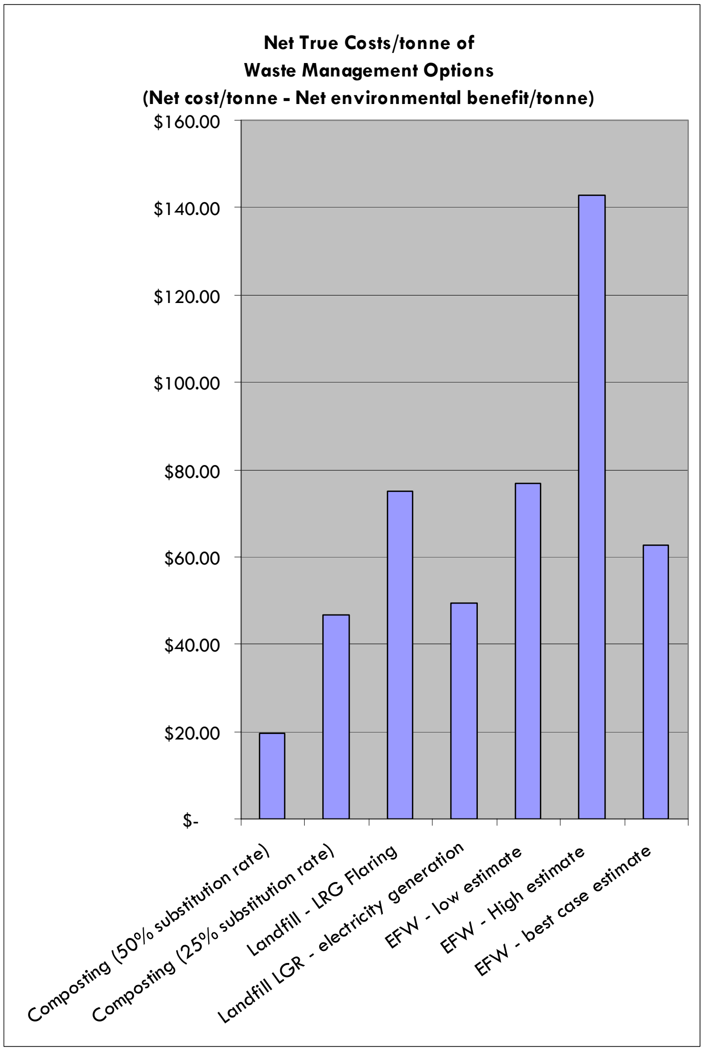
By reducing the compost to fertilizer/pesticide substitution rate from 50% to 25%, the "true cost" increases from $19.66 per tonne to $46.58 per tonne for a mix or organics (35,623 leaf/yard/brush and 16,381 food waste).

<u>Relative to other waste management options, composting remains the most cost-effective option for the Region of Niagara.</u>

Table 8.1c: Impact on the True Costs of 25% compost to pesticide/fertilizer substitution rate

True cost of Waste Management Options							
	Composting (50% substitution rate)	Composting (25% substitution rate)	Landfill - LRG Flaring	Landfill LGR - electricity generation	EFW - low estimate	EFW - High estimate	EFW - best case estimate
Net True Cost	$ 927,746	$2,197,763	$ 3,545,130	$ 2,329,162	$ 3,619,527	$ 6,733,275	$2,959,035
True cost per tonne	$ 19.66	$ 46.58	$ 75.14	$ 49.37	$ 76.72	$ 142.72	$ 62.72

Chart 8.1d: Impact on the True Costs of 25% compost to pesticide/fertilizer substitution rate



8.2 Modifying the value of carbon dioxide (CO2) to $4 per ton and $85 per ton

The value of a ton of carbon dioxide varies the North American (unregulated) marketplace, from $1 to $4 (US$) per ton with values exceeding $100 per ton in jurisdictions where carbon trading is regulated. The recently completed Stern Review[19] on the economics of climate change estimates the environmental cost of a metric tonne of CO2 emissions at $85 (US$).

The model uses a value of $36 per ton for one ton of carbon dioxide equivalent (eCO2) based on GHG offset valuation used by Seattle City Light. While this assumption may seem conservative, it is reasonable to input both a low ($4) and high ($85) value in order to test the sensitivity of composting versus other waste management options.

Table 8.2a Environmental Benefit per ton for CO2 = $4; $36; $85 per ton

		Environmental Benefit per ton		
		CO2=$4	CO2=$36	CO2=$85
COMPOSTING	L&Y&Brush	**$25.88**	**$34.55**	**$47.84**
	Food waste	**$29.29**	**$65.25**	**$120.33**
LANDFILL - LGR Flaring	L&Y&Brush	**$1.08**	**$16.61**	**$40.40**
	Food waste	**-$2.33**	**-$14.09**	**-$32.09**
LANDFILL LGR Electricity generation	L&Y&Brush	**$9.38**	**$26.72**	**$53.27**
	Food waste	**$6.13**	**-$2.53**	**-$15.78**
EFW	L&Y&Brush	**$20.43**	**$22.80**	**$26.44**
	Food waste	**$20.33**	**$21.98**	**$24.51**

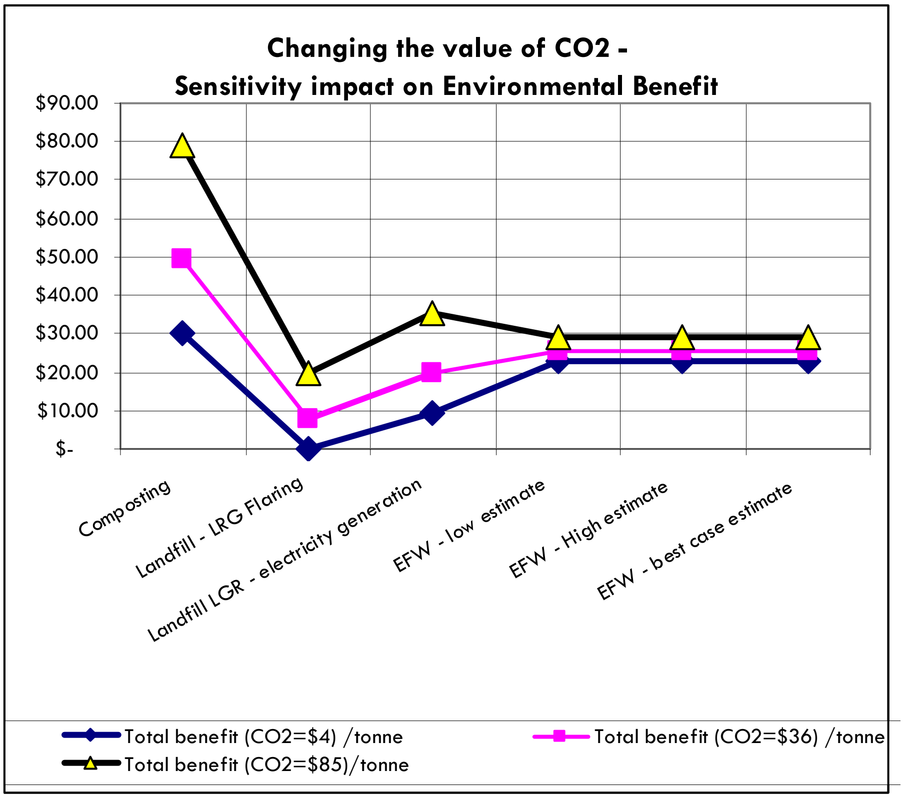
The results show that irrespective of the value that is assigned to CO2, composting consistently remains the environmentally preferable option from a monetized "environmental benefit" perspective. (See Table 8.2b and chart 8.2c)

Table 8.2b Impact on the environmental benefit of various CO2 values: $4; $36; $85 per tonne

$ Value of Environmental Benefit (Impact) in $Can						
	Composting	**Landfill - LRG Flaring**	**Landfill LGR - electricity generation**	**EFW - low estimate**	**EFW - High estimate**	**EFW - best case estimate**
Total benefit (CO2=$4) /tonne	**$ 30.22**	**$ 0.01**	**$ 9.37**	**$ 22.87**	**$ 22.87**	**$ 22.87**
Total benefit (CO2=$36) /tonne	**$ 49.59**	**$ 7.79**	**$ 19.63**	**$ 25.28**	**$ 25.28**	**$ 25.28**
Total benefit (CO2=$85)/tonne	**$ 79.25**	**$ 19.70**	**$ 35.35**	**$ 28.97**	**$ 28.97**	**$ 28.97**

[19] *Stern Review Report on the Economics of Climate Change*: www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change

Chart 8.2c Impact on the environmental benefit of various CO2 values: $4; $36; $85 per tonne

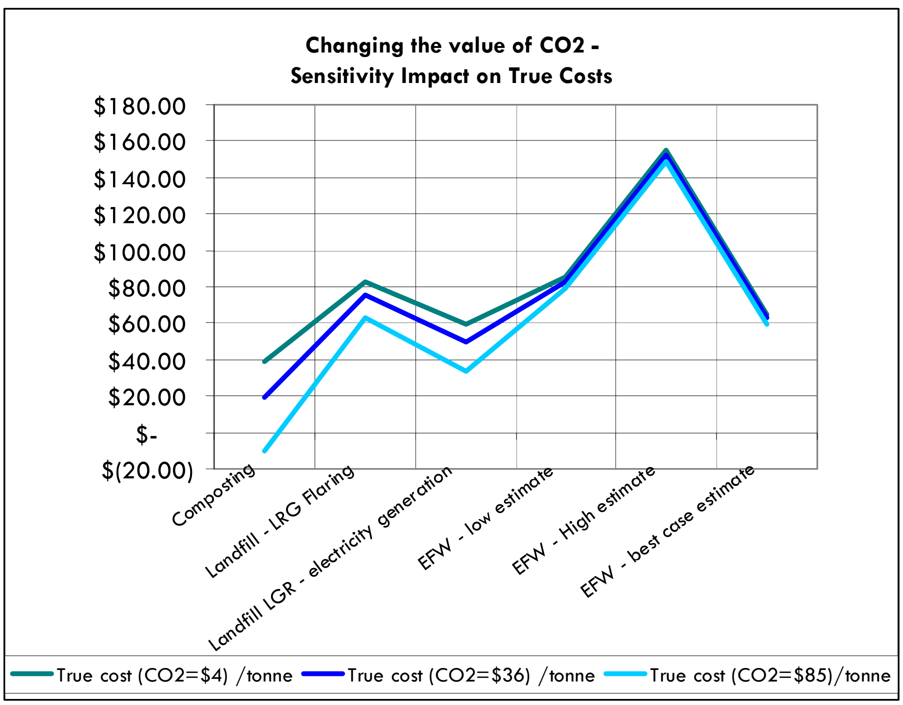


The results show that irrespective of the value that is assigned to CO2, composting consistently remains the cheapest option in terms of "True cost" (Net cost – environmental benefit). (See Table 8.2d and chart 8.2e)

Table 8.2d Impact on the "True Costs" of various CO2 values: $4; $36; $85 per tonne

True Costs Associated with Waste Management Options (CAN$)						
	Composting	**Landfill - LRG Flaring**	**Landfill LGR - electricity generation**	**EFW - low estimate**	**EFW - High estimate**	**EFW - best case estimate**
True cost (CO2=$4) /tonne	**$ 39.03**	**$ 82.92**	**$ 59.63**	**$ 85.13**	**$ 155.13**	**$ 65.13**
True cost (CO2=$36) /tonne	**$ 19.66**	**$ 75.14**	**$ 49.37**	**$ 82.72**	**$ 152.72**	**$ 62.72**
True cost (CO2=$85)/tonne	**$ (9.99)**	**$ 63.23**	**$ 33.65**	**$ 79.03**	**$ 149.03**	**$ 59.03**

Table 8.2e Impact on the "True Costs" of various CO2 values: $4; $36; $85 per tonne



Conclusion

The most comprehensive method for assessing the preferred waste management option for the Region of Niagara should include a full cost accounting of each option which includes both the impact on the environment as well as human health.

Fortunately today, data exists to measure the costs associated with greenhouse gas emissions and sequestration; and other pollution and avoided pollution from collection, processing systems, energy off-setting and end-use product applications.

Together this information expressed as a cost ($) or cost benefit provides a complete understanding of how much each option will cost in terms of operations, environmental degradation and human health.

Applied to the Region of Niagara's option in dealing with the management of organics (leaf and yard, brush, and food waste), the results show that composting has a significantly lower cost to society than landfill (with gas flaring or recovery for electricity generation) and energy-from-waste.

In fact, the full cost or "true cost" of composting in the Region is 60% to 86% lower than both the lowest and highest alternative options, which are landfill with electricity generation, and EFW respectively.

A significant factor which contributes to the economic benefit of composting is the fact that finished compost will be used as a substitute for synthetic fertilizers and pesticides. This environmental and human health benefit cannot be ignored for its upstream mitigation of pollution produced both in the production and end-use phases of pesticides and synthetic fertilizers.

A series of sensitivity analyses were performed to on various economic model inputs in an effort to test the sensitivity of the results (output). In all cases, composting proved to be the most cost effective waste management option from a "full cost" accounting perspective.

Summary of findings and Recommendations:

1. Composting results in the best economic value to a community and results in the least pollution;
2. Every effort should be put towards source separation for composting before any 'disposal' technologies are considered;
3. Those responsible for collection and/or management of waste streams with organics, should collect organics separately for composting rather than disposal.

Appendix A
Calculating the net environmental benefits for composting

Emissions Reductions	Pounds of Emissions Reductions/(Increase) Per Ton of Yard Waste						
	eCO2	ePM2.5	eToluene	eBenzene	eN	eSO2	e2,4-D
Compostables Collection, Hauling & Composting (incl. C sequestration)	440.751	-0.062	-48.900	-7.605E-04	-0.167	-0.435	-0.887
Avoided Garbage Collection, Hauling & Disposal (no LFG recovery - flaring)	-970.769	0.078	3.441	1.781E-04	0.128	0.296	0.103
Avoided Pesticide Production & Use							
Production	54.022	0.093	112.416	0.060		0.452	0.895
Use			27.767	0.001			1.744
Avoided Fertilizer Production & Use							
Production	1,018.308	0.414	146.816	0.253		1.862	2.279
Use					5.355		
Total Emission Reductions Per Ton	**542.312**	**0.523**	**241.539**	**0.314**	**5.315**	**2.175**	**4.133**

Emissions Reductions	**Pounds of Emissions Reductions/(Increase) Per Ton of Food Scraps**						
	eCO2	**ePM2.5**	**eToluene**	**eBenzene**	**eN**	**eSO2**	**e2,4-D**
Compostables Collection, Hauling & Composting (incl. C sequestration)	440.751	-0.062	-48.900	-7.605E-04	-0.167	-0.435	-0.887
Avoided Garbage Collection, Hauling & Disposal (no LFG recovery - flaring)	734.874	0.078	3.441	1.781E-04	0.128	0.296	0.103
Avoided Pesticide Production & Use							
Production	54.022	0.093	112.416	0.060		0.452	0.895
Use			27.767	0.001			1.744
Avoided Fertilizer Production & Use							
Production	1,018.308	0.414	146.816	0.253		1.862	2.279
Use					5.355		
Total Emission Reductions Per Ton	**2,247.955**	**0.523**	**241.539**	**0.314**	**5.315**	**2.175**	**4.133**

APPENDIX B

Sensitivity analysis #1

Environmental impact with 25% compost to pesticide/fertilizer substitution rate

		Pounds of Emissions Reductions/(Increase) Per Ton Recycled/Composted						
		Climate Change	Human Health - Particulates	Human Health - Toxics	Human Health- Carcinogens	Eutrophica-tion	Acidification	Ecosystems Toxicity
		(eCO2)	(ePM2.5)	(eToluene)	(eBenzene)	(eN)	(eSO2)	(e2,4-D)
COMPOSTING 50% compost replacement	L&Y&Brush	542.31	0.52	241.54	0.31	5.32	2.17	4.13
	Food waste	2247.95	0.52	241.54	0.31	5.32	2.17	4.13
COMPOSTING 25% compost replacement	L&Y&Brush	6.15	0.27	98.04	0.16	2.64	1.02	1.67
	Food waste	1711.79	0.27	98.04	0.16	5.32	1.02	1.67
LANDFILL - LGR Flaring	L&Y&Brush	970.77	(0.08)	(3.44)	(0.00)	(0.13)	(0.30)	(0.10)
	Food waste	(734.87)	(0.08)	(3.44)	(0.00)	(0.13)	(0.30)	(0.10)
LANDFILL LGR Electricity	L&Y&Brush	1083.94	0.82	36.77	0.00	(0.09)	2.77	0.01
	Food waste	(540.87)	0.82	36.77	0.00	(0.09)	2.77	0.01
EFW	L&Y&Brush	148.47	2.86	55.14	0.00	0.03	8.06	(0.04)
	Food waste	103.10	2.86	55.14	0.00	0.03	8.06	(0.04)

Monetized environmental impact with 25% compost to pesticide/fertilizer substitution rate

		Value of Emissions Reductions Per Ton Recycled/Composted							Total per ton
		Climate Change	Human Health - Particulates	Human Health - Toxics	Human Health- Carcinogens	Eutrophica-tion	Acidification	Ecosystems Toxicity	
		(eCO2)	(ePM2.5)	(eToluene)	(eBenzene)	(eN)	(eSO2)	(e2,4-D)	
COMPOSTING	L&Y&Brush	$9.76	$2.62	$14.19	$0.48	$0.01	$0.72	$6.78	**$ 34.55**
	Food waste	$40.46	$2.62	$14.19	$0.48	$0.01	$0.72	$6.78	**$ 65.25**
COMPOSTING	L&Y&Brush	$0.11	$1.35	$5.76	$0.24	$0.01	$0.34	$2.75	**$ 10.55**
25% compost replacement	Food waste	$30.81	$1.35	$5.76	$0.24	$0.01	$0.34	$2.75	**$ 41.25**
LANDFILL - LGR Flaring	L&Y&Brush	$17.47	-$0.39	-$0.20	$0.00	$0.00	-$0.10	-$0.17	**$ 16.61**
	Food waste	-$13.23	-$0.39	-$0.20	$0.00	$0.00	-$0.10	-$0.17	**$ (14.09)**
LANDFILL LGR Electricity generation	L&Y&Brush	$19.51	$4.12	$2.16	$0.00	$0.00	$0.91	$0.01	**$ 26.72**
	Food waste	-$9.74	$4.12	$2.16	$0.00	$0.00	$0.91	$0.01	**$ (2.53)**
EFW	L&Y&Brush	$2.67	$14.29	$3.24	$0.00	$0.00	$2.66	-$0.07	**$ 22.80**
	Food waste	$1.86	$14.29	$3.24	$0.00	$0.00	$2.66	-$0.07	**$ 21.98**