Life Cycle Assessment of Municipal Solid Waste Management Methods: Haifa Case Study

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Abstract

Eight solid waste management system scenarios were developed and compared for the Municipal Solid Waste Management System of the city of Haifa, Israel, by using the life cycle assessment (LCA) methodology. The solid waste management methods considered in the scenarios were the household participation of waste separation, the mixed and separate collection of dry recyclable waste and wet biowaste, recycling by material banks (MB) and material recovery facility (MRF), composting, biogasification, incineration, refuse derived fuel (RDF) production, and landfilling. The goal of the study was to determine the most sustainable option of municipal solid waste management system for Haifa. The waste management scenarios were compared using the LCA computer model known as "Integrated Waste Management – IWM-2". The inputs and outputs of each management stage were defined and the inventory analyses calculated by the model were presented as waste flows, quantities of solid waste landfilled, the key emissions to air and water, main contributions to climate change, fuel consumption and recovery, and economic cost. The impacts were then quantified with valuation method to evaluate and compare their importance. Sensitivity analysis has been used to test household source separation rate used in the initial life cycle model. The results showed that household participation of keeping the dry recyclable waste clean is more effective than keeping the wet biowaste clean; and introduction of the combination of MRF recycling and biogasification is the most environmentally and economically feasible option for Haifa.

Keywords: life cycle assessment, recycling, composting, biogasification, incineration, landfilling

Introduction

What is the correct balance between environmental and economic factors of one waste treatment system compared to another? What is the correct mix of waste recycling, composting, and energy recovery options? These are some of the key questions that should be addressed before

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commencement of any waste management operation (Nilsson-Djerf and McDougall, 2000). The application of life cycle assessment (LCA) in the waste management sector has become a useful tool in comparing the environmental and economic cost of alternative waste treatment systems and identifying the most favorable one for system performance improvement.

Israel Ministry of Environmental Protection has prepared a wide range of laws and regulations on solid waste. However, municipal solid waste management is still a continuous challenge in Israel. Since 2003, the Central Bureau of Statistics (CBS) of Israel began conducting survey on the quantities of domestic, commercial and yard waste collected by local authorities. The information collected by the CBS and the Ministry of the Environment has improved the available waste data (CBS, 2006). Haifa is the largest city in Northern Israel and the third-largest city in the country, with a population of about 267,700. According to the latest survey conducted in 2005, the amount of total waste generated in Haifa is 160,736 ton/yr and waste generation rate is 1.65 kg/capita/day (or) 601 kg/capita/yr. The organic materials are the main components of the waste stream, in terms of weight, constituting 38% of Haifa's solid waste, followed by paper 28% (paper 22%, cardboard 6%) and plastic 13% (film 12%, rigid 1%). The rest are glass 5%, textile 3%, diapers 3%, metal 2% (Fe 1%, nonFe 1%), and miscellaneous 8% (Israel Ministry of Environmental Protection, 2006).

LCA has a lot to offer in terms of selection and application of suitable MSW management techniques, technologies, and programs to achieve specific waste management objectives and goals. Thus, several studies in the literature used the LCA as a tool for municipal solid waste management (Sonesson et al., 2000; Arena et al., 2003; Dahlbo et al., 2005; Aye and Widjaya, 2006; Bovea and Powell, 2006; Ozeler et al., 2006; Emery et al., 2007; Lee et al., 2007)

The objective of this study was to use the LCA as a tool to compare different solid waste management system options and determine the most feasible system for Haifa, Israel. To this purpose, eight different scenarios of municipal solid waste management (MSWM) systems that include different municipal solid waste processing and disposal methods were developed and, then, compared with respect to their environmental impacts and costs by using the Integrated Waste Management – IWM-2 Model developed by McDougall et al. (2001).

Methodology

Scope Definition

Eight different scenarios of municipal solid waste management system that include different solid waste processing and disposal methods were developed and compared with respect to their environmental impacts and economic cost. The solid waste management methods considered in the scenarios were the household participation of waste separation, the mixed collection or the separate collection of dry recyclable waste or wet biowaste, recycling by material banks (MB) or material recovery facility (MRF), composting, biogasification, incineration, refuse derived fuel (RDF) production, and landfilling. Environmental impacts were evaluated by considering their waste flows, quantities of solid waste landfilled, key emissions to air and water, contributions to climate change, fuel consumption and recovery, and economics. The results take into account the upstream and downstream emissions and resource consumption associated with energy recovery, avoided use of conventional fertilizers, and the avoidance of virgin materials due to recycling.

The Functional Unit and System Boundaries

The function of the system under study is to manage household solid wastes in the area of study. The functional unit selected for the comparison of the alternative scenarios is the management of 1 tonne of municipal solid waste. The system boundaries selected for the life cycle of solid waste were defined as the moment when material ceases to have value, becoming waste and when waste becomes inert landfill material or is converted to air and/or water emissions or regains some value.

Waste Management Scenarios

There are eight waste management scenarios analyzed in the study. Full description of the scenarios is given in Figure 1.

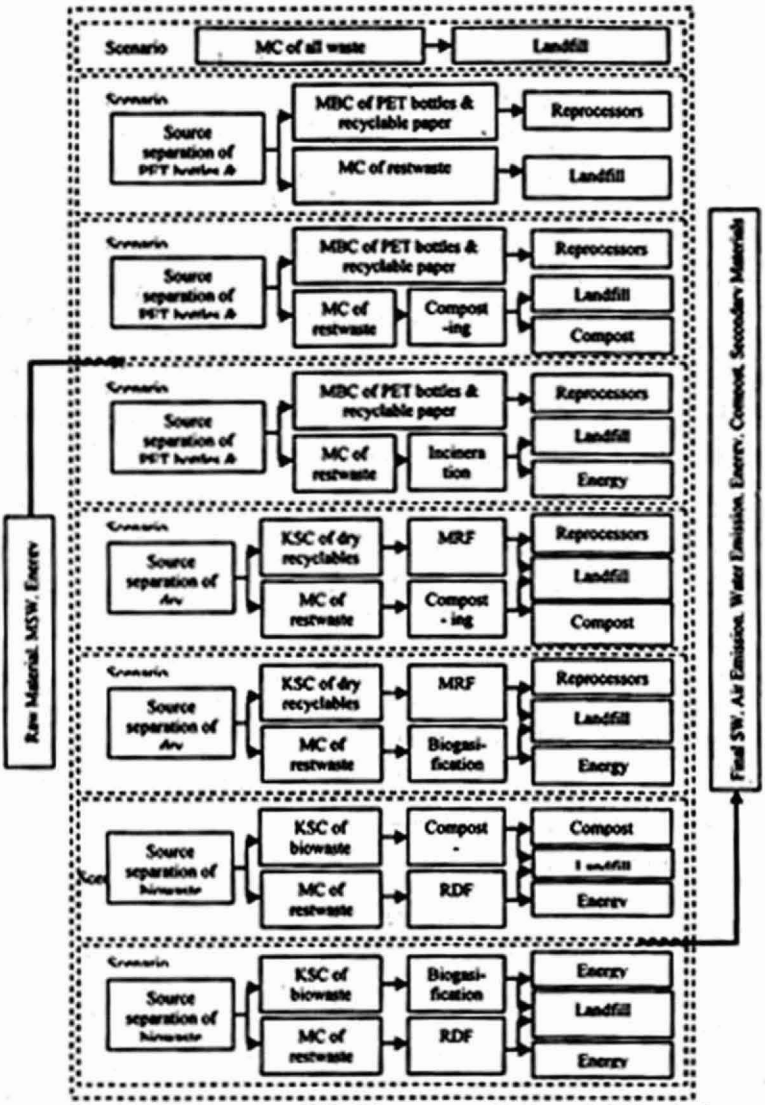

Figure 1. Eight scenarios of MSWM systems used in the study MC- mixed collection, MBC- material bank collection, KSC- kerbside collection, (----) system boundary, (→) inputs and outputs

Life Cycle Inventory

The data collection was mainly based on the projects conducted by Israel Ministry of Environmental Protection and Shaldag Environmental Solutions and Management Ltd. (Israel Ministry of Environmental Protection, 2006), CBS of Israel (CBS, 2006) and the resources available online at the website of Israel Ministry of Environmental Protection, http://www.sviva.gov.il. These data include population, waste generation rate, waste characteristics and composition, waste management application, uses of transfer stations and landfill sites, the cost calculations for the alternatives and operational recommendations for the landfill site.

The Life Cycle Inventory (LCI) constitutes a detailed compilation of all environmental inputs (material and energy) and outputs (air, water and solid emissions) during each stage of the life cycle of the waste. An LCI has been completed for all the activities required to manage the waste from the time it leaves the household to its ultimate disposition: the household participation of waste separation, the mixed collection or the separate collection of recyclable/dry waste or bio/wet waste, the management of the waste in a material bank, transfer station and/or in a material recovery facility, the recycling process of recovered fractions, the composting or biogasification process of the biowaste fraction, the incineration process or resource derived fuel production process, and the management of the waste in the landfill. The savings from energy generation from electricity, compost (avoiding fertilizers) and recycled material (avoiding virgin material) have also been included in the model.

Valuation

The environmental impacts resulted from the model were quantified and converted into monetary units by valuation method. The externalities for global warming potential and air emissions were estimated from the findings of the work of Eshet et al., 2005.

Sensitivity Analysis

Sensitivity analysis has been used to test the assumption used in the initial life cycle model by varying household participation/source separation rate. The effect of changing the percentage of source separation rate of waste from 80% to 60% has been studied.