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The environmental and financial benefits of recovering plastics from residual municipal waste before energy recovery

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ABSTRACT

A life cycle assessment was carried out to investigate the environmental benefits of removing dense plastics from household waste before burning the waste in an energy from waste (EfW) facility. Such a process was found to improve the climate change impacts of the waste management system by 75% and the non-renewable resource depletion impacts by 18%. A preliminary financial assessment suggests that the value of the plastics recovered in this way would be less than the reduction in electricity income for the EfW leading to a loss of £2-5 million per year. However, if the plastics were separated by householders for a kerbside recycling scheme, the higher price commanded by the higher-quality reclaimed plastics and lower processing costs means that overall the operation would be financially viable giving a net present value of £768 000 at a 5% rate of return. In both cases, there is a further financial benefit to the EfW operator resulting from the additional gate fees for processing waste to replace the plastics removed. Further work is required to assess the costs and effectiveness of using both kerbside collections and mechanical recovery to reduce the plastics content and carbon intensity of EfW feeds.

1. Introduction

The relative environmental advantages of managing residual municipal waste in energy from waste (EfW), landfill or mechanical biological treatment processes have been debated for many years. Life cycle assessment (LCA) is one of the techniques used to inform the discussion. LCA is an environmental management technique that allows the determination of the environmental impacts and benefits of providing and using goods and services. LCA studies are based on the compilation of inventories of the materials and resources consumed and environmental emissions released during an activity. The results of the inventories are then aggregated using equivalence factors into standard categories such as climate change, acidification and human toxicity. Many computer-based tools are available to perform LCA studies and there is an international standard for carrying out and reporting LCAs (BS EN ISO 14040, 2006).

Several LCA tools have been developed aimed specifically at waste management processes; the principal ones being EASETECH, Waste and Resources Assessment Tool for the Environment (WRATE), and the USEPA's Decision Support Tool (DST). There is an extensive literature on the subject of waste management LCAs (for example Villanueva and Wenzel, 2007; Bates, 2009; Christensen et al., 2009; Finnveden et al., 2009; Michaud et al., 2010; Schott et al., 2016), and the predominant views are that materials recycling is generally environmentally beneficial and that a well-operated EfW has distinct environmental advantages over landfill. The benefit of EfW over landfill from the climate change perspective is particularly strong when the EfW is displacing power and/or heat produced from a carbon-intensive source such as coal or gas. In recent years, improvements in thermal efficiency of EfW and improved aluminium and steel recovery rates from the EfW bottom ash have increased the environmental advantages of EfW compared with landfill. However, international commitments to reduce greenhouse gas emissions are reducing the carbon intensity of electricity generation – this in turn is reducing the environmental advantages of EfW (Burnley et al., 2015).

LCAs of waste management systems do not provide definitive results, not least because the results are very dependent on some of the assumptions made. The main areas of sensitivity being; the fossil fuel(s) displaced by any energy from waste processes, the efficiency of the EfW, the scope for combined heat and power operation, the global warming potential assigned to methane and whether credit should be given for the long-term sequestration of biological carbon in landfills.

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The advantages and disadvantages of burning waste plastics in an EfW are less well-documented. In favour of this practice, contaminated and mixed plastics can only be recycled in very low-grade applications and in July 2017 China announced it was going to ban the import of certain lower grades of waste plastics collected for recycling. The landfilling of plastic is not sustainable when inter-generational equity and the use of finite resources (oil) are considered. The arguments against burning plastics in an EfW note that plastics contain high levels of fossil carbon so cannot be classed as a "renewable fuel". In addition, burning chlorinated plastics requires more scrubbing reagent to reduce acidification impacts with a corresponding increase in solid waste.

This research adopts an LCA approach using WRATE to investigate the impact of reducing the fossil carbon content of EfW feedstock by removing some plastics from the waste. However, there is a trade-off; the financial viability of EfW depends partly on the income from power sales and plastics are an energy rich fuel, whose removal would significantly reduce the saleable energy. A preliminary estimate is made as to whether the reduction in energy income could be offset by income from the sales of reclaimed plastics.

2. Materials and methods

2.1. Description of scenarios

This assessment is based on the management of 100 000 tonnes of municipal waste through a system of kerbside collection of dry recyclable materials (glass, paper and metals), kerbside collection of kitchen and garden waste for composting and combustion of the residual waste in an electricity-only EfW with an overall net efficiency of 25% (defined as the useful power exported to the electricity grid divided by the heat content of the feedstock). The electricity produced is assumed to displace power generated from natural gas using a combined cycle gas turbine (CCGT). A small quantity of electrical/electronic material is assumed to be reprocessed or recycled in an environmentally-neutral manner. In the baseline scenario (illustrated in Fig. 1a), the recyclable and organic fractions are separated by householders for collection and all the residual waste is treated by combustion in the EfW. In the plastics recovery scenario (Fig. 1b), this residual waste is first processed in a mechanical separation plant where 60% of the dense plastics are removed by near infra-red (NIR) separation and sent for recycling into low-grade applications with the remainder going to the EfW.

The EfW modelled with WRATE is typical of UK facilities, consisting of a mass burn grate furnace and a boiler raising steam for power generation with an overall thermal efficiency of 25% (based on the lower heating value or net calorific value). Atmospheric pollution abatement is by selective non-catalytic reduction (SNCR) for NO_x control and semi-dry lime scrubbing followed by bag filtration. Ferrous and non-ferrous metals are reclaimed from the bottom ash and the ash is used as an aggregate substitute. The gas cleaning residues are landfilled in a hazardous waste site.

In both scenarios, the compostable and recyclable wastes are transported directly to the composting facility and materials recovery facility (MRF). Onward transport of compost and recyclate are not taken into account because these impacts would be the same in both cases and would also not be significant. In the baseline scenario, the residual waste passes through a transfer station en-route to the EfW which is assumed to be 30 km from the transfer station. In the plastics recovery scenario, the transfer station is replaced by the plastics separation process. The two scenarios are illustrated in Fig. 1.

2.2. Performance of plastic separation processes

The automated separation of plastics from waste is mainly carried out in materials recovery facilities (MRFs) as part of the process of recovering plastics from mixed recyclable waste. The more technically-challenging process of segregating plastics from mixed waste is far less common. In both cases, published data on the performance and resource consumption of plastics separation operations are relatively sparse, but the following sources were identified.

WRATE includes a unit operation based on an MRF that is processing source-segregated recyclables in a semi-mechanised MRF using IR sorting for plastics separation. When developing the WRATE model, plant operators provided data for their process, including the energy consumption for the whole facility of 45 kWh per tonne. However, WRATE's peer-reviewers suggested that 10–20 kWh t^{-1} was typical of this type of plant and a value of 15 kWh per tonne was used in the WRATE models. This is comparable with the values reported in the following paragraphs. Discussions with experts indicated that the recovery rates for all materials were in the range 90–95% and a default value of 91.4% was selected for the WRATE model.

Foster (2008) reported trials using source-segregated mixed waste plastic packaging (excluding bottles) from UK household

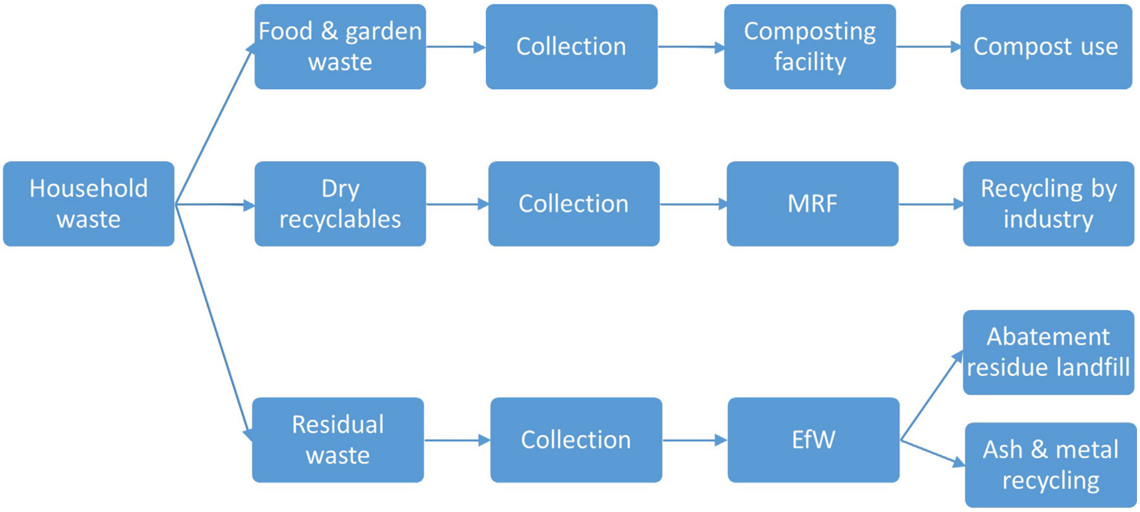

Fig. 1a. LCA baseline scenario.