Renewable Energy 36 (2011) 3031–3036

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Are the aims of increasing the share of green electricity generation and reducing GHG emissions always compatible?

Ali El Hanandeh [a,*], Abbas El Zein [b]

[a] Griffith School of Engineering, Griffith University Nathan QLD 4111, Australia
[b] School of Civil Engineering, University of Sydney NSW 2006, Australia

ARTICLE INFO

Article history:
Received 27 July 2010
Accepted 28 March 2011
Available online 22 April 2011

Keywords:
Energy from waste
Green energy targets
LCA
Greenhouse gas emissions reduction
Climate change

ABSTRACT

Energy from waste (EfW) has been identified as a source of 'green electricity' and has been used as a way of reducing greenhouse gas (GHG) emissions. Nevertheless, selecting an EfW strategy for municipal solid waste management is a challenging task not least because of the uncertainty involved in quantifying the potential economic and environmental impacts. This paper analyses five alternatives for managing the municipal solid waste of Sydney for their 'green electricity' and GHG savings potential under conditions of uncertainty. The impact of paper recycling on the ranking of alternatives was investigated, too. Our analysis shows that maximizing EfW generation potential does not result in greater GHG saving. A combination of food and green waste composting, recycling of metals, paper, glass and plastics while only landfilling waste fractions that are not recyclable may result in the best GHG savings. Furthermore, recycling of paper does not always achieve the best outcome; anaerobic digestion or composting may yield better results from an environmental and energy generation perspective.

1. Introduction

1.1. Background

Life-cycle analysis (LCA) of municipal solid waste management practices is a powerful tool for assessing the overall environmental impact of these practices. However, LCA is a data-extensive exercise. The quality of data will usually have great impact on the credibility of the modeling output [1–3]. Inaccurate data, data gaps and unrepresentative data are sources of uncertainty in LCA [4].

The waste management sector accounts for about 3–5% of the GHG emissions worldwide [5]. Accounting for greenhouse gases (GHG) and other emissions from solid waste management practices has received increasing attention in the last few years [6]. New available technologies, if adopted properly, can contribute significantly to the mitigation of global warming. However, accounting for the global warming potential (GWP) of solid waste management is complicated due to inherent uncertainties in all stages of waste management processes such as transportation, system boundaries, upstream and downstream processes (e.g., [6–11]).

1.2. Waste generation in Sydney

Sydney is the largest metropolitan area in Australia with a total population of 4.1 million and an average population growth rate of 0.82% [12]. Sydneysiders are among the highest generators of solid waste in Australia. Each Sydneysider contributes on average 565 kg of municipal solid waste per year [13]. Table 1 shows the typical composition of waste in Sydney.

The municipal solid waste management sector in Sydney is highly dependent on landfills. However, landfill space is fast diminishing and it is expected that within the next 10 years, the four landfills close to the city will exhaust their capacity leaving the city with one landfill some 250 km away [14]. This, combined with stringent criteria imposed on establishing new landfill sites, targets set for diverting waste away from landfills and increased emphasis on climate change, places pressure on the municipal solid waste system to explore new options. Alternative waste technology (AWT), such as anaerobic digestion (AD), bioreactor landfill, material recovery, composting, has gained popularity in the past few years.

Municipal solid waste contains a large biodegradable fraction and therefore is a good source of 'carbon neutral' energy. Energy from waste (EfW) has been identified as a source of renewable energy under the Renewable Energy Target scheme (RET) in Australia and qualifies for Renewable Energy Certificates (REC) [15].

* Corresponding author. Tel.: +61 2 9351 2134.
E-mail address: a.elhanandeh@griffith.edu.au (A. El Hanandeh).

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doi:10.1016/j.renene.2011.03.034

Table 1
Municipal solid waste composition of Sydney adapted from [13].

Waste stream	Percentage (%wt)
Food waste	35
Green waste	17
Paper	13
Glass	10
Plastics	7
Ferrous metals	2.5
Aluminum	0.2
Wood	1
Others	14.3

1.3. Renewable Energy Target scheme (RET)

Australia derives most of its electricity from coal-fired power stations. These power stations contribute significantly to Australian greenhouse gas emissions. According to the International Energy Agency, 0.89 kg CO_2-equivellant is released per kWhe produced in Australia [16]. In 2009, the Australian government implemented the Renewable Energy Target scheme (RET) which is an extension of the Mandatory Renewable Energy Target (MRET). The RET aims at reducing Australia's dependence on fossil fuel for electricity generation by increasing the share of electricity generation from renewable and green sources to 20% by the year 2020. The scheme employs a mechanism for issuing Renewable Energy Certificates (REC) to generators of 'green electricity'. Starting in 2011, the RET will be restructured under two main categories: the Small-scale Renewable Energy Scheme (SRES) and the Large-scale Renewable Energy Target (LRET). A wide range of renewable sources has been identified under the scheme including solar, wind and energy from waste [15].

The purpose of this paper is to establish whether the focus on increasing the share of green electricity generation as a strategy for reducing GHG emissions will always be optimal. Clearly, competition for organic resources between waste management options affects the EfW output. In particular, the impact of improved resource recovery rate on the effectiveness of EfW as a greenhouse reduction measure will be assessed. LCA of five different alternatives of EfW are compared for GHG savings potential taking into account the inherent uncertainties in the municipal solid waste system. The case of Sydney is used in this study but the results may be applicable to other countries with similar waste composition.

2. Methodology

2.1. LCA scope

The functional unit for our study is 1 Mg (Mg) of municipal solid waste collected and delivered to the waste management facility (ies). GHG emissions that occur as a result of collection, transportation, handling of waste at transfer station and waste management facility, disposal and electricity generation are accounted for. GHG and electricity used in the manufacturing of collection and transportation vehicles, construction of the waste management and disposal facilities are not included in the inventory as they are usually insignificant [17]. Electricity presented is the net electricity generation after taking into account any electricity used onsite. In this study we assume that electricity generated displace electricity from the main grid.

2.2. Modeling

The SIWMS decision support tool is used to simulate the emissions from 5 alternatives for managing the municipal solid waste. SIWMS is an Excel© based program which employs life-cycle approach. It allows the modeler to incorporate uncertainty, through the implementation of Monte Carlo simulations, in almost all waste management parameters and is capable of running up to 5 scenarios simultaneously [11].

Table 2
Waste management alternatives.

Waste fraction	Alternative				
	S0	S1	S2	S3	S4
Food waste	LDF	AD	AD	COMP	COMP
Green waste	COMP	AD	AD	COMP	COMP
Paper	RE	AD	RE	COMP	RE
Metals	RE	RE	RE	RE	RE
Glass	RE	RE	RE	RE	RE
Plastic	RE	RE	RE	RE	RE
Other	LDF	LDF	LDF	LDF	LDF

LDF: Landfill with landfill gas collection and electricity generation. COMP: windrow composting. RE: recycling. AD: anaerobic digestion.

2.3. Waste management alternatives

Five waste management alternatives, described in Table 2, are designed keeping in mind the following three key objectives:

(a) increase green electricity generation;
(b) reduce greenhouse gas emissions from waste management activities;
(c) reduce landfilled waste.

Table 3
Parameter ranges used in the simulation.

Parameter	Unit	Range	Source
Population growth rate	%	0.7–1.0	[12]
Waste generation growth rate	%	(-0.3) – 0.5	[18]*
Collection route length	km	120–150	Estimated
Recyclables collection route length	km	150–180	Estimated
Distance from MRF to LDF	km	10–20	Estimated
Paper recycling recovery rate	%	40–60	[19, 20]
Plastic recovery rate	%	30–50	19, 20]
Ferrous metal recovery rate	%	70–90	[19, 20]
Aluminum recovery rate	%	85–95	[19, 20]
Glass recycling recovery rate	%	35–54	[19, 20]
Recycled material in paper stream	%	10–20	Estimated
Recycled material in glass	%	5–10	Estimated
Recycled material in Aluminum	%	10–25	Estimated
Recycled material in ferrous metal	%	10–25	Estimated
Recycled material in plastic	%	10–20	Estimated
Tree sequestration credit	kg CO_2	(−1308) to (−2900)	[2]
MRF electricity consumption	kWh/Mg	25–35	[20]
Collection truck fuel consumption	l/km	0.7–0.9	[9]
Composting facility fuel consumption	l/Mg	0.05–0.08	[21]
Compost residue	%	5.0–9.0	[2]
CH_4 emissions from composting	kg/Mg	0.05–0.295	[21]
NO_x emissions from composting	kg/Mg	0.027–0.266	[21]
Compost yield	kg/Mg	400–600	[22]
Food waste moisture content	%	65–75	[23]
Green waste moisture content	%	40–60	[23]
Paper waste moisture content	%	4–30	[23]
Methane generation rate constant (k)	yr^{-1}	0.04–0.058	[24]
LFG collection efficiency	%	50–75	[24]
LFG methane content	%	40–60	[25]
Methane oxidation rate	%	5–10	Estimated
LFG heat content	GJ/Mg	49–55	[26,27]
Electricity generation efficiency from biogas	%	20–30	[28]

*Estimated from the historical data in the report.