

Environmental Life Cycle Assessment of Solid Waste Management:

EVALUATION OF
TWO WASTE DISPOSAL SCENARIOS
FOR THE METRO VANCOUVER REGION



Final Report (Revised)

Prepared for:
Regional Utility Planning Division
Policy and Planning Department
Metro Vancouver
Project Contact: Susana Harder

Prepared by:
The Sheltair Group
Vancouver, B.C.
Project Contact: Ron Macdonald

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Confidentiality Notice:

Data, information, and knowledge have been provided by Metro Vancouver staff and others involved in the solid waste management system in the Metro Vancouver region for this report. The results shown here could not have been derived without this assistance. This information was provided through a combination of official documentation, informal data compilations, and telephone interviews and conversations. The report author believes that no proprietary or confidential information is disclosed within this report.

Disclaimer:

The information compiled for this report has been prepared for the purpose of estimating selected environmental attributes for defined waste management scenarios for the Metro Vancouver region. The analysis is performed using the framework of Life Cycle Assessment.

Readers of this report should ensure that they are aware of the assumptions made in the analysis and any limitations so created. The author assumes no responsibility or liability for any action or activity that is based upon information in this report - whether or not the reader has interpreted the information correctly.

The report includes estimated depictions of the inputs and outputs of the system components based on a combination of literature review and data from operating solid waste facilities both within the region and elsewhere. These characteristics are representative and generic for the types of activities modeled but may represent the impact or emissions of any future activity or facility. Readers are specifically cautioned that this work does not constitute any form of a pre-design, design, or facility specification document, and does not define emissions or environmental impact specifications of any specific facility. It is not suitable for tendering or procurement, for facility permitting, regulatory approval submissions, or for cost estimation or future forecasting.

Note of Revisions: Aug 2008

A revised version of this report was issued in Aug 2008 to correct a calculation error. The revisions affect the calculation of NO_x, PM₁₀, and CO emissions from the flaring of landfill gas in the landfill scenario. Specifically, sections 5.6.1, 5.6.3, and 5.6.4 have been revised. No change to the analysis methodology or assumptions have been made.

Summary

Introduction

This study uses Life Cycle Assessment (LCA) to evaluate the energy & resources consumed and the emissions produced for two hypothetical solid waste disposal scenarios for the Metro Vancouver region^[1]. These scenarios are: (i) a Landfill scenario using an out-of-region landfill, and (ii) a waste to energy scenario using a gasification (WTE) facility located in the region. In this study, solid waste refers to the current municipal solid waste (MSW) that goes to disposal after the existing recycling and other diversion programs.

LCA Overview

Life Cycle Assessment is a methodology for identifying and evaluating potential environmental impacts associated with the entire life cycle of materials and services. To avoid confusion with other analysis terminology it is in this context sometimes called Environmental LCA. The objective of an LCA is to document the ‘environmental burdens’ that are imposed in the creation of a product or process or in this case - in the execution of the service delivery (waste management). The approach expands the analysis viewpoint from a single point in the product chain (e.g. one facility) to incorporate activities that occur throughout the entire life cycle from the ‘upstream’ resource extraction to the final ‘downstream’ disposal. The focus of LCA is on summing up all the energy and material inputs and outputs, and not on the site-specific impacts of a specified facility.^[2]

Objectives

The goal of this LCA study is to evaluate the life cycle environmental burdens of two solid waste management scenarios. The purpose of this evaluation is to:

- Identify the major material and energy inputs and outputs associated with each scenario;
- Quantify these inputs and outputs at a planning level of accuracy; and
- Create an equivalent basis for comparison of the scenarios.

¹ The Greater Vancouver Regional District (GVRD) has recently been renamed Metro Vancouver. References in this document to “Metro Vancouver” refer to this corporate/governmental entity. References to the “Metro Vancouver region” refer to the geographic area surrounding the city of Vancouver.

² Site specific impacts such as the loss of habitat, impacts to watersheds and streams, or local air quality impacts are not handled well by LCA and are best addressed through the tools of human or ecological risk assessment and environmental impact assessment.

Analysis Approach

The LCA evaluates two possible scenarios of solid waste disposal for the Metro Vancouver region. This includes consideration of transportation, handling, and disposal of residual materials. Each component in the scenarios is modeled on actual or anticipated practice in Metro Vancouver's solid waste management system, or accepted modeling practices for determining emissions (e.g. transport emissions).

The LCA scenarios are evaluated by modeling facilities based on existing practices in the region or after expected practices that would likely be included if new facilities were to be constructed. Real operational data have been used wherever possible and these have been refined to account for expected future conditions (for example more rigorous air emission standards). The result is that this LCA is site specific in many features that are part of the Metro Vancouver solid waste management system.

Components of the study that are not specific to this location (e.g. vehicle manufacture, chemical manufacture) or are known with only a broad level of accuracy (e.g. facility construction costs) are evaluated using an economy-scale economic model linked to environmental databases called 'economic input-output life cycle assessment' (EioLCA).

Functional Unit

The functional unit defined for this study is "disposal of 1 tonne of municipal solid waste as currently disposed of in the region".

Process Components

The process components that make up the scenarios include:

- Current trucking formats, load capacities, and fuel consumption.
- Vehicle emissions (on-road and off-road) based on new emission standards coming into effect between 2007 and 2010. Emissions factors were based on values used by the Metro Vancouver in recent emission evaluations in the region through the US EPA models MOBILE and NON-ROAD.
- Landfill operations based on information from the Cache Creek Landfill (vehicle requirements) and Vancouver Landfill (gas compression energy requirements).
- Landfill gas generation based on the US EPA LandGem LFG model - a first order landfill gas estimator using coefficients suitable for an arid location.
- Landfill gas capture based on estimated reasonable capture over the lifetime of the landfill.
- Landfill gas consumption, power generation, and emissions based on data from the landfill gas cogeneration system operating at the Vancouver Landfill.
- Emissions from flaring landfill gas based on EPA "AP-42" emissions factors.

- WTEF emissions, consumption, and material flows based on the Metro Vancouver WTEF scaled-up to higher levels of material handling and with some factors adjusted to represent expected improved air emission controls that would be included in a new WTEF.
- Emissions from electricity consumption (and avoided emissions from power generation facilities) based on an estimated “BC consumption average” which includes the BC production as well as an estimate of the emissions from net power imports.
- Avoided emissions from the generation of steam and hot water based on the displacement of natural gas combustion.
- Upstream emissions from the production of natural gas and petroleum based on Canadian industry average statistics.

Inventory and Impact

A Life Cycle Inventory (LCI) was compiled using a spreadsheet-based system of data tables, coupled with a summation macro. The inventory is focused on resource consumption and air emissions. Data collection consisted of research, interviews, secondary investigation, site tours, and calculations to define the inventory. Extensive manipulation and interpretation of the data was frequently required. No new field sampling or new operational & environmental data was collected from the facilities.

The inventory compiled a range of information including:

- Energy and material inputs to the systems.
- Energy outputs (steam and electricity).
- Total greenhouse gas emissions of GHGs (as CO₂ equivalents or CO₂e).
- Emissions of commonly monitored air contaminants (NO_x, SO_x, PM₁₀, and CO).

Factors evaluated through the inventory summation include:

- Electricity consumption and production
- Net heat production
- Vehicle Fuel Consumption
- Greenhouse gas emissions (CO₂, CH₄, N₂O)
- Common air contaminants (SO_x, NO_x, CO, PM₁₀)

Results: Major Impact / Emissions Sources

A summary of the life cycle consumption, production, and emissions for the 2 scenarios is shown in Table S-1. With respect to identifying the major contributors to the inventory it was found that:

- the primary sources of consumption and emissions for most emissions categories occur at the site of the disposal facilities (i.e. at the Landfill in the landfill)

scenario or at the WTEF in the WTE scenario). This is true for the inventories items: electricity consumption and production, NO_x, SO_x and PM₁₀ emissions, and GHG emissions.

- transportation and material handling emissions are not a substantial contributor to any of the emissions categories.
- the upfront construction of the WTEF or Landfill, when averaged across the lifetime of waste handling do not have a substantial effect on the total inventory.

Table S-1: Summary of Process Scenarios Evaluated (Base Case)

Item	Units	Landfill Scenario	WTEF Scenario
Resource Consumption / Production			
Net Electricity Production Rate	MW (a)	7.2 (0 to 12)	45
Net Electricity Production	kWh / t _{MSW} (a)	125	527
Heat Production Rate	MW (a, b)	8.9 (0 to 15)	28
Heat Production	GJ / t _{MSW} (a, b)	0.56	1.18
Fuel Consumption	L / t _{MSW}	8.6	3.1
GHG Emissions			
Greenhouse gas emissions (CO ₂ equiv)	kg CO ₂ e / t _{MSW}	369	291
Criteria Air Contaminants			
NO _x	kg NO _x / t _{MSW}	0.17	0.19
SO _x	kg SO _x / t _{MSW}	0.06	0.08
PM ₁₀	kg PM ₁₀ / t _{MSW}	0.01	0.03
CO	kg CO / t _{MSW}	0.58	0.09

Notes:

a) Presentation of energy production (electricity or heat) as power - i.e. MW - is somewhat outside the LCA functional unit of energy per unit of solid waste. The presentation includes energy recovery shown on “per unit time” (Rate basis) and “per unit of waste” (LCA basis). Note that the Landfill scenario produces energy at a lower rate but for a longer time than the WTEF scenario.

b) The heat production is in different forms for the two options. For the Landfill scenario the recovered heat is hot water, while for the WTEF scenario the recovered heat is high pressure steam and some hot water.

c) For the electricity and heat recovery rates, the values shown for the landfill scenario are the lifetime average and the range of values (in brackets).

Uncertainties

LCA analysis includes a number of uncertainties and assumptions. Key assumptions were evaluated using the GHG emissions to evaluate the impact of these unknowns. This showed that:

- the Landfill scenario shows a small sensitivity of GHG emissions to the travel distance and the WTEF scenario shows negligible sensitivity to the travel distance.

- the Landfill scenario net GHG emissions are highly sensitive to the landfill gas capture rate and the assumptions of whether carbon storage occurs in the landfill (base case assumed no carbon storage).
- the WTEF scenario GHG emissions are most sensitive to the GHG intensity of consumed and avoided electricity.

Conclusions about the LCA process used to evaluate these scenarios include:

- The structure is useful for compiling all the similar inputs and outputs. By comparing all activities on a “per tonne of MSW” basis has identified several activities (e.g. hauling) which are not substantial contributors to the total emissions inventory.
- The energy recovery (electricity and heat) result in ‘avoided’ emissions of GHGs and air contaminants that would be generated if these energy sources were not available. The LCA is able to quantify and acknowledge these. Thus the impacts of avoided energy use are incorporated in the net scenario totals emissions.
- The process compares the scenarios on a “per unit of waste” basis and not on an annual basis. Some of the emissions from the landfill scenario occur over many years and in reality would not be immediately observed. The LCA framework of a “per unit of waste” basis was found cumbersome for representing the energy inputs and outputs. For discussion these results were also calculated on a “per unit of time” basis and presented for comparison.

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