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Analysing efficiency of Waste to Energy Systems: Using Data Envelopment Analysis in Municipal Solid Waste Management

P. Albores*, K. Petridis, P.K. Dey

Aston Business School, Birmingham, UK

Abstract

In our day-to-day living, a simple underlying principle is to consume resources in one form or another. This consumption generates waste, which needs to be dealt with in a responsible, efficient and effective manner. Waste is mostly collected and disposed by municipalities. This presents a challenge for these municipalities in dealing with ever increasing amounts of waste to be managed. This is particularly critical in cities, where the demand for these services is increasing. Management of municipal solid waste (MSW) continues to be one of the top priorities for human communities in the 21st century. The model of integrated solid waste management, reduction of waste right at the source points before it enters the chain of waste stream, reuse of generated wastes for recovery by recycling, and disposal through environmentally sound combustion facilities and landfills that meet policy standards are being used by communities as they evolve. Solid waste management is known to be an important contributor to various environmental problems, for example climate change (e.g. greenhouse gas emissions from landfills), disturbing multiple ecosystems (e.g. heavy metal emissions into air, soil and surface water), and improper use of resources leading to depletion (e.g. inexistent or inefficient recycling processing methods for a few particular key minerals or metals) among others. The formidable rise in solid waste generation require suitable management systems, which methodically handle these environmental issues and eventually contribute to move towards a more environmentally sustainable society. This paper presents a method based on Data Envelopment Analysis to analyse the efficiency of Waste to Energy systems, looking not only at maximising the positive outputs (e.g. Energy), but also minimising the negative ones (e.g. emissions). The results provide a benchmark for municipalities to aim in the operation of their Municipal Solid Waste Management (MSWM).

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Keywords: Waste to Energy; Data Envelopement Analysis; Municipal Solid Waste.

* Corresponding author.
E-mail address: p.albores@aston.ac.uk

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1. Introduction

It is estimated that the annual worldwide solid waste generation will be increased to 27 billion tons in 2050 from 13 billion tons in the year 1990 (Beede and Bloom, 1995). In 2009, the annual total solid waste generation was approximately 17 billion tons (Chattopadhyay et al., 2009), of which about 1.3 billion tonnes are from cities, and are estimated to generate up to 2.2 billion tonnes by 2025 predominantly due to rise in the population, amassed urbanization and socio-economic development in low income (as well as in middle income as well) countries (Hoornweg & Bhada-Tata, 2012). Global generation of MSW in 1997 was 0.49 billion tons. While, estimated to have a 3.2–4.5% and 2–3% annual growth rate in developed nations, developing nations respectively (Suocheng et al., 2001).

Usually MSW physical composition has organic material, paper, plastic, glass, metals, and other refuse collected by local authorities, principally from homes, offices, institutions, and commercial institutions. Typically MSW doesn't envelop waste collected outside of proper municipal programs, rural wastes, sewage, industrial waste, or construction waste generated through cities. MSW is measured before disposal, and statistical data corresponding to it often include collected material that is sorted for recycling in the later stages of processing. MSW tends to be generated in large quantities from economically rich parts of the world.

The Organization for Economic Co-operation and Development (OECD), a group of 34 industrialized nations as its members, are leaders in MSW generation, producing about 1.6 million tons per day, while, sub-Saharan Africa produces less than one eighth as much (~200,000 tons per day). We intend to work with one of the four developing nations viz a viz (Mexico, India, China and Brazil) which are also listed in the top 10 MSW-generating countries, although size of their urban populations is a major factor in part their urban residents are progressing while adopting to high-consumption lifestyles. The current annual Municipal Solid Waste (MSW) generation is estimated to 1.9 billion tonnes while almost 30% of it is being predicted to be remained uncollected. As for the collected MSW, 70% is taken to landfills and dumpsites, 19% is reused or recycled and the rest (a mere 11%) is being turned over to energy recovery facilities. Although the United States leads the world in MSW output at 621,000 tons per day, China is a relatively close second, at 521,000 tons. Due to this and the fact that it is a developing nation, China is the prime focus in this paper.

1.1 Research Gap

Being a rapidly developing country with a large population, which increased from 963 million in 1978 to 1361 million in 2013, of which urban communities increased from 17.4 to 53.7% (National Bureau of Statistics of China, 2013), a severe need for improvements in both the standards of living and the surrounding ecosystems pose multiple environmental challenges in China. MSW management is one of the major problems that affect China's environmental quality and the sustainable development of its cities. In a short span of 15 years (1996-2011) MSW generated in China has grown from 108.25 million tons to 163.95 million tons (National Bureau of Statistics of China, 2012) Severe environmental issues have aroused due to improper and inefficient disposal of MSW (Tai et al., 2011).

The traditional methods, like landfill, are facing a crisis of shortage in land (Dong et al., 2003). At the same time, waste to energy (WTE) methods such as incineration and gasification are the two primary WTE technologies that have been used successfully throughout the world (Liu and Liu, 2005). It is estimated that about 181 million tonnes of MSW are combusted annually in over 600 WTE facilities worldwide, while 2.9% of MSW treated was incinerated in 2001, this fraction increased to 13.2% in 2006(Cheng and Hu, 2010) producing electricity and steam for district heating and recovered metals for recycling (Themelis, 2003). WTE incineration has been accepted as a more preferred solid waste management option, complementing composting and landfilling (American Society of Mechanical Engineers, 2008, and United Nations Environment Programme, 1996). Incineration of MSW in WTE facilities prevents the possible aqueous and gaseous pollution associated with landfilling and provides a source of