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A case study of packaging waste collection systems in Portugal – Part II: Environmental and economic analysis

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ABSTRACT

An understanding of the environmental impacts and costs related to waste collection is needed to ensure that existing waste collection schemes are the most appropriate with regard to both environment and cost. This paper is Part II of a three-part study of a mixed packaging waste collection system (curbside plus bring collection). Here, the mixed collection system is compared to an exclusive curbside system and an exclusive bring system. The scenarios were assessed using life cycle assessment and an assessment of costs to the waste management company. The analysis focuses on the collection itself so as to be relevant to waste managers and decision-makers who are involved only in this step of the packaging life cycle. The results show that the bring system has lower environmental impacts and lower economic costs, and is capable of reducing the environmental impacts of the mixed system. However, a sensitivity analysis shows that these results could differ if the curbside collection were to be optimized. From economic and environmental perspectives, the mixed system has few advantages.

1. Introduction

The Waste Framework Directive (European Parliament and Council, 2008) highlights the importance of separate waste collection in promoting better recycling and better waste products. The Circular Economy Package adopted by the European Commission in 2015 aims to stimulate Europe's transition towards a circular economy and proposes changes to several waste directives in which separate collection is given a meaningful role (European Commission, 2015). The European Commission directive proposes that "member states should set up separate collection of waste where technically, environmentally, and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors" (p. 18).

Studies of systems for the separate collection of waste have analyzed and assessed the systems from several sustainability-related perspectives, including technical, social, economic, environmental, and social perspectives. Technical perspectives have been analyzed in terms of systems' characterization, performance and fuel consumption (Jaunich et al., 2016; Nguyen and Wilson, 2010; Rodrigues et al., 2016a, 2016b; Teixeira et al., 2014a, 2014b; Wen et al., 2015). Social aspects of interest have included public participation and behavior regarding waste separation (Bolaane, 2006; Martin et al., 2006; Shaw et al., 2006; Oskamp et al., 1996; Wang et al., 1997). Economic aspects have been analyzed either independently (D'Onza et al., 2016; Greco et al., 2015; Miller et al., 2014; Rogge and De Jarger, 2013; Teerioja et al., 2012) or together with environmental aspects, including the costs of collection (Maimoun et al., 2016; Mora et al., 2014; Larsen et al., 2010; Powell, 1996). Environmental aspects have been examined mainly through the impacts of waste collection systems as evaluated from Life Cycle Assessment (LCA) of the components of the collection system, including recycling rates, participation rates, and separation rates (Iriarte et al., 2009; Punkkinen et al., 2012; Rives et al., 2010; Usón et al., 2013; Yıldız-Geyhana et al., 2016), as well different collection system like reverse logistics (Simon et al., 2016). The environmental impacts of diesel consumption during collection (e.g., emissions) have also been studied (Larsen et al., 2009).

The types of assessments referred to above have been useful for clarifying some of the issues surrounding separate waste collection. However, separate waste collection systems can present such a variety of containers and vehicles (Rodrigues et al., 2016a, 2016b), differences on the materials collected for the same waste stream collected in different countries, specific orography features

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of the neighborhood where the collection is made, as well effects of scale from an economic point of view, that the results of such studies have tended to be case specific (Simon et al., 2016), making it difficult for them to be applied to other situations. In practical terms, the decision regarding which type of separate waste collection to adopt is influenced mainly by costs, aesthetic aspects, and other market-related factors. In Portugal, separate waste collection started in the 1990s, in which initiatives to collect glass waste in some municipalities involved the use of drop-off containers. The use of drop-off (or "bring") containers became widespread with the implementation of the Green Dot System in Portugal, with containers being used for glass waste, paper/cardboard packaging and non-packaging waste, and lightweight packaging waste (Martinho and Rodrigues, 2007). Although bring collections dominate separate waste collection in Portugal, there are some pilot cases of curbside collection. One such case is present in western Portugal, where a curbside collection has been run since 2001. Curbside collection has been integrated into the waste management system managed operated by a private company in specific neighborhoods A (located at municipality M1) and B (located at municipality M2). In the rest of the area where the private company operates, the separate waste collection is made using a bring collection system. The curbside collection is made simultaneously with the bring collection in municipalities M1 and M2, and is termed herein a "mixed collection system".

In the Part I paper (Martinho et al., 2017), the mixed collection system was shown to have benefits compared to the exclusive bring system, such as higher material separation rates, higher recycling rates and lower contamination rates, because of the curbside component of the mixed system. However, drawbacks were found in the curbside system, relating to various operational aspects. More information is needed for waste managers make a holistic decision concerning the waste collection system. An additional important area of interest is how the mixed system performs with respect to environmental and economic perspectives. Therefore, the purpose of this Part II paper is to assess the mixed collection system and compare it with exclusive bring and exclusive curbside collection systems with respect to environmental and economic aspects.

2. Methodology

2.1. Recycling schemes and scenarios

The mixed collection system is implemented in the neighborhoods of A and B. The population living in these neighborhoods is around 3800 inhabitants in an area of 2.25 km^2, mostly in detached (single) houses. The waste generated at those neighborhoods is 58,631 kg per month of residual waste plus 3380 kg of yellow stream waste (lightweight packaging (metal, plastic, and liquid packaging cartons)), 3860 kg of blue stream waste (paper/cardboard packaging and non-packaging), and 2400 kg of green stream waste (glass packaging waste).

Yellow, blue and green streams are source separated and collected via mixed collection system, with a curbside collection by bags, which collects blue waste stream and yellow waste streams. In Portugal, the separate collection of paper/cardboard includes packaging and non-packaging waste, in accordance to the rules defined by the extended producer responsibility system for packaging waste managed by the producer responsibility organization (PRO) Sociedade Ponto Verde (SPV). The curbside collection is made on different days, once a week for each stream. The collection is made by a crew of two workers, and the collection takes around three hours. The mixed system also includes a bring collection system, which makes a weekly collection of the same waste streams as the curbside system. Glass packaging waste (green waste stream) is also collected by the bring system, with the collection being made once every two weeks.

Fig. 1 presents the system to be analyzed, which is termed the "Business as Usual" (BaU) system. The BaU system describes the current configuration of the packaging waste source separated collection system (i.e., the mixed system) used in the study area. The BaU system is also compared with two other collection scenarios: the exclusive curbside scenario, where all recyclables are collected using this system, and the exclusive bring scenario, where all recyclables are collected using this system.

2.2. Assessment methods

2.2.1. Environmental assessment

The environmental impact of each scenario was analyzed using LCA. The method used was the CML 2000 (*Centrum voor Milieuwetenschappen Leiden*) (Guinée et al., 2002) with updated characterization factors. Although the CML has 14 impact categories, only the 6 categories most often applied in waste management were used (Pires et al., 2011; Rigamonti et al., 2009; Rives et al., 2010). These six categories were abiotic depletion, acidification, eutrophication, global warming, human toxicity, and photochemical oxidation. The type of LCA applied is an attributional streamlined LCA. An attributional analysis was used because all burdens associated with the life cycle of the separate waste collection system at a specific moment are assessed, and because the impacts of a separate waste collection system have reduced impact on the background system (Chang and Pires, 2015). Streamlined LCA has the advantage of consuming less time and fewer resources, and is less expensive, without losing accuracy and significance (Chang and Pires, 2015). In this respect, the cut-off rule applied was 5% of each life cycle stage. The modeling was performed using Umberto software version 5.5 (ifu Hamburg, 2009).

2.2.2. Economic assessment

The economic assessment aimed to examine expenses and costs occurring during the collection of packaging waste. Five economic indicators were calculated to help understand the economic aspects of the three different waste collection systems studied. The costs for stakeholders outside private company were not considered. Data were provided by private company, sector reports, and the academic literature. The capital costs of collection equipment were annualized by assuming a life-time of 10 years and an interest rate of 4.2%, which is the rate recommended by IAPMEI (2016). Benefits from selling recyclables were considered, with the sale prices for recyclables being those defined by SPV. Also disposal costs and landfill tax applied to the incorrect waste put on the packaging waste containers was also consider. Discounting of future costs was not included in the study as this lay outside the scope of the economic assessment.

The economic assessment was made using economic indicators based on CML et al. (2014) – cost per route, cost per tonne, final cost per tonne, break-even point per route and final cost per inhabitant. Cost per route intends to know how much is spent each time the route is made, including components such as workers, vehicles, containers and others devices affected to the collection. The same components are also used to calculate cost per tonne. Final cost per tonne differs from cost per tonne because revenues from sale of recyclables through SPV, cost of processing recyclables at sorting plant, and costs of sending refuse to landfill (taxes and tariff) are included. Break-even point intends to give the amount of recyclables needed to be collected in such way that costs are equal to the revenues. Final cost per inhabitant includes all components from final costs, being reflected by inhabitant. Such indicators were calculated to compare the scenarios, mostly related to the operation of the collection systems (Table 1).