The Recycling of Organics:
Opportunities for Municipal Programs
and a Case Study for Philadelphia

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Spring 2011

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Acknowledgements

First and foremost, I want to thank Sarah Wu for providing invaluable guidance on my research, dedicating time for weekly discussions, and electing to become the primary reader for my capstone.

A special thanks also goes out to Richard Berman for his direction early on in the brainstorming process and willingness to become the second reader for my capstone.

In addition, several other people deserve recognition for willingly providing essential data and feedback for the completion of this capstone:

- Adam Agalloco - Energy Conservation Coordinator, Philadelphia Mayor’s Office of Sustainability
- Joan Blaustein - Director of Environment, Stewardship & Education Division, Philadelphia Parks & Recreation
- Christopher Crockett - Director of Planning & Research, Philadelphia Water Department
- Alex Dews - Policy and Program Manager, Philadelphia Mayor’s Office of Sustainability
- Katherine Gajewski - Director, Philadelphia Mayor’s Office of Sustainability
- Scott McGrath - Environmental Services Director, Philadelphia Streets Department Sanitation Division
- Andrew Stober - Chief of Staff, Philadelphia Mayor’s Office of Transportation and Utilities
- Mickey Young - Land Revitalization, U.S. EPA Region 3

Dedication

This is dedicated to my husband, Clark, for providing unconditional support and discussing countless aspects of my capstone.

A second dedication goes to Cleo and Hayle for keeping me company, and sane, during many long days of researching and writing.

I also would like to thank my parents, Everett and Ellen, for making me realize a career focused on the environment is the perfect fit for me.

ABSTRACT

THE RECYCLING OF ORGANICS: OPPORTUNITIES FOR MUNICIPAL PROGRAMS

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Sarah Wu, Primary Reader

In 2009, food waste in the United States comprised 14.1% of municipal solid waste, the third largest category after paper and yard trimmings. With food scraps and other organics dominating a large portion of the waste stream, cities across the United States and Canada are slowly adopting organics diversion programs as they learn of the feasibility and paybacks of these programs on a municipal scale. The first part of this capstone examines existing trends in the development and execution of organics programs, including a few precedent examples, as well as techniques to motivate participation among residents. The second portion of this capstone explores the benefits and drawbacks of three viable organics recycling scenarios currently available to municipalities. These options include: increasing the use of food waste disposers in kitchens, developing a community-based network of composting sites, and implementing a city-wide curbside collection program. While these programs can be applied to any city, the third portion of this capstone looks at data specific to Philadelphia because *Greenworks Philadelphia,* the city's comprehensive sustainability plan, includes a goal to divert 70% of solid waste from landfills by 2015. In the end, these organics recycling options are all feasible within Philadelphia, or any municipality, and this capstone provides the foundation for a city to make an educated decision as to which program would best fit the needs of its residents.

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I. Introduction

In 2009, the third largest category, or 14.1%, of municipal solid waste in the United States was food scraps (U.S. EPA, 2010b). As food waste, in conjunction with yard trimmings, dominates a significant portion of the waste stream, cities are looking for alternative methods to handle organics. Previously disposed of as trash, cities now understand organics can be re-used and managed in beneficial ways. Many cities across the United States and Canada are developing a variety of organics diversion programs at the municipal level.

The beginning portion of this capstone examines a wide range of information on existing organics recycling programs throughout the United States and Canada. This study presents general trends in organics program development, execution, and results coupled with methods of encouraging resident participation. In addition, the first portion of this capstone examines several case study examples to highlight the logistics and structures of current organics diversion programs.

The second portion of this capstone focuses on three organics recycling options, all of which have potential in most municipalities. This paper discusses utilizing food waste disposers in kitchens, providing a community-based network of composting sites, and developing a city-wide curbside collection program. Each scenario analyzes the program's general feasibility and structure along with the benefits and disadvantages of each option within any given city.

After exploring general municipal opportunities, the final section of this paper explores information and opportunities specific to Philadelphia. The first part of this section presents a background on organics recycling within the city including potential program motivations, a characterization of municipal solid waste, and existing organics diversion infrastructure. The second portion of this section highlights the feasibility, costs, and benefits of implementing each of the previously discussed organics recycling scenarios — food waste disposers, community-based composting, and curbside collection — in Philadelphia to support the waste reduction goals of the city's sustainability plan, *Greenworks Philadelphia.*

This capstone uses a variety of terms to describe the prevention of organic materials from ending up as a part of the waste stream. This paper uses food scraps and food waste interchangeably to identify food that is not consumed but instead traditionally discarded in the trash. The term organics refer to all materials that naturally decompose including food, yard trimmings, wood, and compostable papers. This study also uses organics recycling and organics diversion interchangeably to describe the process of converting organic waste into a resource. Composting, household composting, and backyard composting are additional terms to describe this process, but these terms typically refer to small scale individual methods, not large industrial operations.

Ultimately, the overall goal of this capstone is to provide a basic knowledge of organics recycling programs to municipalities. Using the information presented here, a city will become familiar with the types of organics diversion programs available and be able to make an educated decision about which program may fit best within their city. The specific information related to Philadelphia will inform the city about which organics recycling option best meets local needs.

II. Organics Recycling in the United States and Canada

The United States and Canada are seeing a paradigm shift in the management of municipal solid waste. Organics, such as food scraps and yard trimmings, which once were viewed as trash, now are being valued as a useable resource. As of January 2010, over 121 municipalities in the U.S. and Canada had implemented residential programs that collect organics from residents for recycling (Anderson, Liss, & Sherman, 2010). In addition to curbside programs, cities provide informal options supporting backyard and community composting.

The initial section of this capstone aims to provide a wide array of information on organics diversion programs throughout the U.S. and Canada. This paper highlights general trends in organics programs development, implementation, and outcomes and explores various methods of motivating residents to participate in organics recycling programs. Finally, this opening capstone section summarizes several case study examples for specific program structures and operating logistics.

Municipal Organics Recycling Trends

There are two trends occurring in municipal composting programs in the United States and Canada. A large majority of cities provide information on backyard composting to households in order to promote do-it-yourself composting. In addition, an increasing number of municipalities are initiating city-run programs with a majority providing residential curbside collection and a few others offering centralized drop-off locations for food scraps within the city.

An informal survey of organics recycling initiatives shows that a significant majority of these programs are centered on the West Coast of the United States, for both promoting backyard composting as well as developing more advanced curbside programs. A smattering of other initiatives are present around the country, typically in liberally-minded cities such as Boulder, Colorado; Austin, Texas; and Ann Arbor, Michigan; as well as localized efforts in smaller, more rural or suburban communities. Currently, no large-scale curbside organics collection exists on the East Coast, and the only big cities in the region promoting household composting are New York City and Boston. Ontario and Nova Scotia are the providences in Canada leading the way in organics diversion programs.

Most cities take a very simple approach to organics recycling by providing support for backyard composting. A city's involvement typically includes supplying information to citizens about the benefits of composting, how to get started, the different types of composting methods available, and bins to buy or build. Most of this information is available online through cities' websites, often provided by their departments of public works or sanitation. Some cities go further to support citizens by subsidizing the purchase of bins or providing composting classes for hands-on training on starting a system at home. These endeavors are low-cost to cities and involve limited time on the part of city employees, after initial information is gathered.

While still supporting backyard composting efforts, more and more cities also are developing centralized city-run programs. Curbside organics collection is similar to trash and recycling services because residents are required to separate their food scraps and leave them at the curb for collection. The organization of collection programs varies depending upon the city, with most programs either collecting food waste separately or together with yard trimmings (Anderson et al., 2010). Some cities who do not to provide collection services instead offer a drop-off location for residents to bring their food scraps for composting (Cambridge Department of Public Works, n.d.). However, organized curbside collection can be logistically difficult and expensive for a city to implement. Case study examples of existing curbside programs, to follow, shed light upon this area.

Motives for Establishing Programs

The recycling of organics provides a variety of benefits to the environment, municipalities, and residents. Composting food scraps is a way to reuse valuable material while creating a product that enhances soil quality. Organics diversion also can increase a city's waste diversion rates, decreasing the amount of materials placed in landfills and helping meet sustainability goals. Other, more specific rationales vary depending on the type of program a city chooses to institute.

On the most basic environmental level, recycling organics converts a perceived waste into a resource. Compost produces rich, dark soil filled with valuable nutrients and micro-organisms, and the use of compost enriches soil quality by increasing the quantity of its organic matter. High organic content provides multiple benefits to soils such as increasing plant productivity, reducing soil-borne plant diseases, and improving retention of water. All of these factors help to prevent soil erosion and land degradation, decrease the necessity for synthetic fertilizers and pesticides, and reduce irrigation needs (Brown, 2007). However, the help compost provides in establishing healthier soils is not likely a major motivator for cities to promote food scraps recycling.

Instead, the support of sustainability targets is a leading motivation for cities to adopt organics recycling. Many cities are developing sustainability plans that focus on providing a greater quality of life for their citizens and attracting new residents and businesses. Often these plans include high diversion or zero waste goals. These goals are being voluntarily created by some cities, while other municipalities, especially in California, are creating targets in response to state and local regulations (U.S. EPA, 1995). Diverting organics is important because they are a large percentage of the solid waste stream. In the end, communities with zero waste goals, and many with aggressive high waste diversion goals, will not reach their targets without establishing an organics recycling program.

Diverting organics from the municipal solid waste stream has a variety of impacts upon the environment and a city. Acquiring valuable assets from trash allows these materials to be reused, reducing the need to extract virgin materials, an environmentally damaging and energy intensive process. Removing recyclable items from the waste stream also allows a city to concentrate on the residual waste and how these components can be reused or diverted. Lastly, preventing food scraps from ending up in a landfill, which has significant impacts upon the environment, is another reason for a city to embrace an organics diversion program.

Landfills are a noteworthy source of methane, a potent greenhouse gas 21 times more harmful than carbon dioxide. Greenhouse gases, both natural and anthropogenic, trap heat in the atmosphere causing rising temperatures on the earth’s surface. Landfills account for more than 20%, and the second-largest source, of human-made emissions in the United States (U.S. EPA, 2011b). In landfills, carbon-intensive materials, such as food scraps, yard trimmings, paper, and wood, degrade anaerobically due to the lack of oxygen, which produces methane. In comparison, the natural decomposition process controlling a compost pile produces essentially zero methane and instead acts as a carbon sink (U.S. EPA, 2006). Diverting food scraps from landfills, and ensuring they are properly composted, considerably reduces the consequential greenhouse gas emissions.

The fiscal impact landfills have upon a city also is an important motivator in the development of an organics recycling program. Many cities consider organics diversion programs a solution to high landfill fees and an increasing shortage of landfill space (U.S. EPA, 1995). As an example, the pending closure of the Fresh Kills Landfill in New York City led the government to investigate backyard composting as a local solution for waste management that does not require transporting waste outside the city (NYC Department of Sanitation, 1999). Toronto experienced a similar situation and implemented a curbside organics recycling program when the city's tipping fees tripled due to the closure of a local landfill (City of Toronto, 2001). Reducing the amount of re-usable materials headed to a landfill extends its useful lifetime and lessens the pressure to establish a new one, an onerous process influenced by environmental and societal pressures.

A large scale organics collection program has a significant impact upon municipal solid waste because food scraps are gathered in bulk, an outcome that is very difficult to achieve through individual composting efforts in a smattering of backyards (NYC Department of Sanitation, 1999). Bulk diversion from landfills allows cities to save money on tipping fees and redirect that money toward more sustainable waste management techniques. Large scale organics recycling also has the potential to decrease the frequency of collection for municipal solid waste resulting in fewer trucks and work hours (Anderson et al., 2010). All of these examples have positive fiscal and environmental outcomes making curbside collection a viable option for many cities.

In addition to meeting high waste diversion goals by gathering food waste in bulk, curbside organics collection has the ability to include a variety of additional materials. Most large-scale collection programs involve industrial organics processing that can incorporate items not suitable for many other composting systems. One example is meat, fish, and dairy products, which are decomposable but not able to be processed by household composting bins. Soiled paper is another major waste that is often discarded with traditional trash but easily incorporated in an industrial organics recycling operation. These items include tissues, napkins, paper towels, and pizza box liners as well as paper products that hold food items such as ice cream cartons, milk cartons, wax cardboard, and paper plates and cups (Goyton, February 11, 2011). Including these materials in an organics diversion program increases a city's diversion rate above the percentage of food scraps in the trash stream.

While backyard composting does not divert as much waste as curbside collection, this type of program accrues different benefits to municipalities and residents. For starters, backyard composting reduces the need for garbage trucks to cart away food waste, which eliminates carbon dioxide emissions from transportation and allows trucks to remain on their routes longer. Backyard composting ideally includes yard trimmings along with food scraps which allows for a greater reduction of curbside pick-ups, especially during the spring and fall. In addition, backyard composting keeps valuable nutrients on-site, allowing residents to use the rich soil on their own gardens and save money by eliminating the use of synthetic fertilizers.

Regardless of the program type, organics recycling also offers a variety of other benefits to a city. In general, improved sanitation and greater public health are positive outcomes. Separating food waste removes a majority of the wet and putrid materials from the municipal solid waste stream. Eradicating these moist, smelly substances from trash and placing them in airtight, latched containers avoids pest and odor issues often associated with waste (U.S. EPA, 2011a). In addition, organics comprise up to 70% of municipal solid waste by weight (U.S. EPA, 1995). Therefore, removing food scraps, and thus the bulk of the moisture, odor, and weight, from trash, makes the task of collection less unpleasant and tiring for city workers. In essence, the whole system becomes more sustainable for garbage collectors as well as neighborhoods (Goyton, February 11, 2011; Haggi, January 28, 2011).

Encouraging Resident Participation

Understanding what motivates citizens to participate and what benefits they accrue is critical to the success of any municipal program. Resident participation in an organics recycling program is dependent upon a variety of factors including public policy, cost of participation, and personal beliefs. On a household level, residents gain an increased understanding of waste management issues which is beneficial to a city as a whole. Also, providing proper education and outreach to citizens helps avoid barriers often associated with organics recycling programs.

One of the most obvious reasons residents participate in any program is because it is mandatory. Requirements for organics recycling can follow a similar path to that of traditional recycling and yard waste, as many of these programs have become mandatory over the last several decades. Toronto, San Francisco, and Seattle have ordinances in place mandating the recycling of food organics. In 2002, Toronto required the addition of all organics to the collection of its existing yard waste program. After years of a voluntary program, San Francisco, in 2009, realized a mandatory organics recycling program was necessary to reach the full potential of its waste diversion goals (Anderson et al., 2010). San Francisco uses this ordinance to require collectors to educate and inform customers about properly source-separating materials. Warnings are initially issued to residents for inappropriate sorting, and fines are issued to those who are blatantly non-compliant (SF Environment, n.d.). Finally, Seattle also recently required single family residents to participate in its curbside organics collection program or household backyard composting (Yepsen, 2009).

Financial incentives also promote organics diversion participation. In a study on food scraps recycling in King County, Washington, residents indicated they would be more likely to participate in their existing program if there was a reduction in their household’s garbage bill (Belcher, 2008). In cases where a municipality establishes a cost-saving organics recycling program, extending those saving to residents is a way to encourage participation. However, financial incentives are most successful in communities where residents directly pay for their municipal solid waste pick-up rather than in cities where all city services are lumped together in one bill.

As other reasoning, many residents participate in an organics diversion program because it appeals to their environmental consciousness. As an example, after several years of a free curbside composting pilot program funded through state grants, Denver began charging residents for the service in order to continue the program. The city initially lost approximately 35% of its customers, but has since had new customers enroll in the program and continued interest in expansion outside the pilot areas (Goyton, February 11, 2011). In addition, Portland has significant public support for its Portland Composts program. In 2007, the city surveyed residents about the addition of food scraps to their existing yard waste bins and found that out of 6,000 responses, or 67% were in favor of the program (Haggi, January 28, 2011).

Establishing organics recycling programs that engage the environmental consciousness of residents has benefits for a city in additional ways. An organics recycling program is a highly visible initiative showing residents their city is making progress toward sustainability, and participating individuals feel as if they are a part of their city's bigger green objectives. Winning public support for these types of programs helps a city mold future behavior change towards other important environmental issues (Cousart, October 8, 2009).

By participating in organics diversion programs, residents also gain an increased awareness of waste management and view organics as a resource rather than waste. Having residents separate their own food waste heightens public appreciation of the amount of waste generated and where that waste goes once it is collected. Especially with backyard composting, residents start to understand trash does not magically disappear once it has been collected by a garbage truck. This impact often prompts citizens to be more self-aware of their actions and reconsider their purchasing and disposal habits (NYC Department of Sanitation, 1999).

Finally, public education is an important component to encouraging participation in an organics diversion program because people perceive food waste to rot quickly, be smelly, and attract bugs (Anderson et al., 2010). San Francisco states these issues are the major deterrents to household participation in their curbside program. Outreach campaigns educating residents about proper handling of food waste, such as emptying food waste daily, regularly cleaning kitchen buckets, and using baking soda and vinegar to counteract smells, help ease the concerns of participants (Solid Waste Association of North America, 2008). The King County, Washington, food scraps recycling study found a much larger percentage of residents participating in a composting program disagreed that a food waste container in their kitchen would smell bad, than compared to residents who had not participated in the program (Belcher, 2008). This shows that cleanliness issues surrounding food waste is an initial concern but is often overcome as residents gain knowledge and experience with the recycling of organics.

In conclusion, organics diversion trends in municipalities are focused on backyard composting and larger-scale curbside collection. Many different reasons are indicated for the promotion of composting, including sustainability and waste management goals, landfill and greenhouse gas emissions concerns, fiscal impacts, and improved sanitation and public health. Participant motivation is influenced by organics recycling laws, garbage bills, sense of environmental responsibility, and cleanliness perceptions. Finally, one of the important lessons for a city embarking upon an organics diversion program is to understand the demand for food scraps recycling to ensure the city constructs a plan appropriate for its residents.

Precedent Programs

As more and more communities are getting involved in organics recycling, precedent programs are growing in number and providing a greater range of examples for cities looking to invest in new waste management techniques. The following pages outline three programs at the head of the organics recycling movement that exemplify the best in the field, especially when considering a potential program implementation in Philadelphia. First, this section discusses a community-based approach in the New York City followed by curbside programs in San Francisco and Toronto. Unfortunately, the lack of cities utilizing food waste disposers as a formal organics recycling technique prevents a precedent example on this topic.

New York City Compost Project

Of cities that encourage organics recycling, most promote do-it-yourself household composting or operate a full-scale curbside collection program. New York City varied from the norm by supporting a variety of community-based composting sites throughout the city. Run through its Department of Sanitation, Bureau of Waste Prevention, Reuse and Recycling, the NYC Compost Project provides composting outreach, education, and technical assistance to residents and businesses in New York City's five boroughs.

In the early 1990s, New York City was preparing for the mounting costs of municipal solid waste disposal as the impending closure of the Fresh Kills Landfill would require the city to export its garbage. Looking to increase the recycling rate, the city conducted a curbside food organics recycling collection pilot program in two different neighborhoods in Brooklyn. Successes of the program varied between the sites but were mainly overshadowed by concerns over odor, vermin, and storage space in many high-rise building. In the end, the city did not implement a full-scale program due to the prohibitive costs and environmental impacts of an additional fleet of trucks for a low anticipated diversion rate (NYC Department of Sanitation, 2001).

Although the organics recycling pilot program provided beneficial education about waste management strategies to residents, the Department of Sanitation felt food composting options would be more successful in a decentralized format. The city founded the NYC Compost Project to provide information to residents about composting and its horticultural and ecological benefits. The Department of Sanitation partnered with the city's four Botanical Gardens, well-established and visible presences in their communities, (NYC Department of Sanitation, 2001) and with the addition of the Lower East Side Ecology Center in Manhattan, the NYC Compost Project launched sites in all five boroughs. NYC Compost Project's mission is to support backyard and on-site composting in the city by providing technical assistance to residents, community gardens, coops, and others groups (NYC Department of Sanitation, n.d.).

These five sites provide the foundation for composting in their boroughs through the funding they receive from the Department of Sanitation. Each location hosts a composting demonstration site displaying different types of backyard composting bins and explaining their use. Plus, the NYC Compost Project staff runs composting workshops and certification courses, provides composting outreach at numerous public events, and operates a phone hotline and email account from each location. In total, the program has 10 full-time and 3 part-time employees housed at the various host locations throughout the five boroughs (Sheintoch, February 10, 2011).

A significant component to this program has been the development of hundreds of community-based composting sites around the city. At these locations, neighborhood groups have agreed to run and maintain composting operations and receive start-up and continued technical assistance from the NYC Compost Project staff. A majority of these community-based sites exist in community gardens, but there also are locations at schools, parks, residences, and private businesses (NYC Department of Sanitation, n.d.).

A few of the exemplary community-based sites have been designated NYC Compost Project Demonstration Sites. This distinction indicates the location is providing continuing composting education to NYC residents and has become a supporting, satellite location to its borough's main demonstration site. Many other community-based sites also help distribute literature or host composting workshops or events. In addition, some locations open their doors to the general public by providing drop-off sites for food scraps, leaves, and other organics (NYC Department of Sanitation, n.d.).

Through examining its composting options in the 1990s, New York City determined it would never be able to achieve high waste diversion levels by backyard composting efforts. Only a small percentage of residents have access to suitable outdoor space, and even fewer find the prospect of composting appealing (NYC Department of Sanitation, 1999). Therefore, the city does not collect any data on the amount of tonnage this program diverts from landfills. However, it does have some information on the number of people who participate in the program from data collected through the compost hotlines, emails, workshops, and outreach events. From July 2009 to June 2010, the program received about 4,500 calls to the compost hotline and 5,700 emails, while 6,800 people attended composting workshops and 9,600 people participated in Master Composter activities (Sheintoch, February 10, 2011). In comparison to New York City's entire population, these numbers amount to a very small portion of the residents.

In conclusion, New York City was able to study their composting options fairly early on in the 1990s and create a viable program based upon their most promising alternative. The Department of Sanitization does acknowledge, however, that a municipal organics recycling program has the potential to evolve over time if many components fall into place such as the appropriate land-use regulations and permits, state-of-the-art facilities, collection efficiency, capture rate and final compost quality. At the present time, the city is satisfied with its ability to increase the awareness of solid-waste and recycling issues at a small level for minimal costs and is committed to continue providing education and subsidized bins to residents through the NYC Compost Project (NYC Department of Sanitation, 2001).

The Fantastic Three in San Francisco

San Francisco is the one of the most quintessential environmentally-friendly cities in the United States. Even with a population of almost 800,000 in only 47 square miles, San Francisco was the first large city in the U.S. to develop a curbside organics recycling program (Farrell, 2005). Rolling out the Fantastic Three program took years of testing pilot programs for a variety of components and strong cooperation from the city's haulers.

In 1989, the State of California passed a mandate requiring all cities to divert 50% of their municipal solid waste from landfills by 2000. Failure to meet this deadline would result in heavy daily fines (Farrell, 2005). In response, San Francisco implemented a curbside recycling program that was fully operational by the mid-1990s. Yet even with strong residential participation, diversion rates remained constant around 20%. A waste characterization study in 1996 revealed residents were still throwing out large amounts of trash, with 26% being comprised of food scraps. With yard trimmings only consisting of 5% of the waste stream, San Francisco realized capturing food waste was essential to reach the state's 50% diversion mandate (Macy, 2000).

A full-scale residential organics recycling program took several years to develop. The city and one of its permitted haulers, Sunset Scavenger, spent two and a half years in the late-1990s collaborating on a series of pilot projects aimed at finding the optimal program for the city that balanced residential and driver satisfaction, diversion rates, and cost. The project tested a variety of topics including type of organics collected, bin size and configuration, vehicles, and collection frequency. Pilot neighborhoods generally were single-family attached housing in demographically different areas of the city. If organics recycling would not work in these areas, it most likely would not work anywhere in the city because the selected neighborhoods also had good to high recycling participation and average to high yields in yard trimmings (Macy, 2000).

In April 1999, San Francisco announced its final pilot, called The Fantastic Three, which morphed into the city's signature waste management program. The city began with 2,800 households before rolling out a city-wide expansion in February 2000. Now three-fourths of the city's single-family and small, multi-family homes, a number above 200,000 households, participate in the program. To participate, each household was given three 32-gallon wheeled carts: a black one for trash, blue for co-mingled recycling, and green for organics plus a two-gallon kitchen pail (Macy, 2000). The program collects all food scraps including meat, in addition to soiled paper, wax cardboard, wood crates, animal bedding, and yard trimmings (Macy, 2002).

Collection occurs weekly, with all three waste categories picked up on the same day. Due to their relatively consistent volumes, recyclables and trash are collected in a side-loading split dual 40/60 compartment semi-automatic compacting vehicles. Each truck is operated by a single employee and serves approximately 1,800 to 2,000 households per week. Due to seasonal variations in volume, organics are collected in a separate side-loading single compartment semi-automatic truck, also run by a crew of one and capable of serving almost 6,000 household per week. To maximize program efficiency, Sunset Scavenger had to re-arrange their existing collection to accommodate the volume differences between the two types of collection trucks (Macy, 2000). Organics are taken to the city's transfer station before being loaded into trailers and hauled to a composting facility, approximately 65 miles away, run by Sunset Scavenger's parent company, Norcal (Macy, 2002).

The city conducted extensive outreach to inform residents of the Fantastic Three program. Mailing, in three languages, went to all households publicizing the program, and detailed brochures were delivered with the carts. Bins and kitchen pails were affixed with labels indicating which materials were appropriate for each bin. A customer service hotline, also available in several languages, was provided by the haulers, and a public ad campaign was enacted on buses and bus shelters. Higher levels of contamination, unacceptable materials mixed in with organics, were present during the beginning periods of the program, but dropped over several weeks and have continued to stay low. Haulers also place tags on bins to remind residents of appropriate bin materials, after observing instances of potential contamination (Macy, 2002).

Funding for the program is controlled by the San Francisco Refuse Collection and Disposal Rate Board which sets rates for a five year period. Using a pay-as-you throw system, residents are charged for trash services based only upon the volume of their black cart, which creates incentives to maximize their use of recycling and organics bins (Macy, 2002). Rates are established to help cover the costs of the recycling and composting services provided by the city and are recommended to the board based upon analyses of costs and projected diversion rates. Norcal, the city's only permitted hauler by ordinance, also is provided with financial incentives, based on a two tiered system, to help achieve target tonnage goals and prioritize rapid expansion of the recycling programs (Farrell, 2005).

Due to the success of the organics program, San Francisco has adopted stricter landfill goals of 75% diversion by 2010 and 100% diversion by 2020 (Farrell, 2005). Prior to 2009, organics participation was estimated at 35-40% with a capture rate of eight pounds of residential organics per week (Anderson et al., 2010). After years of the Fantastic Three program being voluntary, San Francisco enacted a mandatory recycling and composting ordinance for the city including all residential buildings, commercial properties, food vendors, and events, to help move toward the goal of zero waste by 2020. The city's current diversion rate is 77%, and San Francisco also provides organics recycling services to commercial facilities (SF Environment, n.d.).

Like any program, San Francisco has experienced challenges with the implementation of the Fantastic Three. Additional collection vehicles are being tested for some of the tight, dense neighborhoods and hilly areas within the city. Space constraints are an issue because houses are often attached and garages are infrequent, so most residents have little space to store three different bins. The program helps residents find places to store bins and suggests sharing blue and green bins with neighbors. Finally, including large apartment buildings in the program also is a challenge, and San Francisco is testing strategies to provide organics service this sector of the city (Macy, 2002).

Toronto's Green Bin Program

Toronto, Canada, is another city that has been on the forefront of alternative waste management techniques. Initially pressured by high disposal costs, the city adopted an uncompromising waste diversion plan that included the establishment of a full-scale curbside organics collection program to all residents. The program has proven to be successful after almost 10 years of implementation.

In 2000, the City of Toronto was facing a serious challenge over disposal of the city's future municipal solid waste. The city-owned Keele Valley Landfill was scheduled to close in 2002, and Toronto's only option was to truck its garbage 10-hours away, increasing the costs of disposal by 300%. Proposing a new disposal site in Michigan eventually led to political opposition from the United States and threats of closing the border, although Toronto had no way of predicting this resistance (Anderson et al., 2010). With no other potential landfill sites in Ontario, Toronto saw the traditional methods of disposing of trash were no longer practical, and landfilling waste would be financially crippling at the city's current disposal rates. To find a comprehensive solution to this waste management issue, the city's mayor created a Waste Diversion Task Force team (City of Toronto, 2001).

With significant public input, the Waste Diversion Task Force developed an aggressive plan to reduce household garbage going to the landfill. The proposal aimed to divert as much of the remaining municipal solid waste as possible by providing an updated co-mingled recycling program and new curbside organics recycling collection throughout the entire city. With this plan, Toronto established high diversion goals: 30% by 2003 (Phase 1), 60% by 2006 (Phase II), and 100% by 2010 (Phase III). This strategy was a "…massive undertaking – completely re-engineering the existing collection, transfer, and processing system…" (City of Toronto, 2001).

After conducting a series of pilot projects to understand the levels of participation and anticipated recovery rates, Toronto launched its curbside organics recycling program called the Green Bin Program. Starting in September 2002, the program concentrated on rolling out collection to Toronto's single-family homes for several years before tackling multi-family and commercial organics recycling. For Toronto, multi-family collection is both critical and challenging, for as many as 40% of the city's residents live in apartment and condominium buildings (Dello, 2002).

Toronto carefully planned the logistics of their organics collection. Split-compaction collection trucks pick-up organics on a weekly basis while alternating the other compartment for collection of recyclables and residual refuse. The city provides residents with two organics containers, a pail for use in the kitchen and a 16-gallon latched and wheeled green cart for setting at the curb for collection. The Green Bin Program collects virtually all organic materials including fruit and vegetable scraps, meat, fish, and dairy products, pasta, bread, and cereal, coffee grounds and filters, soiled paper towels and tissues, paper food packaging, diapers, sanitary products, household plants, animal waste, bedding and litter, and dimensional wood. However, yard trimmings are collected separately depending on the time of year (Anderson et al., 2010).

The bi-weekly collection of refuse has motivated many residents to participate in the weekly organics recycling program because most people want to avoid having their kitchen scraps sitting around for two weeks. The city also uses financial incentives to entice participation by charging for trash collection by volume at an annual rate depending on a household's choice of five garbage bin sizes. In contrast, organics and recycling collection are provided free of charge with little to no limit upon the amount placed at the curb (Gorrie, 2010).

While most of the collection is done through private franchise agreements, the City of Toronto owns and operates its own organics processing facilities. Plastic bags to store food waste as well as the addition of unconventional organics, such as diapers and sanitary products, are permitted in collection streams due to the process utilized at the city's facilities. The organics are first put through a hydropulper to shred the plastics allowing them to float to the top of the slurry and be skimmed off. The remaining food waste is processed through an anaerobic digester, where the methane gas is collected for energy. Finally, the de-watered digestate is composted. Almost all other municipalities in the Greater Toronto Area also execute organics recycling programs but do not allow the inclusion of plastics as they strictly rely on composting methods, not a hydropulper and digester, to process their organics (Gorrie, 2010).

Overall, Toronto's Green Bin Program has been highly successful. A total of 510,000 single-family homes are a part of the program with over 90% participating at a rate of approximately ten pounds of organics per week. Organics collected in green bins consist of 28% of the waste stream, and the city captures an estimated 72% of organics that are discarded. A total of 127,600 tons of organics have been diverted each year. Pilot programs now are being implemented to serve multi-family households (Anderson et al., 2010).

Toronto's program has not come without its difficulties. The demand for the program has continued to grow, especially with the addition of multi-family buildings, and the city has had difficulty keeping up. While processing a majority of the organics, the city's facilities have not had the capacity to process everything and outsourcing has led to some problems with contractors. In the end, the city aims to become self-sufficient (Gorrie, 2010). Toronto officials also understand their organics go through a very complex processing system and in hindsight, this system may have been executed more effectively by the private sector (Anderson et al., 2010).

III. Municipal Program Opportunities

A city has a variety of options available when considering what type of organics recycling program to implement. This capstone section discusses three organics diversion scenarios, which can be applied to any municipality, for their overall feasibility, benefits, and downsides. The first method investigates the use of food waste disposers in kitchens while the second method evaluates a network of community-based composting sites. The final method explores a large scale, city-wide curbside collection program.

Each organics recycling scenario is able to process different types of materials. Industrial systems generally have the ability to handle all organics such as food scraps including meat, fish, and dairy products, yard trimmings, wood, and compostable paper and products. Smaller-scale individualized methods typically are able to process food scraps and small amounts of yard trimmings and paper. This study assumes that the food waste disposer and community-based composting schemes divert only food scraps, while curbside collection includes a much wider range of compostable materials.

Food Waste Disposers

While not a commonly adopted method, the first alternative in this capstone for recycling food scraps integrates them into a city's existing municipal water infrastructure by encouraging the use of food waste disposers (FWD). More commonly known as a garbage disposal, an FWD is a small kitchen appliance that attaches to the underside of a kitchen sink, pulverizes food scraps into small pieces, and flushes them, with the aid of water, into the sewer system. Using this as a substitute to traditional collection, food waste is diverted, on site, from a city's municipal solid waste stream. Three major components influence the feasibility of using FWDs as an organics recycling option: the food waste disposer unit, the sewer system, and the wastewater treatment facility.

The food waste disposer unit is the beginning step in a scheme that utilizes a city's existing water infrastructure as an organics diversion tool. Currently, as many as 50% of households in the United States have FWDs installed in their kitchens, and this number may be as high as 80% in new home construction (Marashlian & El-Fadel, 2005).

Residents in existing homes bear a majority of the financial infrastructure burden of this scheme by paying for the installation costs of an FWD, and with an anticipated lifespan of approximately 12 years, all households are subject to replacement costs as some point (Diggelman & Ham, 2003).

An FWD uses energy to mince food waste and water to flush the food through the grinding chamber and cool the system’s motor. A typical household disposer has a one-half to three-quarters horsepower motor and is used approximately the same amount of time each day regardless of household size (Evans, Andersson, Wievegg, & Carlsson, 2010). At a highly conservative two minutes of use a day, a one-half horsepower FWD uses less energy than a 75-watt light bulb uses in ten minutes and is a negligible energy increase to residents. Extra water use also is insignificant as it amounts to only 2.2% of daily household consumption (Marashlian & El-Fadel, 2005).

After food waste is ground in an FWD, water flushes it through household pipes, and the food scraps become incorporated into a city’s sewer system. Due to this integration, cities have concerns about how shredded kitchen waste impacts the condition of sewers. However, having a similar density to wastewater, ground food scraps do not significantly impact the sewage velocity (Bolzonella, Pavan, Battistoni, & Cecchi, 2003). Flow velocities in sewers are specifically designed for long-term self-cleaning where solids may settle during low flow-periods but re-suspend when velocities increase. In addition, the output of FWDs is very fine and highly biodegradable with times of high use typically occurring when sewers are at high velocity flows. In the end, only a small amount of food waste actually settles in the sewers (Evans et al., 2010). New York City’s comprehensive study on the future use of FWDs showed that no significant adverse impacts on sewers were expected and that potential future maintenance costs were minimal (NYC Department of Environmental Protection, 1997).

With the use of FWDs, an increase of fats, oils, and grease (FOG) in sewer systems is often an additional concern as FOGs can accumulate and cause pipe blockage. However, field studies of households FWDs hypothesize that FOG particles adhere to food waste particles when flushed with cold water in the grinding chamber. Upon arriving in the sewer system, FOGs are not free floating, and therefore cannot attach to the sewer surfaces and cause sedimentation. Thus, no evidence supports an increase in fats, oils, and grease in sewers is an outcome of household FWD use (Evans et al., 2010).

Using FWDs as an organics diversion strategy impacts a city's wastewater treatment facilities more than its sewer system. A wastewater facility is required to meet certain parameters for biochemical oxygen demand (BOD) and chemical oxygen demand (COD) as well as for nutrients such as nitrogen, ammonia, and phosphorus. Food waste changes the composition of the wastewater by adding carbon to the system, but there is not a general consensus about how significant the composition change is. Some studies show an insignificant impact or slight increase in BOD or COD load (Bolzonella et al., 2003; Evans et al., 2010; Marashlian & El-Fadel, 2005; NYC Department of Environmental Protection, 1997) while others note there is an improvement in the nutrient removal of nitrogen and phosphorus (Bolzonella et al., 2003; Diggelman & Ham, 2003). A 15-year study of the use of household FWDs finds the biological processes acclimate, and eventually equilibrate, to the new composition of the wastewater load (Evans et al., 2010). As these studies show, added carbon does not affect a facility's ability to process wastewater but may require additional monitoring to ensure water quality requirements are properly met.

As ground food waste impacts the composition of wastewater, it also increases the volume of materials added to the wastewater system in the form of both additional suspended solids and water. Consequently, treatment facilities are required to treat more wastewater and use more energy in the process. Before relying on garbage disposers as a method of recycling organics, a city must be certain their wastewater treatment facilities can handle the extra flow. With additional flow, a treatment plant produces more sludge, and there are three main end-uses — land application, incineration, and landfilling — of sludge, also known as biosolids (U.S. EPA, 2010a). Using biosolids as a fertilizer in land applications is a way of using FWDs to recycle valuable nutrients found in organics, while incineration and landfilling are merely diversion and reduction techniques for waste, and do not ultimately recycle the organics. The environmental and cost impacts biosolids have upon a city vary depending on how the biosolids are managed.

Using FWDs to manage kitchen scraps has a variety of benefits. Firstly, this option is attractive for cities that already have suitable, centralized sewer and wastewater treatment options as it heavily relies on existing water infrastructure. FWDs also are an appealing option where curbside collection is difficult such as in mountainous areas; a collection of small, decentralized towns; or a dense urban core with narrow streets (Bolzonella et al., 2003). Biosolids from wastewater treatment plants are a form of composting and considered a good soil amendment for a variety of land applications such as use on agriculture crops, fertilizer for park and gardens, and reclamation of mining sites (U.S. EPA, 2010a). Finally, food waste typically consists of 70% moisture content, thus using existing infrastructure designed to manage water has the potential to be an advantageous way to handle this type of waste (Diggelman & Ham, 2003).

Aside from infrastructure benefits, organics recycling through FWDs has other social benefits. Many residents already have FWDs within their households making it easy for them to participate in this program. The potential diversion rate of this scenario within each household also is high as residents grind pre- and post-consumer food waste, and FWDs mince almost any food items, with only highly fibrous wastes and some shellfish being unfit (Marashlian & El-Fadel, 2005). High diversion rates have the ability to decrease the need for municipal solid waste collection and accrue cost saving and environmental benefits from fewer trucks on the road. In addition, FWDs offer on-site continuous disposal which eliminates the need to store food scraps for later collection (Bolzonella et al., 2003). As stated previously, removing food scraps from municipal solid waste eliminates smells and potential pests making it cleaner to collect.

Using FWDs to recycle a city’s food waste bring up concerns in addition to the benefits. Most importantly, not all cities have wastewater treatment facilities with the ability to absorb the extra flow food scraps add to the system. Plus, many older cities have combined sewer systems where the infrastructure for sanitary waste and stormwater run-off are integrated and both receive treatment at wastewater plants. In heavy storm events, excess stormwater inundates the treatment facilities, and combined systems are designed to overflow this mixture of run-off and sewage into local water bodies (Philadelphia Water Department, n.d.). Called combined sewer overflow (CSO), this system has serious implications on the sanitation and quality of a city’s rivers, and the severity of this problem in a particular city would have an impact upon the possibility of using FWDs as an organics recycling option.

In addition, the condition of biosolids, especially for use in land applications, has become an increasing concern in recent years. Wastewater treatment facilities process more than human waste and food scraps as residents also flush many household cleaners, personal care products, and drugs down the drain. While treated and processed to meet strict regulations, concentrations of metals, inorganic chemicals, pharmaceuticals, and hormones are still found in biosolids. Further evaluation of these pollutants is needed to determine the potential risks involved (U.S. EPA, 2010a), especially when biosolids are applied to land. In the end, food scraps that are not combined with biosolids are void of these concerns and may be considered a higher quality, more valuable compost.

Certain cities also experience additional hurdles for this type of food waste recycling program. Building codes should be checked and revised as necessary because not all codes allow the use of FWDs. A comprehensive study in New York City was necessary to overturn a city-wide ban (NYC Department of Environmental Protection, 1997). In areas where the availability of water is a concern, a system like this is not optimal, even though additional water use in homes is negligible. Plus, this organics recycling option does not divert yard trimmings or compostable papers from landfills. Regardless, a public awareness campaign is necessary to inform residents of use of FWDs as a waste management strategy.

Using FWDs as an organics diversion method is simple, straightforward solution that relies on the existing infrastructure of a city. With minimal costs to residents and a city, this option has more benefits than it does drawbacks. For a city starting to understand the extent of its composting potential, FWDs provide a low-cost solution that is easy to structure and implement.

Community-Based Composting

A second alternative for diverting food scraps from municipal solid waste collection is to promote household composting supplemented by a network of composting sites throughout the city. Backyard composting is the most frequently used recycling method and is easily adopted for households that have at least a small amount of outdoor space available. Indoor composting also is possible and especially useful for residents who live in apartments or units without outdoor access. However, some residents may be interested in recycling their food waste but unwilling or unable to compost within their household. By providing a network of drop-off locations throughout a city, community composting programs allow residents to recycle organics regardless of space constraints.

Providing assistance is a way to encourage households to adopt or continue composting. Outreach and education campaigns are an important way to notify the public about the multiple benefits of composting. A city's parks and recreation division, or similar non-profit organization, could consider holding classes on introductory and master composting to teach residents, in a hands-on environment, how to properly compost. Much of the same information offered through a class should be available to residents on a comprehensive website, similar to that of the Los Angeles County Public Works, including composting facts and instructional videos (Los Angeles County Public Works, 2002). A city also should provide a location where residents can purchase, perhaps at a subsidized price, a composting bin, and a tool-rental or sharing program would give residents access to necessary equipment at a low cost. Finally, a compost hotline, similar the ones available through the NYC Compost Project, gives residents the ability to ask questions and find technical assistance along the way (NYC Department of Sanitation, n.d.).

Beyond individual efforts, a network of community-based composting sites can take a variety of forms depending on residents' demands and available funds. This organics recycling option includes three variations, each one building upon the presence of the previous. Ultimately, these options can all be used simultaneously and interchangeably depending on the individual preferences of the residents. The following paragraphs discuss the three possible community variations — Variation 1: Information Sharing Model, Variation 2: Community Drop-Off Model, and Variation 3: Commercialization Model.

Variation 1: Information Sharing Model is the first and most basic level of support by allowing a city to provide networking opportunities for citizens who are interested in composting. Connecting household composters who are willing and able to accept additional food scraps to other households who are looking for a place to compost allows residents to communicate with one another and find a suitable location for their food waste. Philly Compost, an organics recycling collection service in Philadelphia, provides an online map of available composting locations, an example that other cities could follow. This map highlights common composting sites open to everyone and allows households to add privately-owned sites, if they are willing to accept food scraps from others (Philly Compost, n.d.). This type of interface is fairly easy to replicate by any municipality since it requires little funding and is a low maintenance initiative for a city, as local citizens input is most data. However, a service like this is most useful to residents that are self-motivated in diverting food waste from the garbage.

Variation 2: Community Drop-off Model is a network of community drop-off sites for composting at a variety of locations throughout the city. Co-locating sites at existing city facilities such as neighborhood parks, community centers, school yards, or libraries is advantageous, as is teaming up with groups already involved in composting efforts, such as community gardens or urban farms. Cambridge, Massachusetts, for instance, has developed a community partnership with the local Whole Foods Market to allow customers to drop off food scraps in designated bins in their parking lot (Cambridge Department of Public Works, n.d.). Other cities could take advantage of similar opportunities by partnering with large food retailers or restaurants interested in organics recycling.

In a community drop-off model, each site provides composting basics for residents including bins for collection and tools for turning the compost. Residents sign-up for the service at their nearest neighborhood site, and in return, gain access to the location for dropping off their food waste. The sites are run and monitored in several ways: users maintain and turn the bins on an as-needed basis, city funding provides a staff member to monitor and manage compost bins, or members of the partnering groups, such as urban gardens or food retailers, manage the organics. The logistics of this type of operation vary from location to location depending on the amount of community involvement.

As these sites develop, a city has to determine the appropriate number of city-wide locations based upon resident demand and the city's density. Locations also have to be strategically placed throughout the city assuming most residents are willing to walk about a quarter of a mile to a composting site while carrying their organics. Cities need to monitor rules and regulations associated with the use of these sites to ensure the program runs smoothly.

Variation 3: Commercialization Model offer a network scenario strengthened with the addition of small local composting businesses and further public/private partnerships, in demand for community-based sites increase. Grants and loans to local start-ups promote and encourage small-scale businesses that pick-up food scraps and process compost, or these companies charge a small fee to residents to cover the costs of their services. Cities make the locations outlined above, or vacant lots, available to these businesses to run their compost sites. In return, companies give soil back to the city for use on municipal areas or sell it to the surrounding community. In addition, some of these businesses may consider the use of in-vessel organics recycling systems that allow for a greater quantity of food waste to be processed, if demand for composting grows.

For all three variations, many benefits accrue for a city and its residents by encouraging an increase in community composting. First, backyard composting relies completely on human power and nature to turn food waste into rich soil. This eliminates the need to haul food waste to a landfill and saves money for the city through reduced trucking costs and landfill fees. Household composting also incorporates yard trimmings with food scraps allowing for a greater reduction of curbside pick-ups. In addition, composting is beneficial to the residents because it keeps valuable nutrients on-site. These nutrients turn into a rich soil that when used on homeowner’s gardens saves money by eliminating the need to purchase fertilizers.

In addition, promoting household and neighborhood composting has drawbacks. This type of composting allows residents to recycle only certain types of food waste such as fruit and vegetable scraps, coffee grounds, and eggshells. Backyard systems cannot handle materials like meats, fish, and dairy, as they often attract pests, and the heat created by bin composting is not sufficient to kill pathogens possibly present in these foods (PA DEP, n.d.). Excluding these food items reduces the amount of food scraps recycled. Also, a community drop-off model may encourage a limited audience to participate as not everyone is enthusiastic about having to carry their own food waste to a specified location. Even willing participants only travel so far, and this system only attracts households who are eager to make an extra effort to divert their food scraps.

Community-based composting is a way to engage citizens in hands-on efforts to become aware of and reduce food waste. With guidance and monitoring from a city, sites develop that are primarily run by citizens at low cost. Not without its benefits and drawbacks, a community-based composting network is a successful scheme for cities to begin making steps towards organics diversion.

Curbside Collection

This final option examines a city-wide curbside organics collection program, similar to existing municipal trash and recycling services. Certain infrastructure must exist, or be created, to ensure the feasibility of this program. Curbside organics programs are complex, as cities can choose among many options for the type of materials accepted, bins, trucks, routes, and collection frequencies. Education also is an important component to ensure residents separate the appropriate materials and participate in the program. Finally, implementing a pilot program helps a city understand the feasibility of curbside organics recycling and the potential for future expansion.

For a city to begin an organics recycling collection program, certain infrastructure must be in place, or developed. A processing facility with the ability to handle the anticipated organics diversion rate of the city must be located nearby, and organics hauling options must be available to collect and move organics from households to the processing facility. Determining if a city will operate and manage the collection and processing of organics, or contract it out to private companies, also is an important consideration.

Once infrastructure is established, a city must consider what organic materials it will accept, which is highly dependent on the city’s processing facility. Organics are divided into many categories and collected in a wide array of combinations. A simple solution for municipalities with existing curbside yard trimming programs is to add vegetable and fruit scraps, uncoated paper napkins, cups and plates, and coffee grinds and filters to its collection. Cities beginning new programs typically include all food scraps such as vegetable and fruit scraps, breads, cereal, pasta, and meat, fish and dairy products. The inclusion of non-food organics, such as soiled paper, wax cardboard, and compostable plastics, is possible as is the addition of more uncommon items like plastics bags, animal waste, and diapers. While yard trimmings are highly compostable, their addition to organics curbside programs vary depending upon their percentage of the waste stream, presence of existing collection programs, and changes in seasonal volumes.

Collection bins and trucks are critical components of a curbside organics recycling program. Organics have high water content, which makes them heavy to move and lift in large volumes; an average 32-gallon container of food waste weighs 150 pounds (Coker, 2009). Thus collection bins, versus bags, optimize ease of collection for residents and sanitation workers. Therefore, most successful programs provide a rolling, latched bin between 20 and 64 gallons depending on generated organics volumes, which residents place at the curb for collection. Including a small, latched pail to store daily kitchen organics, or suggesting residents come up with their own containers, is helpful for frequent transferring of food scraps into the larger bin (Anderson et al., 2010). Collection trucks come in three forms: non-automated, where workers collect trash manually; semi-automated, where workers move bins into position for an automated system to pick them up; and fully-automated, where mechanical arms reach out and pick up bins. Materials are loaded at the rear, side, or front of trucks, and a single compartment interior collects one type of waste while a split-body interior allows for the collection of multiple types and volumes of waste at once. Retrofitting existing trucks for automation or compartments is possible (Coker, 2009). The number of sanitation workers per truck varies depending upon the truck specifications. A city’s existing collection technique and waste management fleet may influence the type of bins and trucks selected for an organics collection program.

Optimizing the collection of three streams of materials — trash, recycling, and organics — maximizes the efficiency of a curbside program. Weekly collection of organics is favorable to keep putrid materials from lingering in households, and decreased volumes, due to the elimination of organic content in trash, may allow for bi-weekly garbage collection. Less frequent trash collection incentivizes residents to utilize organics recycling bins, but ultimately, collection frequencies may be dependent upon a city’s health code requirement (Anderson et al., 2010). A variety of configurations are available for collection using single and/or split-bodied trucks. Ideally, establishing effective collection combinations and routes allows a city to utilize the fewest trucks possible while minimizing costs, emissions, and vehicle miles traveled.

Outreach to residents to influence behavior change is a critical component of a successful organics collections program. Most residents initially have concerns over smells and pests, however providing information addressing these issues can diminish their reluctance to participate in the program. Outreach materials need to educate residents on how to properly sort organics and provide the details of collection. Informing residents of the proper materials to sort makes storage and collection easier and prevents contamination at organics processing facilities.

Implementing a pilot program is an excellent way to test the logistics of a curbside organics collection program. A pilot allows a city to assess residents’ reaction to the program and the effectiveness of its outreach campaign by tracking participation rates, contamination levels, and residents’ concerns. Projecting anticipated volumes and diversion rates from a small sample will help configure more efficient collection routes and project costs for a full-scale program.

A curbside organics recycling program has plenty of benefits for a city and its residents. Collecting organics in bulk leads to higher diversion rates of municipal solid waste for landfills. Boosting diversion rates often helps meet sustainability goals of a city and reduces environmental and fiscal costs of using landfills. Most curbside programs also collect a variety of materials, such as soiled paper and wax cardboard, which backyard composting is unable to recycle.

Curbside organics programs at a large scale also can have drawbacks. While projects typically accrue long-term savings, upfront costs associated with developing and implementing a program, purchasing collection trucks and bins, and providing outreach to citizens can be a major barrier. Running a full-scale program also requires a substantial amount of time and effort on the part of city employees. As pilot programs and collection initially start, the use of additional trucks may cause an increase in the vehicle miles traveled and carbon dioxide emissions in a city. Finally, a curbside collection system uses additional energy and fuel to transport and process organics.

In conclusion, curbside organics collection is possible with careful development. Having an organics processing facility nearby is essential to begin a program as are available upfront funding and public support. With multiple options in acceptable materials, trucks, bins, and collection frequency, choosing a program that best fits its needs is critical for any city. Furthermore, implementing a large-scale program requires much time and effort, and a city should understand adjustments will be necessary to make a program run most effectively.

IV. A Case Study for Philadelphia

Similar to the United States as a whole, Philadelphia is seeing a shift in how it manages its municipal solid waste. The city is aggressively pursuing residential curbside recycling and looking for additional ways to increase the city's diversion rate, including examining how organics recycling may fit into the city's current programs. Yet, organics diversion is not entirely new to Philadelphia, and the first part of this section provides a background of organics recycling within the city including motivations for establishing a program, presence of organics in the municipal solid waste stream, and existing organics diversion infrastructure. This second portion of this section examines how the scenarios outlined in the previous section — food waste disposers, community-based composting, and curbside collection — would apply to Philadelphia.

A Background of Organics Recycling in Philadelphia

The beginning portion of this capstone section examines how an organics diversion program might fit into the current context of Philadelphia. It investigates the motivations the city has for establishing an organics recycling program and how much organic material is present in the city's municipal solid waste. In addition, having an inventory of existing organics diversion infrastructure in Philadelphia provides a basis for the current organics recycling market, and how it can be developed further.

Program Motivations

Philadelphia aspires to develop an organics recycling program for many of the same reasons previously mentioned in the national trends. More specifically, Philadelphia's comprehensive sustainability plan, *Greenworks Philadelphia*, sets targets to be reached by 2015 that will increase quality of life for the city's residents. By adopting an organics diversion program, the city would make progress towards three of these targets. An organics recycling program has the most impact upon *Target 7: Divert 70 Percent of Solid Waste from Landfill* as composting directly removes food scraps from the municipal solid waste stream and prevents them from entering a landfill. Organics diversion helps the city meet *Target 12: Reduce Vehicle Miles Traveled by 10 Percent* by decreasing the frequency of trash collection services and number of trucks on the roads. An organics recycling program also furthers *Target 5: Reduce Greenhouse Gas Emissions by 20 Percent* by avoiding emissions created by landfills and diminishing emissions from collection trucks (City of Philadelphia, 2009). Finally, organics recycling can potentially save Philadelphia money by reducing collection costs and trash tipping fees.

Waste Composition in Philadelphia

Understanding waste composition is critical to managing waste and developing organics recycling programs. Knowing the percentage and tonnage of organics and food scraps in municipal solid waste helps determine the most appropriate organics diversion program by documenting fiscal and environmental costs and savings. For each organics recycling scenario in Philadelphia, waste composition data are necessary to calculate anticipated participation and diversion rates of organics and/or food scraps.

The U.S. Environmental Protection Agency gives a valuable overview on disposal habits of typical Americans by examining municipal solid waste generation and recycling, which is seen in *Appendix A: Organics Composition in U.S. Municipal Solid Waste*. However, habits vary across different regions in the United States, and a report specific to a particular area is critical for optimizing an effective waste management plan. In Philadelphia, the Streets Department Sanitation Division commissioned consultants to perform a waste characterization study, which was completed in October of 2010. This report highlights many aspects of Philadelphia's waste stream and acts as a comprehensive update to a similar report conducted in 2000 (Philadelphia Streets Department Sanitation Division, 2010).

The Streets Department Sanitation Division is responsible for the waste collection from approximately 540,000 premises in Philadelphia through curbside collection. Service is provided to single residential households, residential buildings with up to 6 units, and small businesses. Collection includes trash, residential renovation waste, and single-stream recycling year round along with bagged leaf collection in November. Due to an expanded single-stream recycling program and increased diversion of highly recyclable materials, organics are a larger percentage of the waste stream in 2010 than in 2000 (Philadelphia Streets Department Sanitation Division, 2010). About 60% of the generated waste is buried in landfills at a cost of $68 a ton, while the remaining 40% is incinerated in waste to energy facilities (McGrath, February 25, 2011) at a cost of approximately $57 a ton (Merritt, 2011).

According to Philadelphia's waste composition study, the city generated approximately 623,000 tons of municipal solid waste between April 2009 and March 2010. Organics, including food scraps, liquid food waste, grass clippings/leaves, brush/pruning, compostable paper, and clean wood, comprise 25.0% of the waste stream, totaling around 155,667 tons. Food scraps alone are the third largest category of generated municipal solid waste at 9.4% or 58,517 tons. Each household serviced by Philadelphia Streets Department generates 577 pounds of organics, including 217 pounds of food scraps, per year. This equates to 11.1 pounds of organics, consisting of 4.17 pounds of food scraps, per household per week (Philadelphia Streets Department Sanitation Division, 2010).

$$All\ Organics$$

$$\frac{organics\ generated\ per\ year}{occupied\ households} = organics\ generated\ per\ household\ per\ year$$

$$\frac{155{,}667\ tons \times 2{,}000\ pounds\ per\ ton}{540{,}000\ households} = 577\ pounds$$

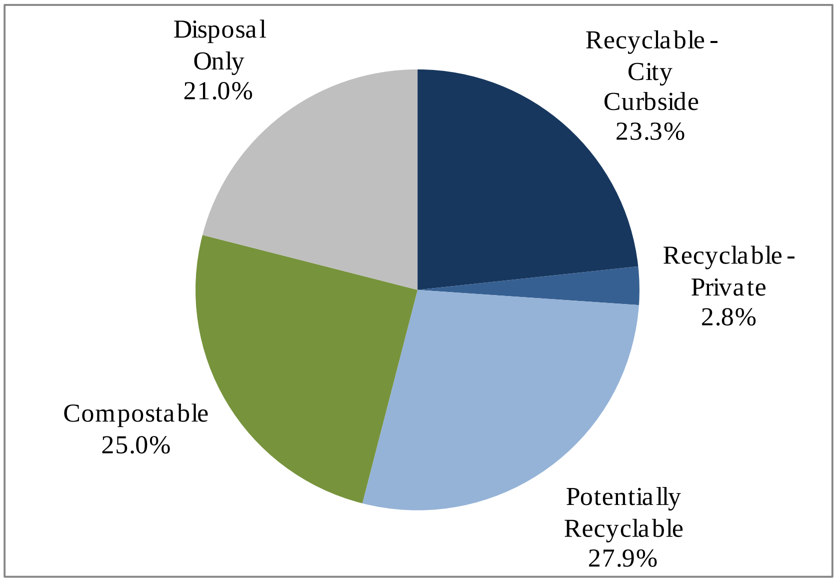
$$Food\ Scraps$$

$$\frac{food\ scraps\ generated\ per\ year}{occupied\ households} = food\ scraps\ generated\ per\ household\ per\ year$$

$$\frac{58{,}517\ tons \times 2{,}000\ pounds\ per\ ton}{540{,}000\ households} = 217\ pounds$$

The potential of Philadelphia to meet its goal of 70% diversion of solid waste by 2015 is seen in *Figure 1: Recoverability of Philadelphia's Residentially Generated Waste.* All of the organic waste, listed above, the city generates is recoverable through organics recycling. With the addition of recyclable and potentially recyclable materials at 54% of the municipal solid waste stream, Philadelphia has the ability to reach a diversion rate of 79%.

Figure 1: Recoverability of Philadelphia's Residentially Generated Waste[1]



Existing Organics Recycling Infrastructure

Although the City of Philadelphia does not have an established municipal program for recycling organics, other sectors are launching an industry within the city. The following is not intended to be an exhaustive list of all the organics diversion options within the city, but a representative sample of existing services. Several organizations, including the Schuylkill Environmental Center, Penn State Cooperative Extension, and Pennsylvania Resources Council, provide composting workshops to residents at a variety of locations throughout the year. Columbus Square Park in South Philadelphia offers a Compost Club to the neighborhood, which is discussed in greater detail in the

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[1] (Philadelphia Streets Department Sanitation Division, 2010)

community-based composting section. Three for-profit businesses, Philly Compost, Bennett Compost, and the Pedal Co-Op, offer organics collection services to residential and commercial customers in the Philadelphia area. Philly Compost also supplies an online user-generated map of available community-based composting sites within the city. Finally, several organics processing facilities are located within the region, including Two Particular Acres in Royersford, Pennsylvania and an industrial facility, Wilmington Organics Recycling Center, which recently opened in Delaware.

Food Waste Disposers

This analysis shows the City of Philadelphia has the appropriate infrastructure in place to support FWDs as an organics diversion strategy for household food waste. The success of this approach depends upon changing residents' behavior and the city's water and streets departments. This section describes how an FWD program would work in Philadelphia considering installation and repair costs to residents, increased volumes, energy use, and cost to the water department as well as likely diversion rates influencing municipal solid waste tipping fees and greenhouse gas emissions.

As organics recycling for this scenario starts in the home, this program option for Philadelphia begins with the implications to a typical homeowner. Being a city with an older housing stock, this paper assumes approximately 25% of units currently have FWDs, compared with an estimated national average of 50% (Marashlian & El-Fadel, 2005). Many households and apartments require installation of FWDs to participate in the program. At Lowe's, a one-half to three-quarters horsepower household FWD ranges from approximately $99 to $249, and the store offers an installation/replacement service for $115, if a home is already equipped with the necessary hook-ups (Lowe's Home Improvement, 2011). In instances where additional plumbing or electrical work is needed, prices may increase depending upon the conditions within each home. FWD installation will require a minimum investment of about $200 to $375 per household.

While the cost of initial installation is significant, the following calculations show the added energy and water use and costs to residents are negligible. An average household running a one-half to three-quarters horsepower FWD for approximately 36 seconds per day (Evans et al., 2010), consumes an additional 1.70 kilowatt-hour (kWh) per year.

$$average\ power\ of\ a\ FWD \times amount\ of\ time\ used\ per\ year = kWh\ per\ year$$

The Pennsylvania Public Utility Commission lists the electric generation prices of 25 different electric suppliers in Philadelphia with the average price equaling 9.12 cents per kWh (Pennsylvania Public Utility Commission, 2011). Consuming an additional 1.70 kWh per year, by using a FWD, amounts to an extra 15.5 cents per year to a household electric bill.[2]

$$\begin{aligned} &electricity\ use\ per\ year \times cost\ of\ electricity \\ &\qquad = cost\ of\ additional\ electricity\ use\ per\ year \end{aligned}$$

As previously noted in this capstone, a household creates 217 pounds of food scraps per year. Assuming households grind an estimated 75% of food scraps and use on average 1.4 gallons of water per one pound of food scraps to help flush the food waste through the FWD grinding chamber (Marashlian & El-Fadel, 2005), a household with a FWD uses an additional 228 gallons of water per year.

$$\begin{aligned} &pounds\ of\ food\ scraps\ per\ year \times gallons\ of\ water\ per\ pound\ of\ food \\ &\qquad = gallons\ of\ water\ per\ year \end{aligned}$$

The Philadelphia Water Department charges a fee to all residential customers for water and wastewater use. Most households have a 5/8-inch size meter and are charged \$29.85 per 1000 cubic feet for water usage and \$21.30 per 1000 cubic feet for wastewater generation (Philadelphia Water Department, 2010). At an additional 228 gallons, or 30.4 cubic feet, per year of water usage, a household is charged an extra \$1.56 on their existing water and wastewater bill.

$$water\ use\ per\ year \times cost\ for\ water\ use = cost\ of\ additional\ water\ use\ per\ year$$

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[2] This calculation includes additional generation charges only and does not include transmission or service charges.

Similar to the energy and water use impacts upon individual households, the influence FWD use has on the city's water infrastructure also is insignificant, when compared with overall daily use. The Philadelphia Water Department currently runs three wastewater treatment facilities, which collect the extra wastewater if FWDs are to be used for recycling organics. In 2008, these facilities had a total capacity of one billion gallons daily during wet weather conditions, but treated an average of 461 million gallons per day (mgd). The water department also runs nine pumping stations which treated an estimated 458 mgd in 2008 (Crockett, February 2, 2011).

The additional volumes of wastewater and water created by a FWD organics recycling program depend upon the achieved diversion. With a U.S. Census household population of 566,697 in Philadelphia (U.S. Census Bureau, 2011), this section assumes a current diversion rate of 25%, and examines scenarios of 50%, and 75% diversion rates as the program and FWD installation grows. Given these assumptions, added wastewater ranges from 0.097 mgd to 0.290 mgd across the three plants and is an additional 0.02% to 0.06% load per day. The additional water volume is 0.088 mgd to 0.265 mgd over all nine pumping stations adding 0.02% to 0.06% in increased demand.

$$(gallons\ of\ food\ waste + gallons\ of\ water)\ per\ year\ per\ household \times number\ of\ households = additional\ wastewater\ volume\ per\ year$$

$$gallons\ of\ water\ per\ year\ per\ household \times number\ of\ households = additional\ water\ volume\ per\ year$$

Added energy use also occurs at the wastewater treatment plants to treat the extra flow and at the water treatment plants to treat the additional water needed to flush the food waste through the system. The wastewater treatment facilities currently use approximately 794 kWh per million gallons per year while the water treatment plants use around 856 kWh per million gallons per year (Crockett, February 2, 2011). The total added energy use for the wastewater plants ranges from 28,000 kWh to 84,100 kWh per year while additional energy use for the water treatment plants is from 27,600 kWh to 82,800 kWh per year.

$$[(gallons\ of\ food\ waste + gallons\ of\ wastewater) \times energy\ use]\ per\ year\ per\ household \times number\ of\ households = additional\ wastewater\ energy\ use\ per\ year$$

$$(gallons\ of\ water \times energy\ use)\ per\ year\ per\ household \times number\ of\ households = additional\ water\ energy\ use\ per\ year$$

For a full range of data on additional volumes and energy use of the Philadelphia Water Department, see *Table 1: Impacts on the Water Department per Year Using Food Waste Disposers.*

Table 1: Impacts on the Water Department per Year Using Food Waste Disposers

	Baseline	Potential Increase	
Diversion Rate of Food Scraps	25%	50%	75%
Added Volume to WWTP (mgd)	0.097	0.193	0.290
Added Energy Use at WWTP (kWh)	28,019	56,038	84,057
Added Volume at WTP (mgd)	0.088	0.177	0.265
Added Energy Use to WTP (kWh)	27,603	55,205	82,808
Net Added Energy (kWh)	55,622	111,243	166,865

The cost per kWh at the wastewater treatment plants is 6.9 cents while the cost per kWh at the water treatment facilities is 6.0 cents (Crockett, February 2, 2011). This results in an added cost of $384 to $1,150, per year, for wastewater treatment use and $321 to $964 for water treatment use. That is a total added cost of $705 to $2,120[3] to the Philadelphia Water Department.

$$added\ energy\ use\ per\ year \times cost\ of\ energy\ use = added\ energy\ use\ cost\ per\ year$$

Philadelphia's wastewater treatment facilities filter solids from wastewater, as the U.S. EPA requires 85% of suspended solids to be removed from the final treated effluent. After this treatment process, Philadelphia sends suspended solids, or sludge, to the Biosolids Recycling Center, a facility run by a private company under a contract with the city. The facility dewaters the sludge producing a biosolids cake, which is approximately

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[3] Cost calculations do not include the added costs of dewatering biosolids or maintenance for sewers, water treatment plants, and wastewater treatment plants due to minimal increased use.

30% solid and 70% water. A variety of land applications are used for 70% of the biosolids cakes while the remaining 30% are directly landfilled (Philadelphia Water Department, n.d.). Using FWDs as a method for recycling organics initially diverts all food waste flushed down the drain from reaching a landfill, but some that food waste is not recycled due to the city's current practices of landfilling a portion of its biosolids.

Despite low additional costs for extra water and energy use in households as well as at various treatment plants, this scenario saves the most money by diverting food scraps from landfills and incinerators. Assuming 30% of the biosolids cakes are still landfilled, diversion of food waste varies from 8,580 tons to 25,700 tons[4] in these FWD scenarios. This option saves an additional \$346,000 to \$1,040,000 per year tipping fees for the Philadelphia Streets Department.[5]

$$\begin{aligned} &tons\ of\ food\ scrapes\ per\ year\ per\ household\ \times number\ of\ participating\ households \\ &\quad = \ tonnage\ of\ food\ scraps\ diverted \end{aligned}$$

The use of food waste disposers also decreases net greenhouse gas emissions. Avoiding landfilling food scraps eliminates 974 to 2,920[6] metric tons of carbon dioxide equivalents ($MTCO_2e$) per year. Added energy use from the Philadelphia Water Department and participating households produces an additional 152 to 455[7] $MTCO_2e$ depending on the diversion rate while applying biosolids in land applications acts as a carbon sink for 2,060 to 6,180 $MTCO_2e$. Overall, recycling food scraps by utilizing FWDs has net greenhouse gas emissions of -2,880 to -8,640 $MTCO_2e$ per year.

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[4] Some households not serviced by the Streets Department may decide to use FWDs as an organics recycling option. As their food waste is not currently calculated into Philadelphia's overall tonnage, diversion rates for this program may not directly reflect the impact upon the city's tonnage, waste transportation, and tipping fees.

[5] Revenue saved only accounts for the reduction in tipping fees and does not include money saved on decreased transportation costs or fewer work hours.

[6] Carbon dioxide equivalent emissions are calculated as following: composting includes soil carbon storage; combustion include nonbiogenic CO_2, N_2O emissions, avoided utility emissions, and transportation emissions; and landfill includes CH_4 emissions, long-term carbon storage, avoided utility emissions, and transportation emissions (U.S. EPA, 2006).

[7] Emissions from energy use are calculated from the U.S. EPA's Power Profiler (U.S. EPA, 2011c).

$$\begin{gathered} tons\ of\ food\ scraps\ diverted \times MTCO_2e\ per\ ton\ from\ landfills \\ = avoided\ MTCO_2e\ from\ landfills \end{gathered}$$

A complete summary of the water and energy uses and additional savings to the city based upon the various diversion rates is shown *in Table 2: Diversion, Costs, and Emissions per Year Using Food Waste Disposers.*

Table 2: Diversion, Costs, and Emissions per Year Using Food Waste Disposers

	Baseline	Potential Increase	
Diversion Rate of Food Scraps	25%	50%	75%
Tonnage Divered	8,578	17,156	25,735
Energy Costs (Savings)	$705.09	$1,410.18	$2,115.26
Tipping Fees (Saving)	($345,915)	($691,830)	($1,037,745)
Net Cost (Savings)	($345,210)	($690,420)	($1,035,630)
Emissions (Avoided) ($MTCO_2e$)	(974)	(1,948)	(2,922)
Emissions Added ($MTCO_2e$)	152	303	455
Emissions (Sink) ($MTCO_2e$)	(2,059)	(4,118)	(6,176)
Net Emissions (Savings) ($MTCO_2e$)	(2,881)	(5,763)	(8,644)

In addition to energy, water, and diversion calculations, other items are necessary for an FWD-based organics diversion program to be successful in Philadelphia. As the installation, repair, and replacement costs of FWDs in this scenario falls to homeowners, the city should consider providing incentives through rebates and subsidizes to encourage their purchase and use. Plus, amending the existing building code to require the installation of FWDs in renovations or new construction would increase market penetration over time and help decrease the financial burden upon homeowners.

Water is abundant in Philadelphia and lack of access does not hinder this type of organics recycling option. Along a similar line, rainfall is frequent and being an older city in the Northeast, Philadelphia has difficulty with CSO compliance during storm events. Currently, a combined sewer overflow system serves half of the city (Philadelphia Water Department, n.d.). However, the wastewater volumes added by a FWD organics recycling program are so small in comparison with current daily generation adopting such a program does not severely impact CSO issues. Implementing an outreach campaign about water use, in general, during periods of heavy rainfall could educate residents about CSO concerns to counteract the small amounts of additional water from FWDs.

The end use of Philadelphia's biosolids has a significant influence on the success of using FWDs as an organics diversion option. The application of biosolids on the land closes the loop for food waste by returning nutrients to the earth. In contrast, the impacts of landfilling biosolids do not differ much from retaining food scraps a part of the municipal solid waste stream. If Philadelphia chooses to implement a program utilizing FWDs, the city also must consider recycling 100% of the remaining biosolids to reduce the fiscal and environmental impacts upon the city.

The data in this section shows implementing an organics recycling program in Philadelphia by using FWDs is feasible. Increased costs of energy and water use to residents are insignificant, although costs for installing an FWD could be a barrier to adoption. These costs, however, could be defrayed by the implementation of rebate and subsidy programs. Furthermore, the implications upon the water and wastewater infrastructure of the city are minimal. In the end, the potential diversion rates of food scraps from municipal solid waste and subsequent cost savings would be positive benefits to the city. Providing public outreach to educate residents about the simplicity and overall benefits of this program, while molding behavior change, would be critical to its success.

Community-Based Composting

Philadelphia has a multitude of resources for starting a network of community-based composting sites within the city, and the following section proposes a potential solution while exploring its benefits and costs. With an existing information sharing system already in place, Philadelphia would benefit from a community drop-off system for its residents. This section includes a discussion of composting logistics and equipment, diversion rates with corresponding cost savings, and greenhouse gas emissions as well as approaches for scaling-up the program.

Prior to implementing a new composting program, Philadelphia needs to provide basic information about composting to its residents to encourage the success of backyard composting as well as new community-based sites. As limited resources are available to groups interested in composting, the city should provide educational materials, especially online resources. Information for residents should be supplemented with hands-on composting classes, taught by the city or other outside organizations, as well as the consideration of providing backyard composting bins to residents at a subsidized price. In addition, a public outreach campaign about composting would make residents aware of its benefits while also enticing participation.

With the availability of basic composting information in place, establishing a monitoring agency would enable a community-based drop-off program in Philadelphia to be successful. Philadelphia Parks & Recreation (PPR) is an obvious choice for overseeing a community-based composting initiative, as partnering with PPR would locate sites on current city-owned land where they can be monitored as needed. Through its various parks and recreation facilities, this department runs a variety of locations throughout the city suitable for hosting small composting efforts. Many of these facilities have established a rapport with surrounding residents and can act as facilitators of this program by providing basic materials, education, and assistance as necessary. In line with the future goals of PPR, this moves the department in new directions of programming and community involvement, beyond the traditional role of Philadelphia's recreation facilities (Blaustien, February 15, 2011).

A precedent for this program already exists within Philadelphia on PPR property. Columbus Square Park, at 12th and Wharton streets in South Philly, offers a composting club to its recreation center members. The Columbus Square Advisory Council approved the club, and it started in the summer of 2009. A $5 registration fee is required, and members follow informal guidelines in return for being permitted to leave food scraps at the park's composting site. Currently, 15 to 20 people participate in the program, and the layout consists of two Earth Machine bins located behind the batting cage of the park's baseball diamond (Columbus Square Park, n.d.; Verrecchia, 2011). This type of model is easily replicable to create more community-based locations throughout the city.

In this option for Philadelphia, developing a plan for the establishment of composting sites is important to building a community-based program from the ground up. Determining the location and demand for composting sites is a critical first step. Neighborhood community groups and recreation facility advisory boards can help PPR determine which areas of the city are already interested in composting. In areas with documented demand, PPR can establish a community-based composting site in park or recreation facilities. Pilot sites in several locations around the city would gauge interest in the program and gather knowledge for potential expansion in the future. Providing order and structure to these sites also is an important part to PPR's management of such a program. A suggested list of rules for PPR to provide is included in *Appendix B: An Example of Philadelphia Parks and Recreation Community-Based Composting Rules*. A city-provided foundation would allow residents to take on the majority of the burden of running the operation, making it a minimally-monitored and low-cost venture for the city.

An outline of the technical and logistical feasibility of this type of composting program in Philadelphia is below. Addressing the type and size of bins, number of bins per site, proper mixture of organic components in compost, and time frame for compost to cure are all important aspects to consider. This section also establishes a framework to determine the amount of food scraps this program would divert depending on household participation rate and distribution of sites, and the program's potential cost savings.

The composting bins in this diversion scenario are built from wooden shipping pallets encased in chicken wire. The most common type of wooden pallet in the U.S. is 48" by 40" in size. This sized pallet comprises about 30% of new construction in the pallet market each year and is used in the grocery industry, among many others (Clarke, 2004). Obtaining used pallets from these industries at low to no cost may be possible, and reusing pallets is a great way to prevent them from going into a landfill. An example of this type of bin is shown in *Figure 2: Example of a Pallet Compost Bin.*

Figure 2: Example of a Pallet Compost Bin[8]

The appropriate bin size is critical for maintaining productive compost. A bin should be larger than 3 ft by 3 ft by 3ft (27 cubic feet), as the decomposition process requires a certain mass to maintain a high temperature in the center of the pile as the compost cures. At the same time, a pile should not be too large as it may prevent valuable air flow from moving through the compost. Experts suggest a bin should not be larger than 5 ft by 5 ft by 5 ft (125 cubic feet) (Los Angeles County Public Works, 2002).

Using the described pallet, a 48" long by 40" wide by 40" high bin is easy to construct and within recommended dimensions. A bin is formed using four pallets for sides, with three of them fixed and the fourth attached to hinges to allow easy access into the bin, as needed. Another pallet acts as the top to keep the bin covered at all times, but is on hinges to allow households to open the top to leave their food scraps inside. If desired, a sixth pallet could be used as a bottom piece instead of the ground. Considering these bins are kept outside, wrapping the bin with chicken wire to keep out unwanted animals also is important.

Each composting location constructs two adjoining bins. One bin is actively decomposing into soil while the other acts as a holding tank being filled with scraps. How often the bins switch tasks depends on how fast the compost decomposes and how often the pile is physically turned. Repeating the process of aerating a pile, after it has been hot for three to five days, develops finished soil in one to four months (Los Angeles

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[8] (Lamborn, 2010)

County Public Works, 2002). This scenario assumes an average of two months is necessary for the decomposition process.[9] Once finished, the bin is emptied of its soil and begins collecting new scraps while the other, now full, bin begins to cure.

The concentration of organics within compost impacts its decomposition time and final soil quality. Carbon and nitrogen are two important components in the natural environment and play a large role in composting. A typical pile needs a carbon to nitrogen ratio of approximately thirty to one. This is achieved by adding approximately equal parts of carbon-rich “browns” — dead leaves, straw, wood chips, soiled paper and newspaper — and nitrogen-rich “greens” — vegetable scraps, coffee grounds, and grass clippings (Los Angeles County Public Works, 2002). Therefore, each bin will only accept household foods scraps for about half of its volume. Each site retains a supply of “browns,” which users will add to the compost bin each times they drop-off food scraps.

As previously noted, a typical Philadelphia household creates 4.17 pounds of food scraps each week. However, since food scraps, like meat and dairy products, are not acceptable for backyard composting systems, a community-based composing scenario will not divert this entire amount. As insufficient data is available to determine what percentage of food scraps made up of these products, this study assumes an average household would compost approximately 75% of their generated food waste. Therefore, about 3.13 compostable pounds are produced per household per week. Although yard trimmings can be processed in a community-based program, they are not included in this capstone due to inconsistent volumes generated seasonally and by location, within Philadelphia.

Knowing the weight of food waste created is critical to determining how much volume the food occupies, and thus, how many households can use a single bin. According to U.S. EPA estimates, a 55 gallon drum of food scraps is equal to 412 pounds or 0.133 gallons per pound (U.S. EPA, 1997). At 3.13 pounds of food scraps per week, a household creates 0.416 gallons of food waste.

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[9] Rates of decomposition may vary depending on the time of year with curing being faster in hot, summer months and longer during cold, winter months.

$$\begin{gathered}\mathit{pounds\ of\ food\ scraps\ per\ week\ per\ household} \times \mathit{number\ of\ gallons\ per\ pound} \\ = \mathit{gallons\ of\ food\ scraps\ per\ week\ per\ household}\end{gathered}$$

Each bin collects a household's food scraps for 8 weeks, a total of 3.33 gallons per household, before the bin begins to cure.

$$\begin{gathered}\mathit{gallons\ of\ food\ scraps\ per\ week\ per\ household} \times \mathit{number\ of\ weeks\ to\ cure\ compost} \\ = \mathit{number\ of\ gallons\ per\ household\ per\ bin}\end{gathered}$$

A 48" by 40" by 40" constructed pallet bin holds 44.4 cubic feet, making it capable of holding 332 gallons. As previously mentioned, food scraps only account for approximately half of a bin's volume, or 166 gallons. With each household creating 3.33 gallons per 8 weeks, one community bin supports food waste from 49 households.

$$\frac{\mathit{number\ of\ gallons\ per\ bin}}{\mathit{number\ of\ gallons\ per\ household\ per\ bin}} = \mathit{number\ of\ households\ per\ bin}$$

$$\begin{aligned}&\mathit{number\ of\ households\ participating} \\ &\qquad \times \mathit{tons\ of\ food\ scraps\ diverted\ per\ year\ per\ household} \\ &\qquad = \mathit{tons\ of\ food\ scraps\ diverted\ per\ year}\end{aligned}$$

Installing a single site of two bins diverts 3.98 tons a year and saves the city $253 on landfill and incineration tipping fees.[10] If the project starts with five pilot sites, it will save an average of $1,270 a year in tipping fees and divert almost 20 tons of food scraps from a landfill or incinerator. As the program grows, the city can gauge success through additional tons diverted and their associated cost savings. Considering the nature of this organics recycling program, food scraps diversion rates of 5% and 10% are realistic long-term goals.

$$\begin{aligned}&\mathit{tons\ of\ food\ scraps\ per\ year\ in\ Philadelphia} \times \mathit{desired\ diversion\ rate} \\ &\qquad = \mathit{tons\ of\ food\ scraps\ per\ year\ in\ need\ of\ diversion}\end{aligned}$$

Initially as the city implements a small pilot program of 5 sites, locating community-based composting sites on PPR property is possible, assuming areas of

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[10] Revenue saved only accounts for the reduction in tipping fees and does not include money saved on decreased transportation costs or fewer work hours.

demand coincide with the location of a PPR facility. PPR currently has approximately 150 recreation centers and 60 regional and neighborhood parks around the city. Recreation centers serve most neighborhoods within Philadelphia and are distributed relatively evenly throughout the city, while parks are concentrated around the rivers and streams (City of Philadelphia, n.d.). Assuming a majority of these 210 facilities have the ability to host a composting site, providing enough sites to reach a 0.5%, or even a 1.0%, diversion rate in food scraps would be fairly easy.

As Philadelphia moves toward 5% and 10% diversion rates of its food scraps through this community drop-off program, more composting sites will be needed than are available through PPR property. Identifying extra composting sites requires the cooperation of additional organizations such as other city departments, local schools, community gardens, urban farms, and private retailers. The School District of Philadelphia alone maintains 331 public and charter schools distributed throughout the city, many of which have adjacent schoolyards that may act as potential composting sites (The School District of Philadelphia, 2011). Partnering with other organizations is one of the only ways to make a large-scale network of community composting drop-off sites feasible.

A 5% diversion rate of food scraps is equivalent to 0.35% of Philadelphia's total waste stream and a savings of $140,000 in tipping fees each year. At 2,190 tons of food scraps per year to achieve a 5% diversion rate, Philly needs approximately 27,000 or about 5% of serviced households[11] to participate. At 49 households per site, a 5% diversion rate requires about 550 composting sites.

$$\frac{pounds\ of\ food\ scraps\ diverted\ each\ week}{pounds\ of\ food\ scraps\ per\ week\ per\ household} = number\ of\ participating\ households$$

A 10% diversion rate of food scraps is equivalent to 0.71% of Philadelphia's total waste stream saving $279,000 in tipping fees a year. This tonnage also equates to 4,390

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[11] Some households not serviced by the Streets Department may decide to this community-based network as an organics recycling option. As their food waste is not currently calculated into Philadelphia's overall tonnage, diversion rates for this program may not directly reflect the impact upon the city's tonnage, waste transportation, and tipping fees.

tons of food scraps per year in need of diversion, requiring approximately 54,000 households, or 10%, to participate. The creation of around 1,100 composting sites with 2,200 bins throughout the city is needed to support this participation level.

Backyard and community composting provides a sink for carbon dioxide as well as reduces the amount of greenhouse gas emissions released from food scraps in landfills. A single community-based composting site consumes 0.96 $MTCO_2e$[12] and eliminates almost 3 $MTCO_2e$ per year, while a larger scale program diverting 10% of food scraps sinks 1,100 $MTCO_2e$ and saves around 2,500 $MTCO_2e$ per year. Avoided landfill emissions range from 1.43 to 1,580 $MTCO_2e$ per year.

$$\begin{gathered} tons\ of\ food\ scraps\ diverted \times MTCO_2e\ per\ ton\ from\ landfills \\ = avoided\ MTCO_2e\ from\ landfills \end{gathered}$$

Tons diverted, tipping fees saved, emissions data, and program participation is shown in *Table 3: Community-Based Composting Statistics per Year* for food scrap diversion rates of one site to 10%.

Table 3: Community-Based Composting Statistics per Year

Diversion Rate of Food Scraps	1 Site	5 Sites	0.50%	1%	5%	10%
Tonnage Diverted	3.98	19.9	219	439	2,194	4,389
Tipping Fees (Savings)	($253)	($1,266)	($13,956)	($27,913)	($139,563)	($279,126)
Emissions (Avoided) ($MTCO_2e$)	(1.43)	(7.17)	(79.0)	(158)	(790)	(1,580)
Emissions (Sink) ($MTCO_2e$)	(0.96)	(4.78)	(52.7)	(105)	(527)	(1,053)
Households Needed	49	245	2,700	5,400	27,000	54,000
Community Sites Needed	1	5	55	110	550	1,100
Composting Bins Needed	2	10	110	220	1,100	2,200

The location of composting sites is important to see the approximate distances people travel to participate in this community-based program. According to the U.S. Census data, Philadelphia had 135.09 square miles of land (U.S. Census Bureau, 2011).

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[12] Carbon dioxide equivalent emissions are calculated as following: composting includes soil carbon storage; combustion include nonbiogenic CO_2, N_2O emissions, avoided utility emissions, and transportation emissions; and landfill includes CH_4 emissions, long-term carbon storage, avoided utility emissions, and transportation emissions (U.S. EPA, 2006).

$$\frac{area\ of\ Philadelphia}{number\ of\ composting\ sites} = square\ miles\ served\ per\ site$$

Assuming even geographic distribution, a 5% diversion rate of food scraps requires sites at a 0.5 mile radius, which is approximately equivalent to a five block walk for residents. At a 10% diversion rate of food scraps, a site is necessary more frequently at every 0.35 mile radius or about a three and a half block walk. Both of these distances are roughly comparable to the desired ten minute walking distance used in many of *Greenworks Philadelphia's* initiatives (City of Philadelphia, 2009). However, these numbers only act as an estimate and vary depending on the density and demand of a neighborhood and the availability of sites within that neighborhood.

Aside from program logistics and potential environmental and financial savings, costs are equally important to consider. The materials costs for the construction of an initial bin are approximately $105, plus tax (Lowe's Home Improvement, 2011). The cost of each subsequent bin are lower, from $40-80, as certain tools are a one-time purchase and other materials, such as nails and staples, come in larger quantities and are purchased as needed.[13] At an initial pilot of five sites, maintenance costs also are a consideration as an employee[14] is necessary to help monitor the sites at the cost of approximately $2,525 a year for these five sites. This employee is responsible for constructing the bins, transporting "browns" to each site, removing finished soil from each site as needed, and a small amount of community outreach. If the program proves to be a success, this employee also may take a larger role in technical assistance and outreach to residents. More specific community-based composting cost information is available in *Table 4: Community-based Composting Material and Maintenance Costs*.

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[13] These are retail prices taken from Lowe's and do not consider potential saving from discounted bulk purchases or materials already owned by PPR.

[14] The assumption is this part-time employee would earn $25 an hour.

Table 4: Community-based Composting Material and Maintenance Costs

Materials			
One Time Purchases	quantity	price	total
Flathead screwdriver	1	$0.88	$0.88
6" cutting pliers	1	$7.97	$7.97
Light duty staple gun	1	$14.24	$14.24
Subtotal			$23.09
As Needed Purchases	quantity	price	total
1-1/4" wood screws - box of 100	1	$3.98	$3.98
1/2" staples - box of 1250	1	$2.97	$2.97
Wire netting - 48 in x 50 ft	1	$35.00	$35.00
Subtotal			$41.95
Per Site (2 bins) Purchases	quantity	price	total
Used wooden pallets	9	free	$0.00
1" corner brace	4 packs of 2	$1.52	$6.08
4" T-hinge	8	$1.78	$14.24
4" gate latch	2	$3.48	$6.96
Compost aerator	1	$12.98	$12.98
Subtotal			$40.26
Initial total - one time, as needed & per site purchases		$105.30	
Subsequent totals - as needed & per site purchases		$40.26 to $82.21	

Maintenance	5 bins	10%
	hours per year	hours per year
Bin construction (2 hours / per bin)	10	2,204
Transport browns to site, removal of finished soil (2 hours / 8 weeks)	13	2,865
Community outreach (1.5 hours/ week)	78	17,191
Total	101	22,260
For employees earning $25 per hour	1 employee	9 FTE employees
Salary per employee per year	$2,525	$2,525
Total salary costs per year	$2,525	$556,510

Creating a community-based composting network in Philadelphia is a feasible option for the city as it begins exploring the diversion of organics. By beginning in neighborhoods with existing demand, the city can recycle food waste into a valuable resource while also reducing waste transportation and tipping fees. While this scenario will not make a huge dent in the city's overall municipal solid waste diversion rate, the co-benefits achieved through this program are valuable, and incremental expansion as demand grows will have an increasing impact on environmental and cost savings for the city. Establishing a monitoring agency and appropriate plan for implementation are essential components for launching this type of program within Philadelphia.

Curbside Collection

A curbside organics recycling program for Philadelphia is feasible but would require a greater investment of time and money than the previous two options. Regardless, a full-scale organics collection program could be a successful long-term solution to manage the city's municipal solid waste. The following section explains how a program of this nature could develop in Philadelphia, including the equipment and education necessary, and the costs and benefits it would provide.

Existing facilities in the region could process organics diverted through a curbside program in Philadelphia, but a system would need to be developed to transport the waste. While it would be possible to contract this task out to a private company, this scenario examines how the City of Philadelphia Streets Department would conduct collection. The Streets Department currently owns and operates its own fleet of vehicles for curbside collection of municipal solid waste and recycling. Due to narrow streets and limited storage space, residents place trash into bags and recyclables into small bins. With no heavy lifting required, collection trucks are non-automated and call for three sanitation employees to operate the truck and collect the refuse and recyclables. Each weekday, Philadelphia employs approximately 140 trucks for trash collection and 70 trucks for recycling services (McGrath, February 25, 2011).

To collect organics successfully, Philadelphia would need to venture away from bagged service and offer bins for storage and collection. In the scenario examined below, the city provides each household a 32- or 64-gallon latched, wheeled bin to place curbside and allows residents to determine what they will use to store food waste within the kitchen. The program maximizes its diversion efforts by collecting a wide array of materials including: all food scraps counting meat, fish and dairy products, compostable paper products, clean wood, and yard trimmings. No oil-based plastics are allowed and should residents choose to line their bins, they must do so with paper or compostable plastic.

With the ability of the composting facility to process all organics, the potential diversion rate of the city rises significantly. As previously mentioned, Philadelphia produces almost 156,000 tons of organics per year, of which food scraps account for a little over one-third. At a 25% diversion rate of organics, or 6.24% of the total waste stream, the city diverts 38,900 tons of organics from the landfill. With a bulk operation, diversion rates of 50% and 75% of organics would redirect 77,800 and 117,000 tons. A 100% diversion of organics would eliminate all 156,000 tons, representing 25% of the overall waste stream.

$$\begin{aligned} &tons\ of\ organics\ per\ year \times desired\ diversion\ rate \\ &\qquad = tons\ of\ organis\ per\ year\ in\ need\ of\ diversion \end{aligned}$$

As in previous scenarios, diversion lowers costs by reducing landfill and incineration tipping fees. However in this scenario, organics processing tipping fees also exist. At the Wilmington Organics Recycling Center, costs range from the high \$30s to high \$40s per ton depending upon the material (Sullivan & Goldstein, 2010), but this price is lower than the City of Philadelphia currently pays to landfill and incinerate waste. At a minimum, recycling 25% of the city’s organics saves \$724,000[15] a year. At 50% and 75% diversion rates of organics, costs savings yield \$1,450,000 and \$2,170,000 yearly. One hundred percent diversion saves Philadelphia almost \$2.9 million per year. Organics diversion rates and costs are below in *Table 5: Curbside Organics Diversion and Costs per Year*.

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[15] Revenue saved only accounts for the elimination of landfill and incineration tipping fees and addition of organics processing tipping fees. Changes in transportation costs or work hours are not included.

Table 5: Curbside Organics Diversion and Costs per Year

Diversion Rate of All Organics	25%	50%	75%	100%
Tonnage Divered	38,917	77,834	116,750	155,667
Percentage of Waste Stream	6.24%	12.5%	18.7%	25.0%
Landfill and Incineration Tipping Fees (Savings)	($2,475,105)	($4,950,211)	($7,425,316)	($9,900,421)
Organics Tipping Fees	$1,751,254	$3,502,508	$5,253,761	$7,005,015
Net Costs (Savings)	($723,852)	($1,447,703)	($2,171,555)	($2,895,406)

Under this scenario, organics collection occurs weekly, but separate from trash and recyclables, in semi-automatic, rear-loading trucks. Currently using 70 trucks making one trip to a transfer station per day for recycling pick-ups, the Streets Department Sanitation Division is able to provide weekly curbside collection for 540,000 households. Since the recycling fleet is able to cover the entire city, a similar fleet of 70 trucks is adequate to collect Philadelphia's organics curbside. With almost 350 compactors in the existing fleet and 20% down at any given time for maintenance, the city has approximately 275 trucks available for routes. With 210 trucks in use for trash and recycling collection each day (McGrath, February 25, 2011), 65 trucks are available for organics collection, almost enough to run an entirely separate third fleet of trucks, if desired.

In the proposed scenario for Philadelphia, running several pilot routes, in select neighborhoods with good recycling rates and variations in demographics, gauges the feasibility for a city-wide program. As a pilot does not require an entire fleet of trucks initially, the Streets Department retrofits part of its existing fleet to operate rear-loading two-cart tippers for organics collection. Using the responses in the pilot neighborhoods to inform any changes that need to be made, the city tweaks a full-scale program before rolling it out. With the addition of an organics collection scheme for the entire city, trash collection decreases, giving the city the ability to retrofit its existing trash and recycling fleets to collect the materials simultaneously in the same truck. Due to the seasonable volume variations of organics, the Streets Department Sanitation Division continues to collect organics separately in single purpose trucks. The city develops new routes for trash and recycling, as well as organics collection, to account for the distances and volumes trucks cover and collect each day.

This approach allows Philadelphia to utilize its existing fleet and avoids purchasing any new collection trucks. In the end, the city needs to retrofit approximately 70 organics trucks to operate cart tippers. Using retrofit costs based on a similar project in another city, this addition costs approximately $4,000 per truck (Culbertson & Bowles, 2006) with total upfront costs for organics truck retrofits equaling $280,000. With the addition of organics collection, the remaining volume of trash is reduced by approximately one-third (Anderson et al., 2010). By removing one-third of the trash fleet, only 75 trucks[16] are needed to perform trash collection. Utilizing this reduced number of trash trucks still provides adequate service to residents as 70 recycling trucks are currently able to physically cover the entire city each week. With the addition of the current number of recycling trucks, a total fleet of 145 trucks provides dual-collection of trash and recycling to the entire city. To provide this combined service, the city must retrofit existing trash and recycling trucks to split-body, pivoting compartments.[17]

Under this scenario, Philadelphia uses only five additional trucks for its three-pronged curbside collection than its existing scheme for trash and recycling services. Purchasing new trucks occurs on an as-needed basis as the fleet is occasionally upgraded, and these additional vehicles would reflect the new trash, recycling, and organics collection scheme. As a separate alternative, the city also may consider offering bi-weekly collection of trash and recyclables, on alternating weeks, and avoid the costs of retrofitting non-organics trucks altogether.

Aside from trucks, other expenses accrue in a curbside collection program. Each organics truck requires two sanitation workers compared with trash and recycling which require three. All of these workers may already work for the Street Department Sanitation Division and would switch from trash or recycling routes as the collection

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[16] The number of remaining trucks needed for dual trash and recycling collection is an estimate and should be modified as a program is implemented.

[17] The costs for modifying the existing fleet of trucks for a split body are not calculated due to the wide variety of vehicle makes and models. Again, running a pilot program will allow the city to gain better estimates for these costs.

scheme shifts to accommodate organics collection. Long term, the program requires no additional salaries and eventually may reduce demand for collectors, leading to cost savings through reduced salaries. Purchasing collection bins, at $55 each (Culbertson & Bowles, 2006), for 540,000 serviced households also is necessary. This capstone assumes the city would subsidize part of the bin cost while collecting the remaining $25 from each household. Total initial costs for the program including truck retrofits and collection bins reach approximately $16.5 million.[18] By far, the majority of upfront costs for this program are from the purchase of organics bins. See *Table 6: Organics Curbside Collection Fleet Costs* for a full estimate of costs to establish an organics fleet.

Table 6: Organics Curbside Collection Fleet Costs

	Quantity	Price	Total
Upfront Costs			
Organics Truck Retrofits	70	$4,000	$280,000
City Contribution to Bin Costs	540,000	$30	$16,200,000
Total			$16,480,000

Under this scenario, a variety of sources affect greenhouse gas emissions. A reduction in landfill emissions ranges from 2,490[19] to 9,960 $MTCO_2e$ per year depending on the diversion rate. Unlike the previous two alternatives where no vehicles are needed to move organics, emissions are released in this option as operating a fleet of trucks is necessary to carry the organics to a processing facility. Utilizing the city's existing fleet prevents a net increase in emissions from transportation. Instead, the emissions from the addition of organics collection balance the shift in emissions from the reduction of trash and recycling collection of approximately 1,560 to 6,230 $MTCO_2e$[20] per year. In contrast, recycling organics provides a carbon sink of 7,780 to 31,100 $MTCO_2e$ per year.

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[18] Additional program costs are not included, such as fuel costs and routine truck maintenance as well as public outreach and education materials.

[19] Carbon dioxide equivalent emissions are calculated as following: composting includes soil carbon storage and transportation emissions; combustion include nonbiogenic CO_2, N_2O emissions, avoided utility emissions, and transportation emissions; and landfill includes CH_4 emissions, long-term carbon storage, avoided utility emissions, and transportation emissions (U.S. EPA, 2006).

[20] Fuel emissions are calculated for 100% diesel fuel. Philadelphia's sanitation fleet utilizes fuel containing 2% biodiesel with plans to upgrade to 5% biodiesel. Therefore, fuel emissions calculated here are similar, but not an exact representation of emissions released.

Overall net emissions are -8,720 to -34,900 $MTCO_2e$[21] as the emissions sink from recycling organics and avoided emissions from landfills greatly outweigh the emissions from the truck fleet. See *Table 7: Curbside Organics Collection Emissions Impact per Year (MTCO2e)* for more details.

$$tons\ of\ food\ scraps\ diverted \times MTCO_2e\ per\ ton\ from\ landfills$$
$$= avoided\ MTCO_2e\ from\ landfills$$

Table 7: Curbside Organics Collection Emissions Impact per Year ($MTCO_2e$)

Diversion Rate of All Organics	25%	50%	75%	100%
Emissions (Avoided)	(2,491)	(4,981)	(7,472)	(9,963)
Emissions Added	1,557	3,113	4,670	6,227
Emission (Sink)	(7,783)	(15,567)	(23,350)	(31,133)
Net Emissions (Savings)	(8,717)	(17,435)	(26,152)	(34,869)

In conclusion, the upfront costs of a city-managed curbside organics collection program in Philadelphia are substantial, and potentially cost prohibitive. Grants from the state or federal government may be available to help fund this program, or the city might consider privatizing collection to interested haulers in the region. Despite high upfront costs, this program is able to divert a significant portion of the city's municipal solid waste from landfills and to reduce overall net greenhouse gas emissions. In the end, this program has potential to provide a long-term solution to Philadelphia's waste management while recycling a valuable resource.

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[21] This calculation does not include emissions avoided from a potential reduction in energy use at the City's water and wastewater treatment facilities or reduced truck use due to more efficient routes.

IV. Conclusions

In summary, this capstone provides an in-depth exploration of organics recycling trends, motivations, and implementations. Determining why an organics diversion program is beneficial to a city and how a city will motivate its residents to participate are important considerations when first establishing a program. This paper discusses three potential organics recycling alternatives for a city to pursue: food waste disposers, community-based composting, and curbside collection. Each option has its benefits and drawbacks and only an individual city can determine which program would be the best fit for its residents. Below is a brief summary of the information reviewed in the previous sections of this capstone.

Current organics diversion program trends across the United States and Canada focus upon curbside collection as well as backyard composting. Cities promote these programs for a variety of reasons such as reaching high waste diversion and sustainability goals, reducing greenhouse gas emissions from vehicles and landfills, and saving money on waste tipping fees. Case study precedents show an organics program must be specific to each city, and infinite alternatives are available to make it successful.

With food waste being primarily comprised of water, using a city's existing water infrastructure to recycle organics is a smart alternative. Food waste disposers have the ability to grind almost any household food waste and have a minimal impact upon a city's sewage system and wastewater treatment facilities. Additional energy and water usage is negligible, providing a low-cost solution to residents and a city. Using biosolids from a city's wastewater plants as fertilizer is the final step in completing this organics recycling option. Encouraging behavior change in residents and the installation of disposals within households are major challenges of this alternative. This option is beneficial for cities that are looking for a quick way to increase diversion rates while investing minimal costs in infrastructure.

A community-based composting network provides a city's residents with drop-off locations for food scraps as well as information about backyard composting options. With composting locations located on city-owned land, a city is able to maintain and monitor the sites with minimal effort and cost. This option depends upon households who are willing to walk their food scraps to a designated location and relies on natural decomposition and human power, not generated energy, to process the food waste. Catering only to a specific audience interested in decentralized waste management and the inability to significantly scale-up this program are the drawbacks to this scenario. This option is ideal for a city wanting to make a small, influential impact on households at a neighborhood level, or a city where full-scale collection is difficult.

Maximizing diversion of a city's organics is most likely with the development of a city-wide curbside collection program. Having access to an organics processing facility and the capacity to haul organics are as important as developing the appropriate mix of accepted materials, bins, and collection frequencies. Running several pilot programs through a city is an excellent way to test the logistics of curbside collection before ramping up to the entire city. The upfront cost of establishing a curbside collection program is the major barrier to the success of this organics diversion method. This alternative is most appealing for a city wishing to make a long-term impact on the management of its municipal solid waste by striving for high organics diversion rates of a wide-range of materials.

This capstone provides a framework of common and available organics recycling options for a municipality. Using this information to weigh the advantages and disadvantages of the various options, a city can begin the process of providing organics diversion to its residents. However, each city should create an individual program to meet its specific needs.

For Philadelphia, a final side-by-side comparison of the three scenarios is presented in *Table 8: Comparisons between Potential Organics Recycling Programs in Philadelphia*. Upfront costs include food waste disposer subsidies, community bin construction costs, curbside bin subsidies, and organics fleet retrofits while yearly costs and savings include city employee salaries, landfill and incineration tipping fees, and organics tipping fees, where applicable. Emissions avoided include diverted emissions from landfills, incinerators, and truck use; emissions added include use of energy or trucks; and emissions sink include carbon dioxide stored in soil through the recycling of organics.

Table 8: Comparisons between Potential Organics Recycling Programs in Philadelphia

	Food Waste Disposer		Community-Based Program		Curbside Collection	
Participation						
Number of Households	50%	75%	0.05%	10%	25%	75%
Diversion						
Percentage of Overall Waste	2.63%	3.94%	0.0024%	0.7%	6.25%	18.7%
Tonnage	17,156	25,735	19.9	4,389	38,917	116,750
Materials	All food waste, except highly fibrous foods and shellfish		Fruit and veggie scraps, flowers, eggshells, coffee grounds and tea bags, stale bread, nut shells, hair and fur, and dryer lint.		All food scraps including meat, dairy, and fish products plus compostable paper, yard trimmings, and clean wood	
Costs ($)						
Upfront	$7,083,713	$14,167,425	$406	$40,171	$16,480,000	
Yearly Costs	$1,410	$2,115	$3,175	$556,510	$1,751,254	$5,253,761
Yearly (Savings)	($691,830)	($1,037,745)	($1,266)	($279,126)	($2,475,105)	($7,425,316)
Net Yearly Costs (Savings)	($690,420)	($1,035,630)	$1,909	$277,384	($723,852)	($2,171,555)
Emissions (MTCO$_2$e)						
(Avoided)	(1,948)	(2,922)	(7)	(1,580)	(2,491)	(7,472)
Added	303	455	n/a	n/a	1,557	4,670
(Sink)	(4,118)	(6,176)	(5)	(1,053)	(7,783)	(23,350)
Net	(5,763)	(8,644)	(12)	(2,633)	(8,717)	(26,152)

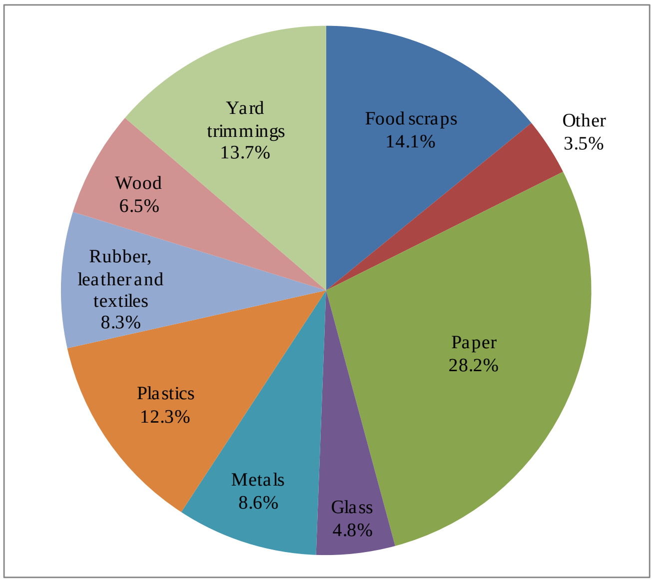
In conclusion, beginning an organics recycling program in Philadelphia would reduce the city's municipal solid waste tonnage, while also potentially decreasing vehicle miles traveled, diminishing greenhouse gas emissions, and saving the city money. Within the city, each of the three described scenarios is feasible, as long as the right conditions are present, and choosing a preferred alternative will require a suitable balance of pros and cons for the city. This capstone aims to provide the necessary background information to the appropriate groups of people within the city in order to make an educated decision about the future of an organics recycling program in Philadelphia.

V. Appendices

Appendix A: Organics Composition in U.S. Municipal Solid Waste

According to 2009 data from the United States Environmental Protection Agency, the U.S. creates approximately 243 million tons of municipal solid waste per year, of which 55% to 65% comes from residential households. Organics, including food scraps, yard trimmings, and wood, make up over 34% of our total generated waste stream and if compostable papers also are included, the percentage is larger. Food scraps account for 14.1%, and while all of this has the potential to be recycled, in 2009 only 2.5% of food waste was recovered through composting. In total, all organics account for about 83.8 million tons of waste each year, 50.0 million tons from residential households, with food scraps totaling approximately 34.3 million tons, 20.6 million tons from residential households (U.S. EPA, 2010b).

Figure 3: United States Total Municipal Solid Waste Generation[22]



In traditional municipal collection schemes, waste in generally collected per household. According to the U.S. Census, the United States had 112,611,029 households

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[22] (U.S. EPA, 2010b)

in 2009, with each household typically including of 2.6 persons (U.S. Census Bureau, 2011). Therefore, each household generated 888 pounds of organics per year or 17.1 pounds per week, which included 365 pounds of food scraps per year or 7.03 pounds per week.

$$All\ Organics$$

$$\frac{organics\ generated\ per\ year}{occupied\ households} = organics\ generated\ per\ household\ per\ year$$

$$\frac{50{,}000{,}000\ tons \times 2{,}000\ pounds\ per\ ton}{112{,}611{,}029\ households} = 888\ pounds$$

$$Food\ Scraps$$

$$\frac{food\ scraps\ generated\ per\ year}{occupied\ households} = food\ scraps\ generated\ per\ household\ per\ year$$

$$\frac{34{,}300{,}000\ tons \times 2{,}000\ pounds\ per\ ton}{112{,}611{,}029\ households} = 365\ pounds$$

Waste composition in Philadelphia varies from average waste composition in the United States for a variety of reasons. Firstly, municipal solid waste is categorized differently by each group. The EPA includes residential, including apartments, commercial, and institutional waste in its calculations, but their study does not include construction waste. A percentage of residential waste is estimated from the entire waste total (U.S. EPA, 2010b). On the other hand, the Philadelphia study includes residential buildings under six units and small businesses but excludes apartment buildings, large commercial businesses, and institutions. However, the city does collect, and therefore includes, construction and demolition materials in their study (Philadelphia Streets Department Sanitation Division, 2010). Other differences in organics also may be contributed to smaller yard sizes in an urban city like Philadelphia and city-living attributing to more frequent dining outside of the home. Again, these variations show the importance of conducting a city-specific waste study to gather the most relevant and accurate information as possible.

Appendix B: An Example of Philadelphia Parks and Recreation Community-Based Composting Rules

Under this community-based alternative, Philadelphia Parks & Recreation allows residents to utilize city-owned land for community-based composting sites. This division monitors the sites and provides the necessary supplies including composting bins, a compost aerator, and "brown" materials to add to the bins. By participating in this program, all composting members agree to adhere to the following rules.

- All members will pay an annual fee of $5 per household.
- New members will participate in an introductory composting orientation offered by the community-based composting site to understand how to appropriately utilize the site
- Members may drop-off food scraps between sunrise and sunset, during regularly schedule hours of the PPR facility, or whichever is longer.
- Members should leave scraps in the bins not currently being cured, which will be labeled for clarification. Bins will be filled on a rotating basis and will switch approximately every 8 weeks.
- Members may only include the following items:
    - Fruit and vegetable scraps, flowers, eggshells, coffee grounds and tea bags, stale bread, nut shells, hair and fur, and dryer lint.
- For healthy soil, each bin must be filled with equal parts "green" and "brown." Each time a member adds "green" material (above list) to the pile, they must add the equivalent amount of "brown" material (leaves, newspaper, etc) from the pile provided by PPR.
- All members will agree to volunteer time toward the upkeep of the site. This includes keeping the site neat and orderly, reporting any problems promptly, and turning the curing compost on a rotating basis.
- Compost turning should occur once on Friday or Saturday each week for the designated bin. All members are required to sign-up for a specific date to complete this task and frequency will depend on the number of households participating.

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