DURHAM REGION

York Region

Durham/York Residual Waste Study

Supplement to Annex E-5:

Comparative Analysis of Thermal Treatment and Remote Landfill on a Lifecycle Basis

July 4, 2007

GENIVAR

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Supplement to Annex E-5: Environmental Analysis

In Annex E-5 of the ‘Alternatives to’ report, the environmental lifecycle implications associated with the four different residual waste processing systems examined in this Study were modeled to allow for the relative comparison of the alternative systems. In order to verify the results from the Integrated Waste Management (IWM) model and the ICF model presented in Annex E-5, it was decided to further confirm these results by using another well accepted life cycle model.

It was decided to also model the environmental lifecycle implications of the management of residual waste by remote landfill, which is the current residual waste disposal method employed by Durham and York Regions. Although the option of remote landfill was not included within the scope of the Environment Assessment Terms of Reference, it is important to understand the environmental implications of remote landfill in order to compare against the alternative residual waste management options being studied.

The model chosen was the Municipal Solid Waste Decision Support Tool (MSW-DST), which utilises average default data from existing waste management facilities across North America. The MSW-DST was developed by RTI International in cooperation with the U.S. Environmental Protection Agency (EPA) Office of Research and Development. RTI International offers research and technical solutions to governments and businesses worldwide in the areas of economic and social development, energy, and the environment. The MSW-DST has undergone extensive stakeholder input and peer review (including a separate review by the U.S. EPA).

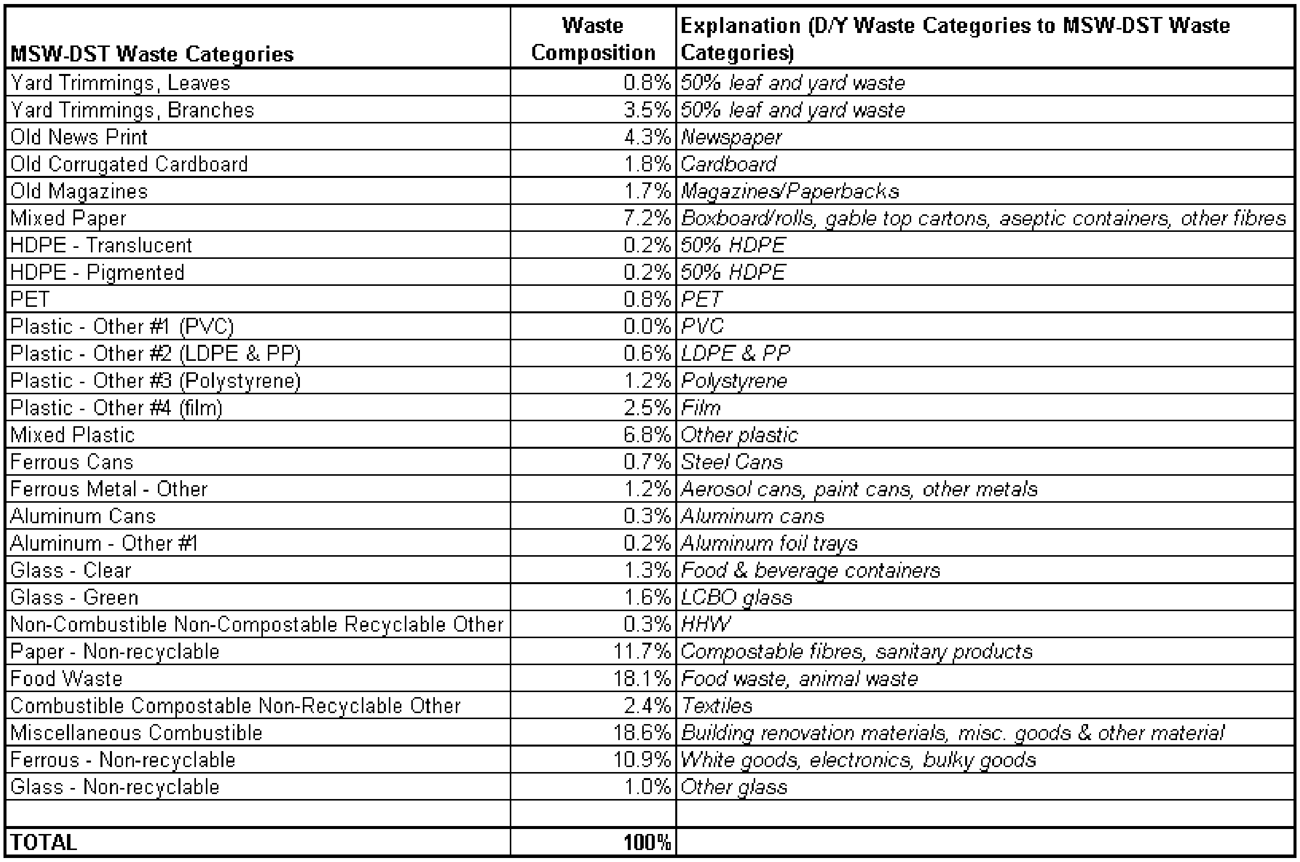
The purpose of this supplementary report is to compare the relative energy and environmental implications of the preferred treatment system (2a - thermal treatment of mixed solid waste and recovery of energy followed by recovery of materials from ash/char) against the base case scenario of remote landfill on a lifecycle basis. It should be noted that this analysis is not intended to provide a complete assessment of the environmental impacts of the residual waste processing systems, but rather to provide a relative comparison of alternatives that can be used as a tool to support the decision making process.

In order to use the MSW-DST model to accurately reflect the alternative residual waste management scenarios, a number of assumptions were made. These are set out below.

Waste Composition

The waste composition projected in Annex C1: Additional At-Source Diversion and Residual Waste (available online at http://www.durhamyorkwaste.ca/processing_system.php) was used as the basis for the MSW-DST model. The waste composition is based on available waste audit data and the assumption is that there is a full recycling and source separated organics program in place, which is achieving 60% diversion. Therefore, the waste input for all of the system alternatives is residual post-diversion waste. The quantity of residual waste was assumed to be 250,000 tonnes, which is the initial quantity of waste approved for consideration in the Environmental Assessment Terms of Reference. The waste composition used in the MSW-DST model is presented in Table 1.

Table 1: MSW-DST Waste Composition



MSW-DST Waste Categories	Waste Composition	Explanation (D/Y Waste Categories to MSW-DST Waste Categories)
Yard Trimmings, Leaves	0.8%	*50% leaf and yard waste*
Yard Trimmings, Branches	3.5%	*50% leaf and yard waste*
Old News Print	4.3%	*Newspaper*
Old Corrugated Cardboard	1.8%	*Cardboard*
Old Magazines	1.7%	*Magazines/Paperbacks*
Mixed Paper	7.2%	*Boxboard/rolls, gable top cartons, aseptic containers, other fibres*
HDPE - Translucent	0.2%	*50% HDPE*
HDPE - Pigmented	0.2%	*50% HDPE*
PET	0.8%	*PET*
Plastic - Other #1 (PVC)	0.0%	*PVC*
Plastic - Other #2 (LDPE & PP)	0.6%	*LDPE & PP*
Plastic - Other #3 (Polystyrene)	1.2%	*Polystyrene*
Plastic - Other #4 (film)	2.5%	*Film*
Mixed Plastic	6.8%	*Other plastic*
Ferrous Cans	0.7%	*Steel Cans*
Ferrous Metal - Other	1.2%	*Aerosol cans, paint cans, other metals*
Aluminum Cans	0.3%	*Aluminum cans*
Aluminum - Other #1	0.2%	*Aluminum foil trays*
Glass - Clear	1.3%	*Food & beverage containers*
Glass - Green	1.6%	*LCBO glass*
Non-Combustible Non-Compostable Recyclable Other	0.3%	*HHW*
Paper - Non-recyclable	11.7%	*Compostable fibres, sanitary products*
Food Waste	18.1%	*Food waste, animal waste*
Combustible Compostable Non-Recyclable Other	2.4%	*Textiles*
Miscellaneous Combustible	18.6%	*Building renovation materials, misc. goods & other material*
Ferrous - Non-recyclable	10.9%	*White goods, electronics, bulky goods*
Glass - Non-recyclable	1.0%	*Other glass*
TOTAL	**100%**	

Energy Grid

The selection of energy grid composition has significant impacts on the output of the life cycle analysis. For example, the net environmental impact of a system that consumes electricity from an electrical grid with a high percentage of electricity generated from coal will be higher than from a predominantly natural gas or nuclear powered grid. As well, the offsets for energy generation and for virgin material displacement credits will be greater from a coal based electrical grid than from a primarily natural gas or nuclear powered grid.

To ensure a conservative analysis of the benefits of energy displacement, a custom energy grid composition was used, which assumes the eventual replacement of coal-fired power plants with natural gas-fired plants in Ontario. The energy grid composition assumed was as follows: 45% nuclear; 31% natural gas; 24% hydro.

Base Case – Remote Landfill Scenario

The assumptions associated with the remote landfill scenario are as follows:

- Waste is transported 300 kilometres (one way), which is the average distance from the centroid of Durham and York Region to remote landfill sites located in southwestern Ontario. It was assumed that 30 tonne transport trucks would be used for the transfer of waste;

- A modern, US EPA Subtitle D-type landfill is used, with a liner system and a gas collection and utilization system;
- There is 60% landfill gas recovery with the landfill gas being utilized to generate electricity;
- The landfill liner has 90% leachate collection efficiency;
- The annual average emission is calculated over the assumed 100 year contaminating lifespan; and
- The average annual precipitation for southwestern Ontario is 860 millimetres.

System 2a – Thermal Treatment of Mixed Solid Waste and Recovery of Energy followed by Recovery of Materials from Ash/Char

The assumptions associated with System 2a are as follows:

- Waste is transported 75 kilometres (one way) from a transfer station to the thermal treatment facility, which is the average distance from the centre of Durham and York Regions to a site located near the periphery of Durham and York Regions;
- A mass burn thermal treatment facility is used with modern air pollution control equipment. Ferrous and non-ferrous metals are recovered from the ash/char;
- Electricity is generated with 20% gross energy recovery efficiency;
- The energy consumption of a mass burn thermal treatment facility is 70 kilowatt-hours per tonne of waste;
- Energy recovered is credited as an energy gain since it is assumed to displace electricity production that depends on conventional fuels. The energy grid composition assumed was as follows: 45% nuclear; 31% natural gas; 24% hydro;
- Median emission rates provided from technology vendors were utilized within the model to calculate the emissions to air. Where no data was available from technology vendors, default emission rates from the MSW-DST model were used; and
- The model calculates both combustion residue and flue gas cleaning residue. Combustion residue includes fly and bottom ash attributed to the combustion of waste and is calculated for each waste component. The flue gas cleaning residues include residue from the spray dryer, carbon injection, and NOx control equipment.

Additional details on the MSW-DST model are available at:
https://webdstmsw.rti.org/resources.htm.

MSW-DST Model

The model was used to calculate the emissions to air of:

- Greenhouse gases (net carbon dioxide equivalent);
- Acid gases (nitrogen oxide, sulphur oxide and hydrochloric acid);

- Smog precursors (nitrogen oxide, particulate matter and volatile organic compounds); and
- Heavy metals (lead, mercury, cadmium) and dioxins; it should be noted that emissions of mercury, cadmium, and dioxins are not standard outputs in the MSW-DST model since data for all operations is not available. The emissions of these pollutants from the thermal treatment facility were calculated based on technology vendors' emissions data.

The model also calculates the net energy consumption and the emissions to water of lead, mercury, cadmium, biochemical oxygen demand and dioxins.

The net energy consumption and emissions of these contaminants are shown in Table 2 on an annual and per tonne basis calculated by the MSW-DST model for:

  - the Base Case: Remote Landfill Scenario; and
  - System 2a: Thermal treatment of mixed solid waste and recovery of energy followed by recovery of materials from ash/char.

The net emissions are the sum of the emissions (or emission reductions) from the following sources:

- The transportation required to transfer the waste to the facility (landfill or thermal treatment facility);
- The facility – landfill or thermal treatment;
- Energy offset from the grid resulting from the energy produced by the facility;
- The transportation and disposal of the residue and ash from the thermal treatment facility;
- Landfill of residue and ash from the thermal treatment facility; and
- Additional environmental effects associated with recycling metals recovered by the thermal treatment facility.

The emissions from each of these individual sources are presented in Table 3 for the remote landfill and Table 4 for System 2a. It should be noted that some of the emissions are presented as a negative value, which represents a net reduction in the emission. Net emission reductions are emissions that are avoided by the production of energy at the facilities offsetting energy from the grid and from the recycling of metals recovered by the thermal treatment facility (virgin material displacement credit).

When calculating the greenhouse gas emissions, the accounting principles established by the International Panel on Climate Change (IPCC) are used in the MSW-DST model. As such, carbon dioxide emissions from biogenic sources are excluded from greenhouse gas emissions. This is standard methodology when performing greenhouse gas inventories according to the IPCC guidelines. The reasoning for this exclusion is based on the source of the carbon that is emitted to the atmosphere. When plants and other photosynthesizing organisms absorb sunlight, they fix carbon dioxide from the atmosphere and store the energy in the form of organic compounds. When this material decomposes or is combusted, the carbon is released back into the atmosphere as carbon dioxide. Thus it is classified as a zero net addition of greenhouse gases to the atmosphere. Carbon that originates from fossil fuels (i.e. coal, natural gas, and oil), however, is included in the sum of greenhouse gas emissions. This is due to the fact that fossil fuels have been removed from the carbon cycle for millions of years and therefore their release increases the net quantity of greenhouse gases present in the atmosphere.

Landfill emissions primarily consist of methane and carbon dioxide. The IPCC methodology on greenhouse gas inventory procedures define that the carbon dioxide component of landfill gas is non-anthropogenic in origin, and therefore is considered neutral in terms of greenhouse gas emissions. Methane, however, is a potent greenhouse gas with a greenhouse potential 21 times greater than carbon dioxide. Although methane is derived from materials that are biogenic, the emissions are still counted as greenhouse gas emissions. This is due to the fact that the anaerobic conditions in which methane forms in a landfill would not have otherwise occurred in nature. This anthropogenic activity thus contributes to a net addition of greenhouse gasses to the atmosphere.

Results

The purpose of this report is to compare, on a lifecycle basis, the relative energy and environmental implications of the preferred treatment system (2a - thermal treatment of mixed solid waste and recovery of energy followed by recovery of materials from ash/char) against the base case scenario, which is the existing practice of sending waste to a remote landfill. The results of the comparative analysis show:

- That for the situation in Durham and York Regions, residual waste managed by thermal treatment is better than remote landfill with respect to energy consumption, emissions to air of greenhouse gases, acid gases, smog precursors and emissions to water. This is shown in Table 2.
- An additional benefit of thermal treatment over the remote landfill scenario is that it provides a local source of energy, which generates a greater quantity of energy than a remote landfill.
- Thermal treatment has a smaller impact on the global and local airsheds since it has lower emissions to air of greenhouse gases, acid gases and smog precursors than the remote landfill scenario. As well thermal treatment has lower emissions to water, therefore reducing the risk to local waterways.
- A remote landfill has lower emissions to air than thermal treatment for heavy metals and dioxins contaminants.
  - It should be noted that the emissions to air from landfill of mercury, cadmium and dioxins were assumed to be zero since the MSW-DST model does not calculate those parameters. It can be assumed that there would be the release of some of these emissions through transportation and landfill operations, however the quantity of these emissions is negligible.
  - It should also be noted that the emissions to air of heavy metals and dioxins from thermal treatment are very small and can be further reduced by modern air pollution control equipment. These emissions are well within the regulatory limits and less than the emissions of these contaminants from many other established industrial sources.

A complete breakdown of the lifecycle emissions for thermal treatment scenario and the remote landfill scenario are presented in Table 3 and Table 4 respectively.

Table 2: Emissions to Air and Water for the Management of 250,000 tonnes per year of Residual Waste by Remote Landfill and System 2a (Thermal Treatment)

	Base Case - Remote Landfill		System 2a - Thermal Treatment of Mixed Solid Waste & Recovery of Energy followed by Recovery of Materials from Ash/Char	
ENERGY CONSUMPTION				
	(GJ/year)	**(GJ/tonne)**	**(GJ/year)**	**(GJ/tonne)**
Energy Consumption	58,000	232	-2,881,000	-11,524
EMISSIONS TO AIR				
Greenhouse Gases	**(tonnes/year)**	**(kg/tonne)**	**(tonnes/year)**	**(kg/tonne)**
Net carbon dioxide equivalent, eCO_2	59,000	236	33,000	132
Acid Gases	**(tonnes/year)**	**(kg/tonne)**	**(tonnes/year)**	**(kg/tonne)**
Nitrogen oxide, NOx	50	0.20	30	0.12
Sulphur oxide, SOx	-29	-0.12	-595	-2.38
Hydrochloric acid, HCl	2	0.01	12	0.05
Smog Precursors	**(tonnes/year)**	**(kg/tonne)**	**(tonnes/year)**	**(kg/tonne)**
Nitrogen oxide, NOx	50	0.20	30	0.12
Particular Matter, PM	9	0.04	-69	-0.27
Volatile organic compounds, VOCs	9	0.03	-62	-0.25
Heavy Metals	**(kg/year)**	**(g/tonne)**	**(kg/year)**	**(g/tonne)**
Lead, Pb (kg emitted annually)	0.0	0.0	8.4	0.03
Mercury, Hg	n/a	n/a	8.5	0.03
Cadmium, Cd	n/a	n/a	0.75	0.00
Dioxins	**(g/year)**	**(ug/tonne)**	**(g/year)**	**(ug/tonne)**
Dioxins, TEQ	0.00002	0.0001	0.012	0.046
EMISSIONS TO WATER				
Heavy Metals & BOD	**(kg/year)**	**(g/tonne)**	**(kg/year)**	**(g/tonne)**
Lead, Pb	0.02	0.087	-0.01	-0.049
Mercury, Hg	0.000	0.002	-0.005	-0.020
Cadmium, Cd	-2.6	-10.4	-35	-140
Biochemical oxygen demand, BOD	85,300	341	1,800	7
Dioxins	**(g/year)**	**(ug/tonne)**	**(g/year)**	**(ug/tonne)**
Dioxins, TEQ	n/a	n/a	n/a	n/a

n/a - not available as value not estimated by model

Table 3: Detailed Breakdown of Annual Emissions to Air and Water for the Management of 250,000 tonnes per year of Residual Waste by Remote Landfill

	Base Case - Remote Landfill			
	Total	**Transfer (300 km)**	**Landfill**	**Energy Offset**
ENERGY CONSUMPTION				
Energy Consumption (GJ/year)	**58,000**	72,082	122,733	-137,070
EMISSIONS TO AIR				
Greenhouse Gases				
Net carbon dioxide equivalent, eCO2 (tonnes/year)	**59,000**	5,012	56,946	-3,302
Acid Gases				
Nitrogen oxide, NOx (tonnes/year)	**50**	42	21	-13
Sulphur oxide, SOx (tonnes/year)	**-29**	12	6	-47
Hydrochloric acid, HCl (tonnes/year)	**2**	0	2	0
Smog Precursors				
Nitrogen oxide, NOx (tonnes/year)	**50**	42	21	-13
Particular Matter, PM (tonnes/year)	**9**	6	5	-2
Volatile organic compounds, VOCs (tonnes/year)	**9**	17	3	-11
Heavy Metals & Dioxins				
Lead, Pb (kg emitted annually)	**0.0**	0	0	0
Mercury, Hg	**n/a**	n/a	n/a	n/a
Cadmium, Cd	**n/a**	n/a	n/a	n/a
Dioxins, TEQ (g/year)	**n/a**	n/a	n/a	n/a
EMISSIONS TO WATER				
Lead, Pb (kg/year)	**0.02**	0.003	0.019	0.000
Mercury, Hg (kg/year)	**0.0004**	0.00002	0.00060	-0.00024
Cadmium, Cd (kg/year)	**-2.61**	0.3	0.1	-3.0
Biochemical oxygen demand, BOD (kg/year)	**85,300**	25	86,026	-64
Dioxins, TEQ (g/year)	**n/a**	n/a	n/a	n/a

n/a - not available as value not estimated by model

Table 4: Detailed Breakdown of Annual Emissions to Air and Water for the Management of 250,000 tonnes per year of Residual Waste by System 2a (Thermal Treatment)

	System 2a - Thermal Treatment of Mixed Solid Waste & Recovery of Energy followed by Recovery of Materials from Ash/Char							
	Total	**Transfer to Facility (75 km)**	**Thermal Treatment Facility**	**Energy Offset**	**Landfill (Residue)**	**Ash Landfill**	**Transfer to Landfill**	**Virgin Material Displacement Credit**
ENERGY CONSUMPTION								
Energy Consumption (GJ/year)	**-2,881,000**	17,072	9,537	-1,478,313	3,668	11,569	10,009	-1,454,538
EMISSIONS TO AIR								
Greenhouse Gases								
Net carbon dioxide equivalent, eCO2 (tonnes/year)	**33,000**	1,187	85,665	-35,617	1,702	242	696	-20,972
Acid Gases								
Nitrogen oxide, NOx (tonnes/year)	**30**	10	189	-134	1	3	6	-45
Sulphur oxide, SOx (tonnes/year)	**-595**	3	29	-504	0	1	2	-126
Hydrochloric acid, HCl (tonnes/year)	**12**	0	15	0	0	0	0	-3
Smog Precursors								
Nitrogen oxide, NOx (tonnes/year)	**30**	10	189	-134	1	3	6	-45
Particular Matter, PM (tonnes/year)	**-69**	1	8	-15	0	0	1	-65
Volatile organic compounds, VOCs (tonnes/year)	**-62**	4	82	-123	0	1	2	-27
Heavy Metals & Dioxins								
Lead, Pb (kg emitted annually)	**8.4**	0	5	0	0	0	0	4
Mercury, Hg	**8.5**	n/a	8.9	-0.4	n/a	n/a	n/a	n/a
Cadmium, Cd	**0.8**	n/a	1.2	-0.5	n/a	n/a	n/a	n/a
Dioxins, TEQ (g/year)	**0.01**	n/a	0.013	-0.001	n/a	n/a	n/a	n/a
EMISSIONS TO WATER								
Lead, Pb (kg/year)	**-0.01**	0.001	0.000	0.000	0.001	0.001	0.000	-0.015
Mercury, Hg (kg/year)	**-0.005**	0.000	0.000	-0.003	0.000	0.000	0.000	-0.003
Cadmium, Cd (kg/year)	**-35**	0.1	0.1	-32.6	0.0	0.0	0.0	-2.8
Biochemical oxygen demand, BOD (kg/year)	**1,800**	6	2	-695	2,571	2	4	-99
Dioxins, TEQ (g/year)	**n/a**	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a - not available as value not estimated by model