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A multi-criteria analysis of options for energy recovery from municipal solid waste in India and the UK

H.Y. Yap, J.D. Nixon *

Faculty of Science, Engineering and Computing, Kingston University, Roehampton Vale Campus, London SW15 3DW, UK

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ABSTRACT

Energy recovery from municipal solid waste plays a key role in sustainable waste management and energy security. However, there are numerous technologies that vary in suitability for different economic and social climates. This study sets out to develop and apply a multi-criteria decision making methodology that can be used to evaluate the trade-offs between the benefits, opportunities, costs and risks of alternative energy from waste technologies in both developed and developing countries. The technologies considered are mass burn incineration, refuse derived fuel incineration, gasification, anaerobic digestion and landfill gas recovery. By incorporating qualitative and quantitative assessments, a preference ranking of the alternative technologies is produced. The effect of variations in decision criteria weightings are analysed in a sensitivity analysis. The methodology is applied principally to compare and assess energy recovery from waste options in the UK and India. These two countries have been selected as they could both benefit from further development of their waste-to-energy strategies, but have different technical and socio-economic challenges to consider. It is concluded that gasification is the preferred technology for the UK, whereas anaerobic digestion is the preferred technology for India. We believe that the presented methodology will be of particular value for waste-to-energy decision-makers in both developed and developing countries.

1. Introduction

Energy recovery from waste or Waste-to-Energy (WtE) has become an attractive option for many countries as an effective waste management solution. WtE technologies can provide valuable energy, reduce the burden on the land required for landfill disposal and mitigate greenhouse gas emissions. As a result – and despite a recent economic crisis – the global market for WtE technologies has experienced substantial growth (World Energy Council, 2013a) and there are now over 1200 operating plants across 40 countries (Ghosh, 2014).

WtE technologies include any waste treatment system that creates energy in the form of electricity, heat or transport fuels from a waste feedstock. These technologies can process many types of waste (e.g. sewage, medical waste, industrial gases etc.), but the most common application is for processing municipal solid waste (MSW). In 2012, the annual global generation of MSW was estimated to be 1.3 billion tonnes, and it is expected to rise to 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata, 2012).

Whilst there is a great potential for generating energy from waste, there are many challenges ahead for the WtE industry and many of the barriers for further development are unique to each country. Policy uncertainties, economic challenges and competition with non-renewable energy sources are some of the key concerns facing the WtE industry (IEA, 2013). The varying composition of waste that changes radically from low-income to high-income countries is also a major issue for deciding on the suitability of different technology types. This is particularly relevant to countries such as India and UK, as they have been identified as countries that require improvements to their waste management strategies (Jamasb and Nepal, 2010; Unnikrishnan and Singh, 2010), but have very different MSW characteristics and socio-economic challenges to overcome.

The Asia-Pacific region has been predicted to be the fastest growing market for WtE with major expansions expected in countries such as India (World Energy Council, 2013a). Urban MSW generation in India is approximately 40 million tonnes per annum (Hoornweg and Bhada-Tata, 2012) and is expected to rise at an annual rate of 1.33% (EAI, 2013). Most of the collected MSW in India is disposed of through unsanitary landfills or uncontrolled dumping in city outskirts (Singh et al., 2011). The Indian Ministry of New and Renewable Energy predicted a 1500 MW power

* Corresponding author.
E-mail address: j.nixon@kingston.ac.uk (J.D. Nixon).

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generation potential from MSW, but only 2% of the WtE potential has been realised (EAI, 2013). Previous attempts on recovering materials and energy from MSW in India have encountered numerous setbacks. One reason which has been attributed to the unsuccessful deployment of WtE in India is that local conditions have not been taken into account (Aswani, 2012). MSW in India is typically high in organic content at round 50% (EAI, 2013). In comparison, MSW in the UK has an average composition of approximately 50% recyclables, 34% biodegradable waste (food, garden and other organic wastes) and 16% other miscellaneous wastes (Defra, 2009) (see Fig. 1a and b).

The UK has predominantly relied on landfills for managing waste in the past. However, this has changed in recent years with waste being diverted from landfills due to stringent legislations and policies such as the EU Landfill Directive (1999/31/EC) (Defra, 2014a). The percentage of waste treated in England through WtE systems is forecasted to rise to 20% by 2020 (IEA Bioenergy, 2012). Another driver for WtE facilities in the UK is that they can contribute towards a renewable energy target of having 15% of the total UK energy generation portfolio being provided by renewable sources. In the past few years, a combination of different market mechanisms and incentives has been introduced by the UK government to promote more WtE activities. However, the UK still faces some major obstacles to the growth of WtE such as public opposition, policy inconsistencies, planning restrictions and financing issues.

Strategic decision making for WtE technology selection is highly complex, especially given the growing number of emerging technological alternatives. Operations research techniques such as Multi-Criteria Decision Making (MCDM) tools are established methods to aid decision makers compare and evaluate technologies. These tools have been widely used throughout the energy industry (Zhou et al., 2006 and Løken, 2007) and are growing in popularity within the field of waste management (Aravossis et al., 2001; Hsu et al., 2008; De Feo and De Gisi, 2010). Studies specific to the application of such tools in MSW management mainly focus on site and treatment strategy selection (Soltani et al., 2015). However, many inappropriate technology selection choices are still being made by key WtE decision makers and research has identified the need for a wider uptake of MCDM methods to address this problem (Nixon et al., 2013a). Whilst the environmental impacts of different WtE technologies have been compared using life cycle assessment tools (Arena et al., 2015 and Evangelisti et al., 2015), there is also a requirement for an MCDM tool that can enable all the trade-offs between the advantages and disadvantages of different technology types operating in varying locations to be assessed. Addressing this gap will facilitate and enhance the global deployment of WtE technologies.

This paper aims to examine and compare WtE technologies used for energy recovery from MSW in developed and developing countries. A specific objective of the study is to outline and demonstrate an MCDM model for evaluating WtE technologies based on countries' unique socio-economic and technological environments. To achieve this, decision making criteria will be determined for the assessment of WtE technologies, and the model will be applied principally to case studies for India and the UK. An outcome from the study will be a methodological approach that can be applied to other countries by researchers and decision makers.

The next section outlines the methodology developed to achieve the aim and objectives of this study. Section 3 explains the decision making model used for analysing WtE technologies. Section 4 follows on with a detailed review of WtE technology alternatives in India and the UK. The output of the review is fed into the model as described in Section 5 and a sensitivity analysis is performed to examine the impact of different opinions on the results of the evaluation. Finally, Section 6 discusses the findings and a conclusion is provided in Section 7.

2. Methodology

The decision making model is initially developed by reviewing MCDM methods and their applications for waste management and energy planning. This enables the most widely used MCDM methods to be identified and determines areas within existing models requiring improvement for the desired application. A review of WtE technologies is performed to gather data and determine suitable evaluation criteria for both India and the UK. The criteria considered encompass a range of financial, technological, environmental and economic factors, and are comparable to those used in similar technology evaluation studies (Hokkanen and Salminen, 1997; Aravossis et al., 2001; Nixon et al., 2013b; Stein, 2013; Ahmad and Tahar, 2014).

To develop credible decision preferences (i.e. provide importance weightings for the selected evaluation criteria), six academic experts – three from India and three from the UK – who specialise in WtE have been engaged and their opinions gathered using surveys. The data collected from the technical review and experts is then fed into an MCDM model to evaluate and compare WtE technologies for India and the UK. The MCDM analysis is performed in SuperDecisions® which is a well-established software package for carrying out MCDM studies based on mathematical decision making theories, and it has been applied by a number of researchers in other studies (Atmaca and Basar, 2012; Banar et al., 2007). The overall outcome from the MCDM model is a preference ranking for each technological alternative. To take into account the potential variations in experts' opinions and gathered data, a sensitivity analysis is conducted. Based on the MCDM results, recommendations for the development of WtE in India and the UK are made.

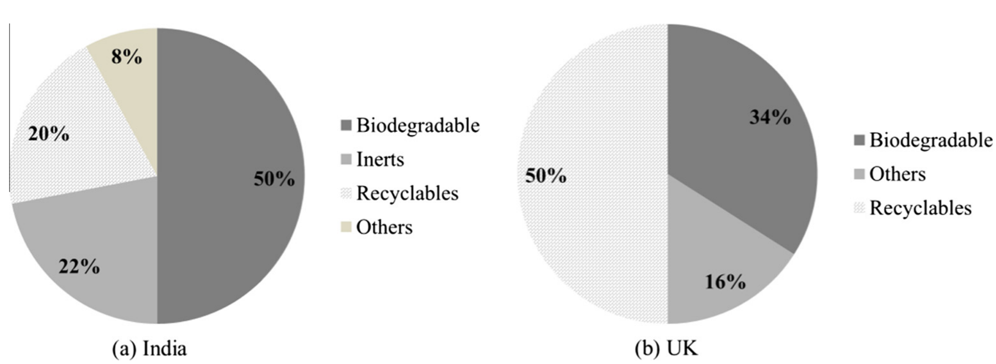

Fig. 1. (a and b) Comparison of average MSW compositions in (a) India and (b) UK (Defra, 2009; EAI, 2013).

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