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Environmental performance of household waste management in Europe - An example of 7 countries

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ABSTRACT

An attributional life cycle assessment (LCA) of the management of 1 ton of household waste was conducted in accordance with ISO 14044:2006 and the ILCD Handbook for seven European countries, namely Germany, Denmark, France, UK, Italy, Poland and Greece, representing different household waste compositions, waste management practices, technologies, and energy systems. National data were collected from a range of sources regarding household waste composition, household sorting efficiency, collection, waste treatments, recycling, electricity and heat composition, and technological efficiencies. The objective was to quantify the environmental performance in the different countries, in order to analyze the sources of the main environmental impacts and national differences which affect the results. In most of the seven countries, household waste management provides environmental benefits when considering the benefits of recycling of materials and recovering and utilization of energy. Environmental benefits come from paper recycling and, to a lesser extent, the recycling of metals and glass. Waste-to-energy plants can lead to an environmental load (as in France) or a saving (Germany and Denmark), depending mainly on the composition of the energy being substituted. Sensitivity analysis and a data quality assessment identified a range of critical parameters, suggesting from where better data should be obtained. The study concluded that household waste management is environmentally the best in European countries with a minimum reliance on landfilling, also induced by the implementation of the Waste Hierarchy, though environmental performance does not correlate clearly with the rate of material recycling. From an environmental point of view, this calls for a change in the waste management paradigm, with less focus on where the waste is routed and more of a focus on the quality and utilization of recovered materials and energy.

1. Introduction

The European Union (EU), through its 28 member states and a total population of about 500 million inhabitants (Eurostat, 2016a), generates more than 200 million tons of household waste every year (Eurostat, 2016b). The Waste Hierarchy (European Commission, 2008) guides the management of household waste in the EU, i.e. prevention is the first option, followed by reuse, recycling, and recovery, and—in case the former options are not possible—disposal, which is primarily into landfills. Statistical information about household waste management is not available at the EU level, but data provided by Eurostat (2016c) on municipal solid waste (MSW) management suggest a good deal of variety in how waste is managed, ranging from systems with high recycling and recovery rates (e.g. in Germany) to systems primarily landfilling the waste (e.g. in Greece). Due to the fact that there is a large variance in how member countries define and report MSW arising (Christensen, 2011), we decided to compare household waste where we could ensure a consistent definition of the waste. We define household waste as "the ordinary waste generated in the household or actually in the house from everyday activity" (Christensen et al., 2011). Several studies covering different geographical areas (primarily regions and cities) in the EU, using life cycle assessment (LCA) methods (Arena et al., 2003; Damgaard et al., 2010; Eriksson et al., 2005; Grosso et al., 2012; Montejo et al., 2013; Rigamonti et al., 2009; Turconi et al., 2011), seem to suggest that reducing landfilling in favor of material recycling

Abbreviations: AD, Anaerobic digestion; LCA, Life cycle assessment; LCI, Life cycle inventory; MBT, Mechanical biological treatment; MRF, Material recovery facility; MSW, Municipal solid waste; NSR, Normalized sensitivity ratio; PE, Person-equivalent; RDF, Refuse derived fuel; SM, Supplementary Material; SR, Sensitivity ratio; WtE, Waste-to-energy.

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and energy recovery is environmentally beneficial, but between recycling and recovery there is not the same consensus for all material fractions. Moreover, it is often highlighted that the choice of LCA methodology and data strongly affects the results (Kulczycka et al., 2015; Laurent et al., 2014a; Merrild et al., 2008).

Almost no studies have been found comparing the environmental performance of national household waste management across Europe. The closest are two studies on municipal solid waste, only addressing greenhouse gas accounting for selected European countries (Gentil et al., 2009; Smith et al., 2001) and a pilot LCA for 9 countries in central and Eastern Europe (Koneczny et al., 2007; Koneczny and Pennington, 2007). In view of the high political focus on the management of household waste in the EU, the abandoning of landfilling (European Commission, 2015, 1999), and the introduction of high material recycling targets for household waste to be met by 2020 (50%) (European Commission, 2008) and 2035 (65%) (European Commission, 2015), we find that a comprehensive study on the environmental performance of European household waste management would be a valuable quantitative contribution to political discussions on the development of European waste management with respect to regulatory as well as technological issues. This paper is our contribution to the quantitative technical-environmental discussion about household waste management in Europe.

The objective of this paper is to quantify, through the LCA methodology, the environmental impacts of household waste management in seven countries within the EU, in order to analyze the sources of the main environmental impacts and national differences, which affect the results. In addition, we wish to compare, for each country, quantified environmental impacts with statistics about how the country meets the Waste Hierarchy. A very detailed data collection process was performed, as reported in Supplementary Material. The LCA approach was chosen because it allows us to perform quantifications without having specific data on each process and plant handling actual waste in the different countries, while it still allows us to pay attention to differences in waste composition, the type of technology used, and how the recycled and recovered materials and energy are utilized on a national scale.

2. Methods and data

This study was conducted according to the requirements of ISO 14044 (ISO, 2006) and the ILCD Handbook (EC-JRC, 2010), as described in the following paragraphs. Details and references to all sources are provided in Supplementary Material (SM). We included seven countries in the study, in order to represent variations in waste composition, levels of recycling, treatment technologies, and energy systems. The countries were Germany, Denmark, France, UK, Italy, Poland, and Greece. The choice of these countries was a compromise between the intent to cover different geographical areas of Europe and the data available to the authors.

2.1. The LCA approach

This study, in LCA terminology, is classified as an accounting study - Situation C1 (EC-JRC, 2010) - with the intent to compare how well the treatment technologies applied in a country fit the waste generation. Due to it being a C1 study, it accordingly uses an attributional approach employing average data in accounting for exchanges over the boundaries of a system: upstream (e.g. ancillary materials and capital goods) as well as downstream (energy substitution after waste incineration, and material substitution after recycling). Some exceptions were introduced for the substituted materials due to the limited amount of data available (more details in Section 2.2.2). More detailed information on the goal and scope can be found in SM Sections 1 and 2.

2.1.1. System boundaries and exchanges over boundaries

Fig. 1 shows the system boundaries of the model. Waste enters the system boundaries of the model after being discarded by households and eventually as source-segregated fractions collected individually. The system includes waste collection, transport, recycling, waste treatment, and the utilization of compost and digestate as well as the further treatment of residues from material recovery facility (MRF), waste-to-energy (WtE), and mechanical biological treatment (MBT). For the sake of simplicity, all the source-sorted fractions are considered without impurities, and

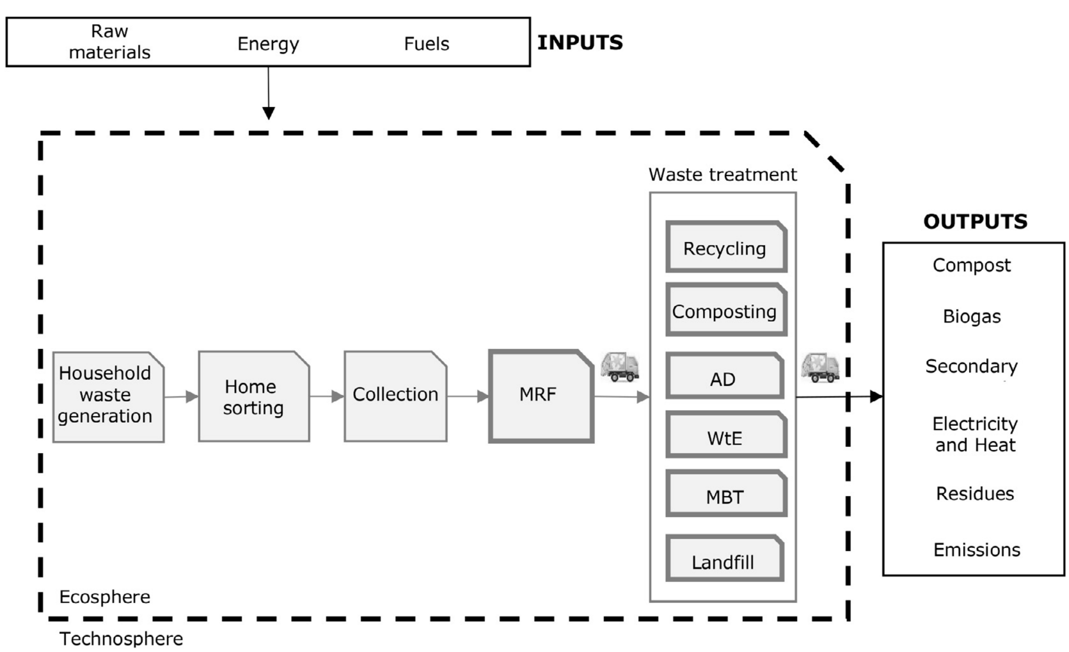

Fig. 1. System boundaries of the LCA study, including materials recovery facility (MRF), anaerobic digestion (AD), waste-to-energy plant (WtE), and mechanical biological treatment (MBT). The trucks indicate the inclusion of waste transportation. The thicker border indicates the inclusion of capital goods in the process, while the dashed border defines the system boundaries of the system.