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# An environmental-economic assessment of residential curbside collection programs in Central Florida

Mousa A. Maimoun [a,*], Debra R. Reinhart [b], Kaveh Madani [c]

[a] Joyce Engineering, Inc., Charlotte, NC, United States
[b] Department of Civil, Environmental and Construction Engineering, University of Central Florida, Orlando, FL, United States
[c] Centre for Environmental Policy, Imperial College London, London, UK

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ABSTRACT

Inefficient collection and scheduling procedures negatively affect residential curbside collection (RCC) efficiency, greenhouse gas (GHG) emissions, and cost. As Florida aims to achieve a 75% recycling goal by 2020, municipalities have switched to single-stream recycling to improve recycling efficiency. Waste diversion and increased collection cost have forced some municipalities to reduce garbage collection frequency. The goal of this study was to explore the trade-offs between environmental and economic factors of RCC systems in Florida by evaluating the RCC system design of 25 different Central Florida communities. These communities were grouped into four sets based on their RCC garbage, yard waste, and recyclables collection design, i.e., frequency of collection and use of dual-stream (DS) or single-stream (SS) recyclables collection system. For the 25 communities studied, it was observed that RCC programs that used SS recyclables collection system recycled approximately 15–35%, by weight of the waste steam, compared to 5–20% for programs that used DS. The GHG emissions associated with collection programs were estimated to be between 36 and 51 kg $CO_{2eq}$ per metric ton of total household waste (garbage and recyclables), depending on the garbage collection frequency, recyclables collection system (DS or SS), and recyclables compaction. When recyclables offsets were considered, the GHG emissions associated with programs using SS were estimated between −760 and −560, compared to between −270 and −210 kg $CO_{2eq}$ per metric ton of total waste for DS programs. These data suggest that RCC system design can significantly impact recyclables generation rate and efficiency, and consequently determine environmental and economic impacts of collection systems. Recycling participation rate was found to have a significant impact on the environmental and financial performance of RCC programs. Collection emissions were insignificant compared to the benefits of recycling. SS collection of recyclables provided cost benefits compared to DS, mainly due to faster collection time.



## 1. Introduction

Residential waste collection services provide waste removal from both single family and multi-family dwellings. A single family dwelling is an individual structure with its own lot and is usually serviced by residential curbside collection (RCC), whereas multi-family dwellings are connected structures and are usually provided with dumpsters for waste collection. RCC (the main focus of this study) includes over 8660 programs throughout the U.S. (Smith, 2012) and serves 71% of the U.S. population (U.S. EPA, 2011a). Collection programs are established by waste management divisions (cities, municipalities, or counties) to provide waste collection and management services for residents. RCC programs usually provide garbage, recyclables, yard waste, and in some cases, food waste collection lines. Typically, such service necessitates a

*Abbreviations:* DS, dual-stream; FDEP, Florida Department of Environmental Protection; GHG, greenhouse gas; GREET, Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation; $GR_T$, generation rate of total waste; MOVES, U.S. EPA Motor Vehicle Emission Simulator; MRF, material recovery facility; MSW, municipal solid waste; MSW-DST, U.S. Municipal Solid Waste Decision Support Tool; MT, metric ton; $N_T$, maximum number of households served by collection contract; PR, percentage recycling; $PR_G$, garbage participation rate; $PR_R$, recycling participation rate; RCC, residential curbside collection; SS, single-stream; U.S. DOE, United States Department of Energy; U.S. EPA, United States Environmental Protection Agency; WARM, Waste Reduction Model; WC, with compaction; WOC, without compaction; $W_G$, annual weight of garbage collected; $W_R$, annual weight of recyclables collected.

* Corresponding author.
*E-mail addresses:* mousamaimoun@knights.ucf.edu (M.A. Maimoun), debra.reinhart@ucf.edu (D.R. Reinhart), k.madani@imperial.ac.uk (K. Madani).

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minimum of three weekly collections. These collection services are provided consistently throughout the year for public convenience, although waste generation rates and collection needs vary seasonally, e.g., during holidays and low-growth vegetation seasons (Maimoun et al., 2013).

In the past, populations in the northern part of the US were served weekly by one day of waste collection, whereas the southern part of the US was served weekly by two days of waste collection to minimize odors (Kim et al., 2006). However, RCC programs are faced with rising collection costs due to an increase in collection services, e.g. recyclable and yard waste lines, providing impetus to switch to once per week or every other week (bi-weekly) waste collection. On the other hand, the main disadvantage of reducing waste collection frequency to weekly or bi-weekly is the health concern associated with leaving food waste in containers for up to two weeks (McLeod and Cherrett, 2008).

In the U.S., the implementation of curbside collection of recyclables increased recycling, diverting reusable materials from the waste stream (U.S. EPA, 2011a). However, customers' convenience plays an important role in the amount of the recovered material. Everett and Peirce (1993) studied the effect of collection frequency, collection day, and containers on material recovery rate, weight of recyclables recycled annually per person, for voluntary and mandatory curbside recycling programs. The study concluded that providing containers slightly improved curbside recovery recycling rate for voluntary collection program, but not mandatory programs. On the other hand, increasing recyclables collection frequency had a slightly positive effect on the recovery recycling rate, while collection day had only a slight effect on that. Lave et al. (1999) argued that for most municipal solid waste recycling categories the costs of collection and processing exceeded the avoided disposal fee and revenues from the sales of recyclables.

Weitz et al. (2002) compared the life-cycle emission of waste management practices in the United States between 1974 and 1997. The study found that adopting alternative municipal solid waste (MSW) management practices significantly decrease greenhouse gas (GHG) emissions, despite twofold increase in waste generation rates between 1974 and 1997. The study also estimated that collection and transportation of MSW and recyclables accounted for 1 million metric tons carbon equivalents in 1997, which was approximately a 2-fold increase in emissions over 1974, mainly due to a 2-fold increase in the amount of MSW generated and needing to be collected.

When exploring life-cycle emissions of waste management practices, Chen and Lin (2008) concluded that improving the collection efficiency and reducing the energy consumption of waste collection vehicles will help the solid waste management industry reach its goal in reducing GHG emissions. To achieve this goal, this study was designed to find the optimal RCC program. The effect of the RCC system design on waste generation rates and recycling efficiency, e.g. less landfilling and more recycling, thus avoiding use of new resources, was explored. This in turn affects waste management cost and environmental impacts of MSW management practice by altering the fate of the waste at the source.

Recyclables curbside collection can be classified according to the number of collection streams. In the U.S., single-stream (SS) and dual-stream (DS) collection are most common. DS collection requires residents to separate cardboards, papers, and magazines from the rest of recyclable materials using 60-L (16-gal) bins, while single stream collection allows residents to mix all recyclable material together using 60-L (16-gal) to 240-L (64-gal) containers. The number of containers provided for residents varies based on the collection system used and the hauling contract. During the last decade, many communities in the U.S. have switched from DS recyclables collection to SS collection for the ease of operation (Fitzgerald et al., 2012). On average, 14 new SS material recovery facilities (MRFs) have been added every year since 1995 (Berenyi, 2008; Fitzgerald et al., 2012). Fitzgerald et al. (2012) examined the quantities of recycled material at three MRFs and concluded that switching from DS collection to SS generated 50% more recyclables. Jamelske and Kipperberg (2006) found that consumers are willing to pay for the combined switch to automated solid waste collection and SS recycling in Madison, Wisconsin. The study presented a positive net benefit from moving to SS recycling with automated collection.

In Europe, Tucker et al. (2001) evaluated the integrated effects of reducing the frequency of curbside collection of newspapers in the UK from once every two weeks to once every four weeks. The study reported a 41% saving in fuel usage, which obviously had environmental benefits as well as cost savings of 60%. However, the net environmental benefits were less than 41% as more residents transported their recycles to collection centers. It was estimated that tonnage recovered suffered a loss of less than 2%, while participation in the curbside collection program dropped by less than 8%. McDonald and Oates (2003) found that the main reasons for non-participation in a curbside recycling scheme of paper within a UK community were lack of recyclables, i.e. paper, and lack of space to store recycling bins. However, the study also reported that more than half of non-participating customers recycle paper using other facilities. The study recommended changing the scheme design (mainly the color of recycling bins), scheme operation and promotions to encourage recycling. In Australia, Gillespie and Bennett (2012) estimated the willingness of households to pay for curbside collection of waste and recyclables. The study observed that respondents had a positive willingness to pay for once every two weeks or once a week collection services, while being less willing to pay for twice a week collection. Understanding the factors affecting recycling behavior is essential to increasing recycling participation (Williams and Cole, 2013). Two trials in England compared the recycling participation associated with changing to SS or DS, while reducing recyclables collection frequency. There was no difference in the recycling participation between SS and DS trials. In comparing DS and SS, Williams and Cole (2013) found that DS collected an average of 5.94 kg/household/week compared to an average of 5.63 kg/household/week by SS.

The design of RCC programs varies significantly among U.S. areas; major differences are the number of collection lines provided (defined as the number of collection services provided to a resident); the collection frequency of each service line; the type of recycling collection system (DS or SS); the number, type, and volume of garbage and recycling containers; and the fuel used. These variables can significantly affect the recycling efficiency and participation rate of RCC programs. As municipalities try to balance environmental and financial impacts of collection services and customer satisfaction, optimal design of the RCC system will be their first step toward sustainable waste management. Accordingly, this research explores the trade-offs between environmental and economic factors to optimize RCC systems.

In 2012, Florida MSW was generated by single-family dwellings (32% of the total generation), multi-family residences (13%), and commercial entities (55%) (FDEP, 2014a). Approximately 35% of the total MSW stream was recycled (FDEP, 2014b). Florida state has an ambitious recycling goal of 75% by 2020 (FDEP, 2013), calling for municipalities throughout the state to modify RCC programs as a means to improve recycling. To increase the recycling efficiency, many municipalities have switched to SS recyclables collection. Moreover, some RCC programs have provided residents with multiple or larger recycling containers to encourage residents to recycle more. At the same time, many collection providers are switching to less frequent garbage collection, due to waste diversion to other service lines (e.g. recyclables and yard waste) and

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