DIVERTING ORGANIC WASTE FROM LANDFILLS AT THE CITY LEVEL:

A COMPARATIVE CASE STUDY OF BOULDER AND SEATTLE

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ABSTRACT

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Landfills are a significant source of greenhouse gas emissions generally, and a leading source of methane emissions in particular. Organic waste, primarily food scraps and yard waste, is the driving cause of these emissions. Thus, even among broader recycling and Zero Waste movements, organic waste is being prioritized for diversion away from landfills. In 2022, Washington State set an ambitious requirement that cities and counties must divert 75% of organic waste by 2030. To help cities considering which policies, programs, and implementation approaches may work best to meet such goals, I conducted a qualitative case study analysis of two cities that have already achieved significant diversion success, Boulder, Colorado, and Seattle, Washington. I carried out a textual analysis of the relevant sections of each city's Municipal Code as well as interviewing an official from each city with management authority over organic waste diversion. I then used a coding analysis process, with codes being drawn from a framework analysis basis. Criteria included diversion practices, education and outreach, management structures, equity considerations, broader sustainability impacts, and measures of success. Through this process, key themes emerged. Both cities utilize a Pay-as-you-throw system, which creates financial incentives to participate in source separation and was highly recommended by a Seattle organic waste manager. Each also dealt with cross-contamination of waste streams, with single-use 'compostables' causing difficulties. Seattle mandates participation in sources separation of waste, while Boulder only requires that haulers provide organic collection services. Both requirements were seen as difficult to enforce, while collaboration and connection with both the community and stakeholders was seen as being more effective. Education and outreach were considered vital, with effective methods including face-to-face interactions, sustainability one-stop-shops, language and cultural accommodations, and utilizing haulers and community partners to expand outreach capacity which is especially relevant for smaller cities. Each city also took steps towards waste reduction, which is increasingly prioritized over diversion as a method of reducing organic waste in landfills. Throughout the planning and implementation process it seems incorporation of community perspectives was observed and was valued by each city. Consideration was also given to broader sustainability outcomes. Boulder emphasized Circular Economy, and both cities spoke to the importance of building soil health and ecology through compost. Altogether these cities present many possible strategies that may help other cities achieve organic waste diversion goals, while still accounting for broader concerns with waste reduction, equity, and sustainability.

Key Words

City of Boulder, City of Seattle, municipal solid waste management, source separation, organic waste management, landfill emissions, Pay-as-you-throw, Zero Waste, Circular Economy

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INTRODUCTION

Whether something is considered waste or not can come down to a matter of perspective. In our bodies, for example, carbon dioxide is a waste resulting from energy production that we need to remove by breathing it out. But to plants, that same carbon dioxide is a resource that lets them photosynthesize to gain energy from the sun. Many ecosystem cycles involve waste from one organism being used by another in a complex web of use and reuse that can re-cycle and renew continuously. Of course this is never perfect as new materials will always enter and leave the system, and systems do eventually shift and change over time. But in general, these cycles stay in relative equilibrium.

However, waste from modern human systems has impacted these cycles in a few major ways. Much of our waste takes a very long time to break down while actively harming ecosystem health, such as the leaching of heavy metals (Jaiswal et al., 2018), or plastics polluting the environment (R. Kumar et al., 2021). Removal of materials is also an issue, breaking the flow of nutrient cycling. Food crops, for example, are shipped away from where they grew, and the waste from food that would normally go to the soil instead often ends up in landfills. This has contributed to global losses in soil nutrients and fertility (Tan et al., 2005), with the use of landfills causing further impacts.

Beyond removing organic materials from the nutrient cycle, landfills contribute to a variety of negative health, economic, and environmental impacts (Danthurebandara et al., 2013). These include groundwater pollution (Siddiqua et al., 2022), and the production of greenhouse gases (US EPA, 2022). According to the EPA, the US produced 292.4 million tons of solid waste in 2018, or roughly 5 pounds per person each day. Of this, roughly 38% was recycled, composted or reused in some way, while around 12% was incinerated to generate energy, leaving the other

50%, or 146 million tons, to fill up landfills across the country (US EPA, n.d.). Washington state was estimated to produce 18.5 million tons total in 2021 with 50.1% going to landfills, roughly equivalent with the national average. While current landfill capacity is estimated to last until around 2060, Washington has had to start using landfills in other states like Oregon as well (WA Department of Ecology, n.d.-b). The landfill for King County in particular is close to full, and recurring expansions have been necessary (Gutman, 2019). Any landfills that are closed must continue to be maintained and monitored for many years (WA Department of Ecology, n.d.-b), which means even closed landfills continue to generate costs. With global waste production estimated to rise 70% by 2050 compared with 2016 levels (Kaza et al., 2018), this will only become more of an issue unless addressed.

These issues, in addition to more general environmental concerns, have led to an increasing number of efforts across the world to reduce and even eliminate waste entirely. Several movements have taken shape, the largest being the Zero Waste and Circular Economy frameworks. These are often closely connected, with some differences in approach and priorities. Both ultimately promote making human systems sustainable and cyclical in a way that attempts to be more compatible with natural cycles and systems (Kirchherr et al., 2017; Zaman, 2015). However, one type of waste is often being prioritized over others, namely, organic waste. This is largely because organic waste is the primary contributor to greenhouse gas (GHGs) emissions from landfills (Park & Shin, 2001), meaning diverting to other end-uses can be a useful step in reducing landfill emissions and meeting various climate goals.

Efforts to prevent organic waste from going to landfills are on the rise including in Washington state, which will serve as part of the framing of this research. Washington passed HB 1799 in 2022, updated in 2024 by HB 2301, which set a goal of 75% diversion by 2030. Together

these laws detail the implementation of phased-in mandates for commercial diversion through 2026, as well as requirements for most cities and counties to offer organic waste collection by 2027, and requirements for cities to utilize and promote local compost. By April 1, 2030, subscription to "source-separated organic waste collection services" will become mandatory for customers, with some exceptions (*HB 1799 - 2021-22*, n.d.; *HB 2301 - 2023-24*, n.d.). While the City of Seattle has already been building up its organic waste diversion policies since the 1980's (Pollans, 2017), until now organic diversion hasn't been a priority for most local governments in the state. With only six years to reach this deadline, there's much work to be done.

Many city governments are trying to determine how they can achieve this ambitious state goal in the time provided. While some policies are laid out by the state, with plans to offer model ordinances by 2025, cities must decide if there are additional policies they may need to implement, as well as consider what programs and implementation strategies they may want to pursue. The City of Renton, located in King County, Washington, was one such city looking for support in this process, including research conducted by master's students. I spoke with them early in my thesis development, which helped to shape the direction of my research into organic waste diversion policy and implementation at the city level. Throughout this process, they have provided insight and assistance. My goal with this thesis then is to conduct research that can provide information that is helpful to decision makers, such as those at the City of Renton, in determining how to meet organic waste diversion goals. This led to the development of my research question:

"What municipal organic waste diversion policies and implementation approaches best achieve climate mitigation, equity, and sustainability goals?

In addition to investigating what most effectively contributes to higher diversion rates at the city level, I wanted to see how diversion policies and strategies fit within broader contexts such as environmental sustainability, including soil health as mentioned above, and consideration of a "just transition" framework. While a just transition is conceived in many ways, and was originally an outgrowth of energy shifts in response to climate change (Heffron, 2021), in this study I take it to mean primarily how equity and justice are taken into account while moving towards new, more sustainable waste systems. I also wanted to consider the differences between larger and smaller cities, as smaller cities are less represented in the literature and may require different strategies. Some consideration will be given for what my findings mean in the context of the recent Washington State policies.

Before addressing how I have worked to answer my research question I want to clarify that for the purposes of this thesis I will only be considering municipal solid waste, which excludes any consideration of wastewater. Organic waste in this context will refer to any organic material that can be utilized through processes such as composting or biogas generation, which excludes already recyclable materials such as paper. In the following sections I will provide further context to make clear what waste systems look like, as well as providing further background on organic waste diversion. I then address the place of this research in the literature and provide an overview of my approach to this thesis project, leading into an explanation of my research approach before concluding with an outline of what will be found in this thesis.

Background

To study organic waste diversion, we first need to understand how local municipal solid waste systems generally function. In the US, modern practices date back to the late 1890's, with methods introduced by George Warring in New York. Today, this system of material flow generally consists of production, consumption, sorting, collection, treatment, processing, and disposal (Kollikkathara et al., 2009). Our consideration begins at the sorting stage, looking at the separation between the different material streams of recycling, organics, and general waste, which we will refer to as garbage. Sorting is crucial as cross-contamination between waste streams can lead to a variety of issues and inefficiencies with recycling and organic waste treatments. The Washington state Department of Ecology at one point went so far as to state that this cross-contamination was "crippling the recycling system," and developed a Contamination Reduction and Outreach Plan to address the issue (WA Department of Ecology, 2020).

This sorting can either be done after the waste is collected, or by those who are generating the waste. The latter option is referred to as source separation, which essentially means that those generating the waste take the time to sort it into the proper collection containers when disposing of it, as seen in Figure 1. This is the most common approach to waste separation, as later separation of mixed wastes is often far more costly and labor intensive (Cimpan et al., 2015). Once produced, waste can be taken directly by the waste generator to a landfill or some kind of processing center, which usually involves fees for disposal. Commonly there is a pick-up system in place with truck collection services known as haulers gathering waste from containers for both residential and commercial customers, as can be seen in Figure 2. They then take that waste to a transfer station that may do some initial processing before ultimately sending out materials either to the landfill or some kind of processing center such as a recycling or compost

facility. All of this is managed by a city or county government, though individual aspects such as hauling are often contracted out to private companies (Kollikkathara et al., 2009).

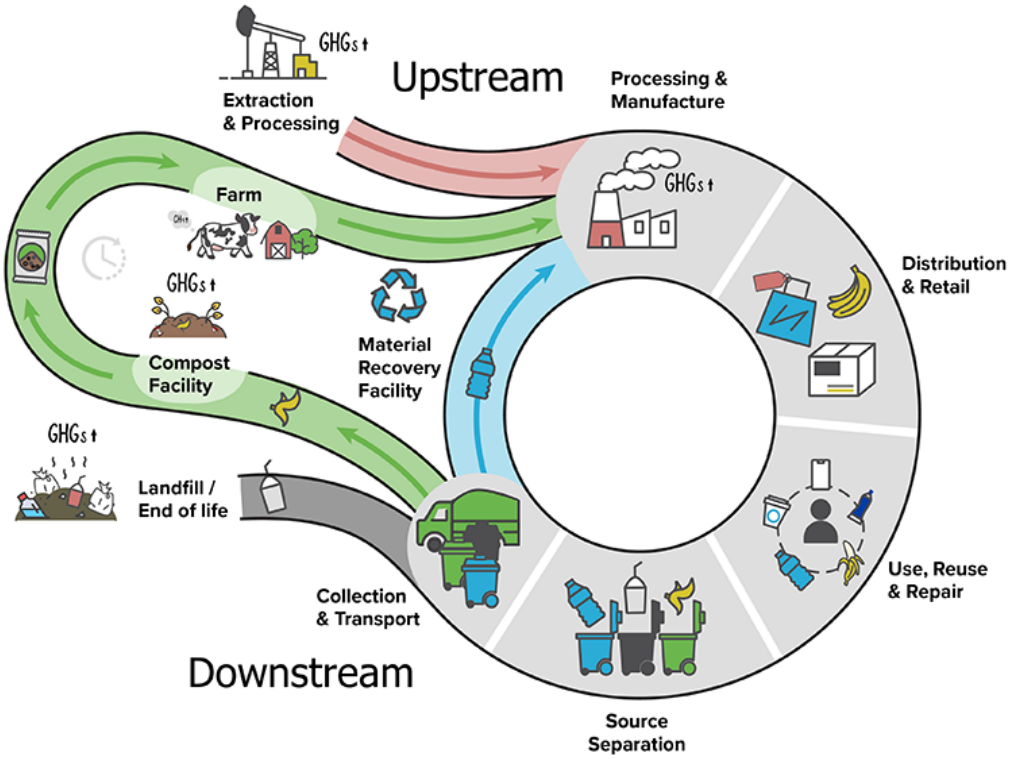
Figure 1.

Source Separation Diagram

Note. Three waste bins demonstrating source separation of organics, recycling, and general waste, also called garbage, into their respective waste streams (Drawn by Keira Jensen)

Figure 2.

Waste Flow and Circularity Diagram



Note. Diagram displaying the flow of materials through a cycle of production, waste, and reuse, with source separation leading to collection and dispersal to the end uses of landfilling, composting, and recycling (Seattle Public Utilities & Cascadia Consulting Group, 2023)

Any waste in the garbage category will all go to either a landfill or incineration complex. Materials such as recyclables and organics will be diverted to appropriate processing facilities, before ultimately feeding back into the production cycle as seen in Figure 2. For organic waste in particular, processing options include composting, anaerobic digestion, and various waste-to-heat approaches among others, all of which are often privately managed (Kundariya et al., 2021). While these processing approaches are usually centralized and accept waste at a more regional scale, approaches like composting and anaerobic digestion can also be carried out on-site at the

source of waste generation (Adhikari et al., 2010; Tian et al., 2023). Many cities, along with other levels of government such as counties and states, are now pursing Zero Waste goals, which attempt to close the resource loop seen in Figure 2 by minimizing both the inputs from extraction and the output into landfills (Zaman, 2015).

Organic Waste and Diversion

While the word organic has been increasingly used as an agricultural descriptor of food prepared without pesticides or similar products, in this context organic simply refers to any material that is produced by, or derived from, a living thing. For the purposes of this thesis organic waste can be thought of as any materials that are made up of the remains of living things, whether it is grass clippings from a yard, food scraps from your dining table, or even the byproducts of an industrial or agricultural process. However, I exclude some materials such as paper products, as these usually seem to be placed in the recycling categories by those managing waste. The US Environmental Protection Agency (EPA) found in 2018 that organic waste, excluding paper and wood, comprised roughly 35% of all solid waste. Of this, yard trimming accounted for 34.5%, while food waste accounted for 61.5% (US EPA, n.d.), making these the two primary categories to address. Interestingly, in Washington state the Department of Ecology found that roughly 25% of current waste produced is organic (WA Department of Ecology, 2021), which is less than the national average. Of the organic waste produced in the US, roughly 40% ends up in the landfill (US EPA, 2022).

Usually when something organic decomposes, it does so in the presence of oxygen from the air. In an enclosed space such as a landfill, however, little oxygen is present. When organic waste breaks down in this setting it releases significant amounts of GHGs such as CO^2 and methane, which is a particularly potent greenhouse gas (US EPA, 2016c). In 2016 the emissions

from landfills made up roughly 5% of total global emissions, though much of this may be due to open dumping which is not a common practice in the US (Kaza et al., 2018). However, landfills in the US still accounted for 119.8 MMT CO^2 equivalent in 2022, or roughly 1.9% of total emissions. This makes landfills the 7th highest single sector out of roughly 50 sectors overall and the 3rd highest in methane specifically (US EPA, 2024). In Washington state, solid waste management accounted for a similar proportion of emissions, at roughly 1.6% in 2019 (Waterman-Hoey, n.d.). These climate impacts, especially the methane emissions, are a large part of what have made organic waste diversion a priority for both federal and local governments (US EPA, 2022).

Organic waste diversion alternatives to landfilling lessen the GHG impacts of organic waste and also provide other benefits (US EPA, 2022). Composting creates soil amendments which can enrich crops, sequester carbon, and help restore soil health (Martinez-Blanco, 2013). Additionally, waste-to-energy operations can produce relatively clean energy using organic waste and other materials (A. Kumar & Samadder, 2017). While there are potential effects on health and other areas to be considered, diversion alternatives seem to cause less harm especially given that landfilling has many other negative consequences beyond GHG emissions (Danthurebandara et al., 2013). These are further reasons why organic diversion is being pursued, and why analysis regarding best practices for achieving diversion is being sought out.

Research Approach and Overview

In the literature there has been much research into the effectiveness of various diversion policies, systems, and technologies, though there are some gaps in what has been covered. Many aspects of organic waste management are well researched in the literature. The various health and environmental impacts of processing technologies such as composting and anaerobic

digestion are well examined (Yoshida et al., 2012), as are policy tools and program approaches such as Pay-as-you-throw (Skumatz, 2008) and organic waste bans (Jones & Briscoe, 2017; Treadwell et al., 2018). Many studies take a life cycle assessment approach (Yoshida et al., 2012), while other methods of assessment include cost-benefit analysis (Lam et al., 2018; Sanciolo et al., 2022), material flow analysis (Turner et al., 2016), SWOT analysis (Paes et al., 2019), socio-ecological systems analysis (Kundariya et al., 2021; Thomsen et al., 2018), as well as several other more specific or individualized assessment types. Qualitative research is, for the most part, focused on motivators for participation in source separation. In large part, most of these studies focus on only one specific policy or strategy, though they may take into account a very holistic analysis of impacts including health and equity. These aspects of the field seem to be well covered.

There have been some case studies in this field, mostly focused on counties or larger cities, though their extent of focus is varied. Many only consider, for example, approaches to processing specifically. This includes holistic studies on biogas (Ncube et al., 2021), composting (Pai et al., 2019), and others making comparisons across processing options (Buratti et al., 2015). There are some that account for a city's approach to diversion in a broader sense, considering multiple policies and strategies at once. These include broad assessment of management strategies in larger cities such as San Francisco, California (Pollans, 2012) or Aarhus, Denmark (Thomsen et al., 2018), or at more regional scales such as the province of Perugia in Italy (Buratti et al., 2015). However, findings from these studies may not be generalizable to smaller cities which have different administrative capabilities and implementation needs. And while smaller cities are considered in several studies, often only one specific policy or implementation strategy at a time is analyzed. Given that more holistic studies of city-based organic waste

diversion policy and implementation feel underrepresented, especially with consideration for smaller cities, this research attempts to contribute in filling this gap.

To this end I have utilized a comparative case study approach analyzing two cities with already successful diversion programs, those being Boulder, Colorado, and Seattle, Washington. While there have been some studies on both cities in this field, which will be explored further in the literature review, these were either conducted some time ago or differ in their focus from my research. In general, I only bring up the history of diversion in these cities as it becomes relevant to my analysis, but for a broad timeline of organic diversion practices in each city I would refer a reader to pages 66-69 and 119-122 of a 2014 assessment by Layzer and Schulman (Layzer & Schulman, 2014). For this thesis I assessed various policies and implementation programs for each city through both textual analysis of city legal codes, and interviews with city officials. In this process I attempted to give a more 'full picture' perspective that seems less common in the literature, while including some consideration of equity and broader sustainability such as impacts on economics and soil health. With one larger city, Seattle, and one smaller city, Boulder, I explore some differences in implementation related to city size, another less investigated element in the literature. All of this will be put into a broader context within the literature review, which is the next section in this thesis. We will then go into the methods, where my approach and reasoning will be further explained. This will be followed by a joint results and discussion section, before ending with conclusions and recommendations.

LITERATURE REVIEW

Literature regarding municipal solid waste systems, including diversion of recyclables and organics, is well established. There are a wide range of studies exploring various aspects of waste policy systems and approaches from many different perspectives. Some consider frameworks such as Zero Waste and the growing field of Circular Economies, and others look at specific approaches to diverting waste from landfills to recycling and composting. Many studies consider factors affecting decisions to participate or not in source separation, often with a greater focus on recycling, that fit into a larger context of research considering participation in sustainability initiatives and systems. Another large section of the literature concerns itself with specific technologies related to organic waste, mostly composting, anaerobic digestion, and incineration, as well as exploring organic diversion policies and programs at the city level. The goals of this literature review are to explore the most relevant areas of these research fields in order illustrate the current state of organic waste diversion, establish key areas of focus for analyzing the case studies of this thesis, and assist in placing the findings for the cities of Boulder and Seattle in a broader research context.

The review will start with an overview of landfills and why diversion is preferred to landfilling. I then cover the different methods of diversion and their various impacts and effectiveness across criteria such as diversion rate, emissions, health, and equity among others. This is followed by a broader consideration of general waste reduction and diversion at the city level, including frameworks commonly used by cities such as Zero Waste and Circular Economy. From there several key areas of management will be defined, with policy and planning approaches for each explored. I conclude by analyzing the literature that already exists regarding organic waste diversion for my chosen case study cities of Seattle and Boulder.

The Impact of Landfills

To understand why there is a growing movement towards waste diversion away from landfills, it is necessary to understand what landfills are and what their use entails. For many decades now landfills have been a key method of waste disposal, and globally are the most common approach to waste management (Crowley et al., 2003). They can be defined as a space designed for storing compact layers of material waste either above or below ground (Crowley et al., 2003), and come in a large variety of forms and sizes, ranging from open dumps to controlled 'sanitary landfills.' However, if gases are allowed to build up, this can result in fires and even explosions. This is avoided through proper design and management, which has led to common aspects of landfill systems including the installation of liners and sealant systems to prevent leaching, as well as routing and flaring gases to avoid buildups. Landfills have remained popular in large part because they have historically been low cost, and don't require much technology to create or operate (Vaverková, 2019). As space becomes more valuable however, and as externalities such as health and climate consideration are accounted for, landfills have become less desirable.

To start, landfills are increasingly known to have negative health, social, and environmental impacts (Crowley et al., 2003; Danthurebandara et al., 2013; Siddiqua et al., 2022; US EPA, 2022; Vaverková, 2019). An extensive review documents the large volume of studies into the various negative effects of landfills as a practice (Danthurebandara et al., 2013). They found that construction of landfills, for instance, can cause damage to the surrounding landscape. Additionally, gases and toxic metals present in a landfill can leach into surrounding soil and waterways, with potential impacts on the environment and human health. They also found that several studies indicated an increase in birth defects for those living closer to landfills,

as well as a potential increase in risk for developing cancer. Property value for nearby residents can also be lowered, in addition to worse views and unpleasant odors (Danthurebandara et al., 2013). Another more recent overview found similar findings in the potential for contamination of the air and local groundwater, in addition to potential marine pollution (Siddiqua et al., 2022). Altogether these various broad-ranging effects have contributed to seeking alternatives to landfilling.

Of greatest relevance to this study, landfills are also known to produce significant amounts of greenhouse gases (GHG). The gases produced by landfills, known as landfill gases, are primarily composed of methane and CO^2 (Park & Shin, 2001). Methane, while shorter lived in the atmosphere, is at least 28 times more effective at trapping heat than CO^2. According to the EPA, landfills are the third largest source of human-produced methane, around 15% of the US total for methane, which makes them significant contributors to GHG emissions and thus to climate change (US EPA, 2016c). The greatest contributor to these emissions is the large amount of organic waste in landfills.

Landfills create anaerobic conditions, meaning there is little oxygen, and organic matter that decays in this environment creates biogas. This is primarily made up of methane, some carbon dioxide, and some smaller amounts of other gases that likely contribute to local negative health effects (Crowley et al., 2003; US EPA, 2016c; Vaverková, 2019). Higher organic content in a landfill leads to greater emissions, with food waste being the biggest contributor (Manheim et al., 2021). In the US around 40% of organic waste produced will end up in landfills (US EPA, 2022) making up about 53% of the total material found in landfills (US EPA, 2018). Food waste makes up roughly half of this organic material, or roughly a quarter of total waste, and by itself is responsible for 58% of methane emissions from landfills (Krause et al., 2023). As a result of all

this, the impact of this organic waste on GHG emissions impacts is often cited as a primary driver for organic waste diversion away from landfills (US EPA, 2016c, 2022). This, in combination with broader movements to reduce food waste, can explain why organic waste diversion is a priority even for places already engaged in Zero Waste efforts more generally.

It should be said that while landfills can have many negative effects, measures to mitigate these impacts are often utilized. The first step is to ensure that a good site for the landfill is chosen, with the goal of causing the least harm to communities and the environment. The landfill must then be lined with the proper material before dumping begins, which can prevent the production of gases that lead to emissions (Crowley et al., 2003). However, the lining material required for this will still eventually break. This can take 50 or 500 years, but the gases will eventually be released (Vaverková, 2019). So, it's not necessarily a question of preventing emissions, but delaying them. Ultimately the gases must be dealt with one way or another.

One review explores the variety of ways this is done, of which flaring is the most common. This process does burn off most of the GHGs, but can still lead to the emission of toxic gases (Crowley et al., 2003). There are also a variety of biotic options emerging, such as biotarps and biofilters, that can reduce methane emissions specifically, with various accompanying benefits (Huber-Humer et al., 2008). With proper management systems, landfill gas can even be burned for heat or used as a fuel that feeds energy back into the grid (Crowley et al., 2003; Karapidakis et al., 2010) and reduces landfill emission impacts (Istrate et al., 2020). The conversion to an energy source is generally the most desirable outcome, whether burned on-site or converted to a form of natural gas that can be used elsewhere. Even if Zero Waste goals are achieved, these mitigation measures would still be helpful, given that our existing landfills will create emissions for years to come as the already present organic waste continues to break down.

Interestingly, one study did find that landfills with proper mitigation measures may be comparable in GHG emissions to some organic waste diversion alternatives (Kong et al., 2012). So, there are ways to at least reduce the emissions of landfills without diverting organic waste. But diversion and landfill mitigation are not mutually opposed, and can both be utilized at the same time. Ultimately though, diversion appears to be more effective in terms of reducing emissions and minimizing other impacts. Especially in relation to a standard landfill, diversion alternatives consistently rank higher in terms of emission reductions (Kong et al., 2012; Yoshida et al., 2012). Additionally, the products derived from organic waste processing can have additional benefits. These include producing cleaner sources of energy through processes like anaerobic digestion (Khalid et al., 2011), as well as the wide variety of soil benefits derived from applying compost, biochar, and other common soil amendments derived from organic waste (Agegnehu et al., 2016). Ultimately to fully address emissions and various other impacts, as one study of urban methane mitigation states, we have to look away from landfills towards alternatives for landfilling our organic waste (Hopkins et al., 2016).

Alternative Organic Waste Treatments

Once the decision has been made to divert organic waste away from the landfill there are several options for where it can go, each with various differences and many shared benefits. Studies exploring these options may be the largest sector of organic waste diversion literature, ranging from broader comparison of benefits to detailed technical analysis of process efficiency. However, these processing options, like landfills, are often more regionally based, and thus largely fall outside of a given city's jurisdiction. As such they will be given less consideration in this study. But, cities do still interact with processors, and may have some routes to influence this aspect of diversion, so it is important to have a basic understanding of how these systems

function. Additionally, understanding the benefits of these diversion options can further highlight the need for diversion.

The main option when considering diversion for organic materials is composting, along with waste-to-energy solutions such as incineration and anaerobic digestion. Waste-to-energy, as its name suggests, is any waste processing solution that is concerned with taking waste and converting it into energy. Pyrolysis and gasification also fall under this category, but do not appear to be fully viable yet (A. Kumar & Samadder, 2017). Additionally, little research seems to have been done into their broader impacts (Istrate et al., 2020). So, in terms of waste-to-energy solutions, we will focus on incineration and anaerobic digestion, both of which are more commonly used and have been better researched.

Incineration

Incineration can burn organics and all other types of waste to produce energy, and has been utilized primarily across the European Union, the US, and East Asia, with some use elsewhere (Makarichi et al., 2018). The practice has been shown to reduce waste volume by 90% and is a cleaner burning fuel source when compared with fossil fuels, though the effectiveness depends on the composition and character of the waste being incinerated. While there are some potential concerns regarding health impacts, such as possible connections to increased birth effects when living near an incineration facility (Vinti et al., 2021), this area of research was seen as limited and in need of further study (Istrate et al., 2020; Vinti et al., 2021). Regardless of findings, concerns over health impacts have contributed to opposition of incineration by local communities in the US (Karim & Corazzini, 2019) including in Seattle (Pollans, 2017). However incineration does, at least, appear to have lower health impacts than equivalent fossil fuel use, and with good design the potential for toxic emissions can be limited (Cole-Hunter et al., 2020).

In terms of climate impacts, several studies found that incineration ultimately produced less greenhouse gas emissions than landfills (Baldasano & Soriano, 2000; Istrate et al., 2020). However, systems that diverted organics towards composting and anaerobic digestion performed even better in terms of emissions (Baldasano & Soriano, 2000). So, while incineration may be worth considering as an alternative to landfilling, with the qualification of health impacts needing further study, it should not be the only solution utilized. It also is not an either-or situation, as incineration can serve as a catchall for waste that can't be reused or recycled in another way. But for treatment of organics specifically, processing methods such as composting and organics should be prioritized.

Anaerobic Digestion

Anaerobic digestion (AD) technologies appear to be an increasingly popular method for processing organic waste. AD at its core is a biological process, where microbes break down organic material in a controlled environment. Similar to landfills this occurs in the absence of oxygen, thus making it anaerobic. The process produces a biogas that can be used for fuel, and leaves a certain amount of processed biomass as a byproduct known as digestate (Adekunle & Okolie, 2015). AD is often used in an agricultural setting to process large volumes of manure or other organic materials, with the infrastructure often located on-site (Clemens et al., 2006; Holm-Nielsen et al., 2009), but more regional processing of municipal organic waste also occurs (Hartmann & Ahring, 2006) The apparatus within which the process happens can either be located on-site or more regionally managed (Adekunle & Okolie, 2015; Holm-Nielsen et al., 2009). One study found that value through AD can be generated in a variety of ways ranging from the sale of biogas, to thermal energy recovery, tipping fees to take in the waste, and the sale of digestate as a fertilizer. Economic viability and cost recovery time can mostly depend on the

market for, and quality of, outputs such as biogas and organic fertilizers in particular (Linville et al., 2015). The output and efficiency of the process does depend on many factors, mostly to do with the composition of the material being processed (Yoshida et al., 2012). The wide variability of inputs is one of the larger barriers to widespread use and commercialization (Linville et al., 2015). Other limitations appear to include high capital costs due to equipment investments, as well as officials and regulators lacking experience with AD (Clarke, 2018).

In terms of impacts, AD was found by several life cycle analysis studies to have a greater positive impact in comparison with both landfills (Ahamed et al., 2016; Yoshida et al., 2012) and incineration (Di Maria & Micale, 2014). Another life cycle analysis based in Milwaukee even went so far as to say that for municipal organic waste, the best solution to minimize GHG emissions was to prioritize anaerobic digestion (Tominac et al., 2020). Additionally, the application of biomass resulting from AD as a soil amendment can reduce the need for more harmful artificial fertilizers by improving soil health and quality (Linville et al., 2015; Timonen et al., 2019), while also building up soil health in a similar fashion to compost application (US EPA, 2016d). While they do appear to present some risk of carcinogenic impact through emissions, the link is not strongly established and regardless it seems that this can be mitigated (Wang et al., 2023). In general, AD can both play a role in reducing emissions from municipal organic waste, and contribute to nutrient cycling and environmental health both for farms and ecosystems more broadly.

Composting

Composting is the breakdown of organic material when oxygen is present. Compost has been promoted as an option to make agriculture more sustainable, in addition to its use as a tool of organic waste management (Blum, 1992). In practice compost can range from a small pile in

the backyard to an upscaled industrial process that can accept waste inputs from an entire region. More decentralized, smaller composting has a lower processing capacity (Hénault-Ethier et al., 2017). The benefits however, especially for composting coordinated at a smaller community scale, can include lower transportation and maintenance costs, a potentially higher quality product (Bruni et al., 2020), as well as broader social and economic benefits (Pai et al., 2019). This approach could be a lower cost solution for cities to implement, though it may be in need of further study in comparison with industrial composting which is better represented in the literature (Barrena et al., 2014).

More industrial-scale, centralized composting has the potential to process the organic waste of several cities at once, such as Cedar Grove Composting which receives material from throughout King County (King County, 2023). To be most effective, one study found that centralized compost processing should be combined with effective source-separation on the collection side of operations. If organics are not properly separated from other materials, composting becomes more difficult as it can contribute to worse odors and heightened levels of heavy metals. These odors have been cited as a barrier to compost implementation (Wei et al., 2017). Additionally, the production of toxic gases and bioaerosols resulting from the process may result in health risks for those living near compost facilities and those working within them (C. Pearson et al., 2015; van Kampen et al., 2012). However, a more recent meta-analysis found that studies on compost health risks were limited and unable to provide any quantified risk, though they still recommended a precautionary approach (Vinti et al., 2021). Additionally, it seems that if source separation is done properly then odors, gases, and bioaerosols can be reduced, which has the added benefit of producing higher quality compost (Wei et al., 2017). In general, the health impacts seem equivalent or potentially better than other processing options.

In comparison with landfills, industrial composting appears to produce less greenhouse gases and other unwanted emissions. So, composting has less emissions than landfilling (Lou & Nair, 2009), though the exact balance and amounts of the various gases depends on the composting approach taken, the materials used, and the mitigation measures taken (Yasmin et al., 2022). While the process does still produce emissions, and lacks any clean energy offset found in a process like AD, there are various mitigation measures. The most significant methane emissions are produced in anaerobic pockets of a compost pile, which can be reduced by making sure the whole pile is properly mixed and aerated. Additives are being considered which could further reduce emissions, meanwhile simply covering the pile with straw or plastic could also reduce emissions (Yasmin et al., 2022). While some emissions are unavoidable in the composting process, there are a variety of low-cost abatement solutions which can minimize this impact (Sánchez et al., 2015). Emissions can also be captured and utilized for other purposes such as funneling CO^2 from compost piles to greenhouses, where the plants will utilize the CO^2 in the photosynthesis process (Thomson et al., 2022).

An additional benefit of compost, as well as anaerobic digestion which produces its own soil amendments, comes in the form of applying compost and other soil amendments as amendments to enrich soil. Compost can be difficult to transport very far, given difficulties in shipping and the energy required. It is possible that production can outpace the application demand within the areas which cities could realistically transport the compost to. However, a study examining this issue in California did find compost could be effectively transported from urban centers to the major farmland areas of the state. Additionally, even taking into account California's policy requiring increased diversion, it would take 14 years to apply compost at recommended rates to all applicable soils across (Harrison et al., 2020), at which point

application could be renewed. Another study of California found that application of these composted organic wastes could lead to significant carbon sequestration annually, with effectiveness of production improving with increased scale (Hall et al., 2022). While there should be caution in generalizing results from one state, this seems like a good sign that compost production won't outpace usage and that municipal production can substantially contribute to improving soil quality.

Summary Comparison

In terms of emissions, all processing alternatives generally seem to perform better than landfills. The differences in emissions between composting and anaerobic digestion are more difficult to distinguish, and depend in large part on the particular approach used and the mitigation measures taken. Both also produce soil additives that can regenerate soil health, displace the use of artificial fertilizers, and sequester carbon. While AD does produce biogas that can offset fossil fuel use, it's not clear if this makes it the better option from a pure emissions standpoint. However, both composting and AD perform better than incineration. For all categories the impacts to health are, unfortunately, less clear. While composting and incineration both show potential impacts, studies are inconclusive and limited. In the case of AD, no research into health impacts was found. Despite these limits, it seems we can say that incineration is the least preferable option. While compost and AD are difficult to rank against each other, it is not necessarily just one or the other. For instance, one study found that in terms of emissions and economics, AD may be preferred for centralized treatment, and compost for decentralized treatments, allowing room for both options (Lin et al., 2018). Given differences in feedstock preference, and demand for what they produce, it could be that both are required, and even incineration could play a role in processing any materials the other methods are unable to accept.

Waste Frameworks and Trends

While diversion of organic waste specifically has been a growing area of focus, largely due to climate concerns, the policies, programs, and implementation strategies addressing organic diversion fit within a broader context of waste management. General concerns with waste have already led to decades of efforts resulting in a wide variety of recycling and reduction programs. These have ranged from the general movement to recycle (Lounsbury et al., 2003), desires to minimize hazardous pollutants (Szasz, n.d.), addressing plastic in the oceans (Stafford & Jones, 2019), or reducing food waste to address food insecurity (Shafiee-Jood & Cai, 2016; Walia & Sanders, 2019). Many programs have been implemented to address each topic, usually separately, at all levels of government from the federal down to the local level. Increasingly however, more holistic approaches and frameworks are being considered that account for the interconnections between various human and natural systems, with an eye towards broader societal benefits. Cities have also been concerned with waste reduction, and increasing the circularity of waste systems, which seems to have contributed to the growing use of the Zero Waste and Circular Economy frameworks. Organic waste management is considered as a factor within these concerns and frameworks, and thus understanding them can be helpful when considering organic waste diversion policy, strategies, and research in a broader context.

"Zero Waste" and Waste Prevention

The first of these frameworks, Zero Waste, is essentially used to envision what it would look like to stop sending any waste to landfills at all, and to form plans and strategies to work towards that goal. This often includes avoiding the use of incinerators, and takes a holistic view from design, to production, and finally to use, reuse, and disposal. The idea gained popularity in the 1990's, with Canberra, Australia as the first city to officially set a goal of Zero Waste. In

2000 Del Norte County, California was the first local US government to create a Zero Waste plan (Zaman, 2015). The idea has since grown in popularity, being adopted and promoted in the US by many cities, counties, states, and even federal departments. A large review found that a holistic point of view is a basic requirement to implement Zero Waste. Though, least in the academic literature as of 2017, they found less consensus for what Zero Waste as a concept fully entails (Pietzsch et al., 2017) Looking at an EPA compilation of Zero Waste definitions, we also see much variation with some remaining more technical and goal oriented while others emphasize a perception shift. Ultimately the emphasis seems to be on local systems and the flow of materials once they have already entered a community, though there is sometimes consideration of the life-cycle impacts of materials and products (US EPA, 2016e).

There has been much research into the Zero Waste approach, such as one study's development of a "Zero Waste Index" to assess effectiveness at achieving Zero Waste. Their goal was to offer a replacement to the simple diversion rate as a measure, and instead utilize a more holistic assortment of assessment criteria (Zaman & Lehmann, 2013). Addressing these criteria and targets, however, can prove challenging. For instance, a study of Ireland and the Czech Republic found that investment in new infrastructure would be needed to successfully reach their Zero Waste targets (Závodská et al., 2014). A comprehensive literature review of the field has also explored barriers and enablers of Zero Waste implementation. Barriers included lack of enabling policy, difficulty in changing consumption behaviors, and a lack of knowledge or technology. Enablers on the other hand included outreach and engagement, public-private partnerships, and political support among others (Pietzsch et al., 2017). While organic waste management is by necessity incorporated into Zero Waste plans, there is some research exploring it more specifically in this context. Usually, this is to look at how a specific technology such as

anaerobic digestion may affect being able to meet Zero Waste goals, including assessments of its effectiveness and potential barriers to implementation (Satchwell et al., 2018). This generally is less policy oriented.

An important aspect of Zero Waste is the need to not just consider recycling and waste treatment, but also reducing the amount of waste produced in the first place (Song et al., 2015). While not always using a Zero Waste framing, waste reduction is a growing area of focus in the literature. The benefits of waste reduction are highlighted by one study which finds that prevention can lead to significant reductions in emissions and energy use, with food waste prevention in particular having the highest impact (Gentil et al., 2011). While recycling requires energy and can produce further waste itself, prevention is preferred due to its ability to reduce the amount of energy, infrastructure and resources needed to collect, divert, and process waste in the first place (Bartl, 2014). Another study makes the point that for a long time, most waste management has been focused on "end-of-pipe" solutions such as recycling and diversion. Having conducted a comprehensive literature review, they found a growing interest in waste prevention as managers begin to consider more holistic "life cycle-based approaches" (Zacho & Mosgaard, 2016) which would also be more aligned with Zero Waste approaches. Local governments themselves have begun to explore the effectiveness of various methods of waste prevention. King County for example ran a study where they increased the number of weeks between collections of waste containers, finding the practice led to an overall reduction of waste generation (King County Solid Waste Division et al., 2008). While the study of prevention does still seem to be in development, especially on the academic side (Zacho & Mosgaard, 2016), we will see waste prevention taken into consideration in several studies throughout this literature

review. In general, the importance of waste reduction as an aspect of waste management planning seems readily apparent given the various benefits derived from it.

Interconnection and "Circular Economy"

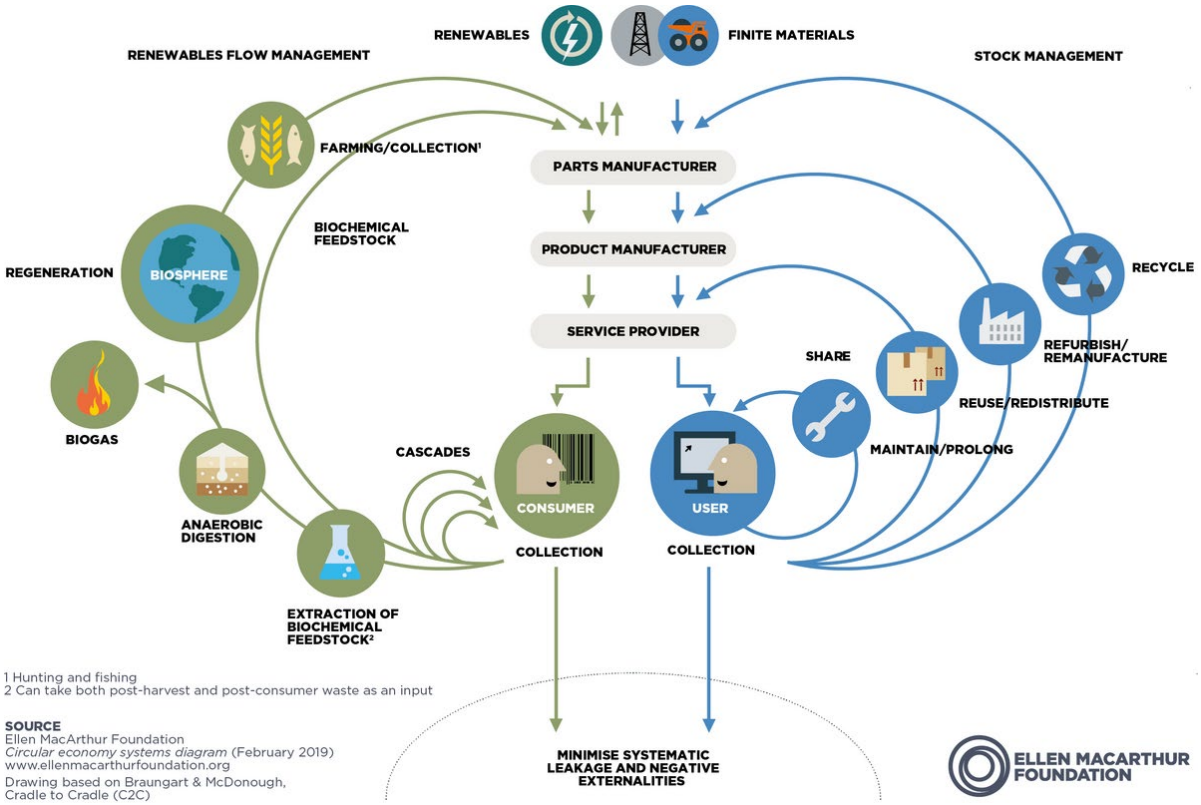
Another growing approach to waste, which can work in tandem with Zero Waste planning, is to consider it within broader systems of material flow and production. The most common framework representing this idea is known as the Circular Economy. This approach, while still assessing systems and taking environmental concerns into account, is based much more on an economic perspective with a focus on value generation. A systematic analysis of definitions for the term found that it commonly involves "a combination of reduce, reuse, and recycling activities" with a primary focus on economic prosperity. Environmental quality is a secondary consideration and few relations are made to sustainable development more generally (Kirchherr et al., 2017). While some research has attempted to connect Circular Economy with sustainability (Geissdoerfer et al., 2017), others suggest the concept needs to be more concrete and limited to be useful in promoting sustainable systems (Corvellec et al., 2022). Another study claims that the biggest contribution of Circular Economy to the literature, given many of its concepts are already mostly accounted for in sustainability research, is its ability to explore sustainability in a "production-consumption culture" along with a focus on material flow and value generation (Korhonen et al., 2018). While the concept may have its limitations, it seems to have a good utility for exploring sustainable material flow and waste systems through an economic lens.

In looking at organic waste, research in this context generally focuses on how to apply value, primarily economic, to various waste materials and streams. As one Circular Economy study states, a focus on "value to waste" is vital, meaning there should be a focus on finding

ways to generate economic value from various types of organic waste (Kharola et al., 2022). A leading organization in regards to the Circular Economy framework, the Ellen Macarthur Foundation, even includes organics as half of the focus in their diagram of a Circular Economy, as seen in Figure 3. In this framework anaerobic digestion, for example, is valued for generating energy and additives which could both be sold as products (Kaszycki et al., 2021).

Figure 3.

Circular Economy Systems Diagram



Note. Diagram displaying pathways and connections of resources and materials within a Circular Economy system (Ellen MacArthur Foundation, 2019)

Some studies have explored common potential barriers to applying value and economizing products made from organic waste. One study found that this includes logistic costs, supply chains issues, lack of homogeneity with materials used, as well as the seasonality and quality of production. However, they also found benefits like being able to create value from waste streams, broader environmental benefits, the development of new business models and value chains, and increased cooperation (Paes et al., 2019). Coordination and collaboration between partners at local and regional levels is a key aspect of this approach, and has developed further into the study of specific locational arrangement such as the growing fields of agricultural and industrial symbiosis (Roth et al., 2023). A study on food waste management found the cooperation between government and public sectors to be important for successful food waste management (Walia & Sanders, 2019), and Circular Economy seems well suited to promoting those connections. These benefits, and the potential for new economic value generation that circularity entails, have likely contributed to making the Circular Economy framework appealing to various cities and local governments. This will be relevant to consider with how organic waste diversion systems are framed and developed in relation to policies and programs.

Policies and Programs

While differences in methods by which organic waste is processed can have significant effects on the overall impacts of the waste system, decisions on these methods tend to be less in a given city's control. Instead, policies, programs, and implementation strategies related to waste prevention, source separation, and waste hauling are aspects more directly controlled by city governments. There is a wide range of research in this area, touching on various aspects of outreach, management, and policy.

One area of study is based more on correlation, observing trends and similarities across a larger group of cities. They then consider what they might have in common that leads either to high diversion rates, or simply having diversion in the first place. Interestingly for cities in Europe, high diversion was most correlated with high income. This could imply that only relatively well-off cities can achieve significant diversion. However, that study does ultimately conclude that policy tools can be leveraged to increase diversion rates regardless of community income (Treadwell et al., 2018). Given another study found no correlation at all between diversion and income (Pollans et al., 2017), we can likely rule out community income level as any kind of determining factor of diversion success. Instead, various policies seem to play more of a role.

Some research has broadly compared a variety of these policy and management options at the city level. While only considering recycling, a study in Japan did note that cities with separation programs that accepted more variety of materials saw higher rates of participation in diversion than programs that accepted less types of materials. Essentially when there are less restrictions or limitations to keep track of in terms what does or does not qualify as recyclables, the better the diversion results. (Matsumoto, 2011). Another study assessing organic waste management specifically used several factors to measure a variety of management approaches including landfill and incineration taxes and fees, Pay-as-you-throw (PAYT) approaches, regional regulations, curbside bag limits, mandatory source separation, and the presence of source-separation infrastructure. While results may be tricky to generalize due to limits of the data, the most successful factors increasing diversion rates seem to be the use of PAYT systems, landfill and incineration taxes, bag limits, and source separation infrastructure (Treadwell et al., 2018). The correlation of PAYT style systems and diversion success was also noted in another

study looking specifically at food scrap diversion in mid-sized US cities. This also found that general organic diversion correlated with a city having previously had yard waste collection, meaning they already had some experience collecting organics. It was also suggested that denser cities are more likely to have organic waste diversion (Pollans et al., 2017). Another study, which conducted interviews with waste managers, found that successful programs correlated with regional mandates, cooperation with haulers, and the use of pilot programs, with motivations for implementation including rising landfill costs (Layzer & Schulman, 2014).

While some trends emerge through all these studies, such as PAYT correlating with diversion, there does seem to be variation between them. Additionally given some of these studies only consider the presence or absence of diversion, rather than rate, it's somewhat difficult to draw any firm conclusions on the degree of effectiveness. These studies are quite useful however in pointing towards the policies and approaches that may be most relevant, such as PAYT, source separation, economic incentives, and landfill taxes among others. We will explore these options below, in addition to others that were common in the literature.

Source Separation Barriers and Motivators

Ultimately, source separation programs can only succeed if individuals and businesses actually participate in them. There is a large field of study examining motivations for participation in such programs. A survey in Sweden found that convenience of organic sorting options was key to participation in the programs (Miliute-Plepiene & Plepys, 2015). Another study similarly found that inconvenience seems to be a consistent barrier to participation in separation programs, either because the facilities or storage were impractical or because it was too time-consuming (Boonrod et al., 2015). When considering separation methods with various levels of complexity, the simplest methods tended to lead to the most effective levels of waste

separation (Chen et al., 2017; Miliute-Plepiene & Plepys, 2015). Interesting to note, trust in local agencies can also be an important factors for participation in a diversion program, as seen in a Vietnam-based study (Loan et al., 2017). If a city or department isn't seen as effective and reliable, participation in a new program such as organic waste separation may be more difficult. These concerns should be considered when developing policies and programs to promote organic waste diversion.

Disincentives, and Mandates

A common approach to increasing diversion is the placement of disincentives and restrictions on putting waste into landfills. One example is the tipping or gate fees charged when bringing waste to landfills, which are usually used to cover operation costs. In this case when someone wants to dispose of something in a landfill they are charged a fee, usually based on the weight of what they want to dispose of. Landfill taxes might be added on top of these fees as a way to increase costs of disposal, in hopes of decreasing landfill usage. In the European Union landfill taxes were more likely to lead to recycling and composting of waste, in comparison with organic waste bans (Clarke, 2018). Another EU based study found that landfill tax based policies were relatively effective, though noted they did not seem to incentivize waste prevention (Mazzanti & Zoboli, 2008). So, while the effects may vary, landfill fees and taxes may be a useful way to increase diversion, with the added benefit of potentially generating revenue for other purposes. However, such policies may not be within and individual city's control.

The next step in severity from disincentives is to make source separation mandatory altogether. This often takes the route of banning organic material from entering landfills, which is referred to as an organic waste ban. In this case, source separation and organic waste bans are equivalent in meaning. On the user end, this either means putting organic waste in the correct

container or taking it to an organic processing facility rather than the landfill. A study of the European Union found that these organic waste bans generally led to waste being diverted towards incineration (Clarke, 2018). A review of organic waste bans in the Northeast of the US found that bans could be effective, with an additional benefit of creating a more reliable source of organic feedstock for hauling and processing companies to utilize. They do note, however, this likely was possible due to other policies supporting the processing industry, as well as high energy prices, population density, and high landfill tipping fees (Jones & Briscoe, 2017).

Looking at a study of grocery stores specifically, waste bans seemed to contribute to only a 4% decrease in waste. Instead, pricing structures that dynamically decreased in proximity with expiration dates were found to have a much greater impact (Sanders, 2018). In a similar vein, a broad ranging analysis of cities from Europe and Canada found no correlation between bans and diversion increases (Treadwell et al., 2018). This matches with a more recent study that analyzed organic waste bans across 36 states which found that bans may have had no effect on landfill diversion. The only state that observed any impact was Massachusetts, which saw their waste going to landfills reduced by 11.2% (Anglou et al., 2023). A thesis exploring the ban in Massachusetts specifically also found it to be effective, even helping reduce diversion rates for organizations already engaged in diversion before the ban was put in place. This was likely due to the increase in available resources and assistance that accompanied the ban (Raczka, 2018). Another assessment looking at a variety of US cities also found strong county and state mandates to be effective, citing policies in California and Hennepin County in Minnesota as key examples (Layzer & Schulman, 2014). It would seem then that the literature is somewhat conflicted on this subject. The lack of a consistent trend may indicate that the efficacy of bans is more context dependent. Given they have proven to be useful in some places, such as Massachusetts and

California, they are likely still useful to consider, albeit carefully, as a method of increasing diversion.

Incentives and Payment Structures

While many diversion programs tend to implement some form of requirement, voluntary approaches utilizing direct incentive programs are also considered. In a study of communities in Thailand, simply making bins available led to a separation rate of 19%, which with outreach was raised to 36%. Once rewards were introduced, separation efficiency rose to 51% (Boonrod et al., 2015). Similar trends were seen in a smaller study of a group of urban households in China, with rewards leading to a significant increase in separation (Xu et al., 2015). This was reflected by another study in Nanjing that detailed an incentive program where participation earned point tradeable for goods. This was cited as a key driver of initial participation, with many individuals claiming they would continue participating even if the incentive program stopped (Li et al., 2017). As one study in Bangkok concludes, these incentive campaigns can be an important strategy for planners to consider and utilize (Sukholthaman & Sharp, 2016). It's worth noting however that research regarding direct incentives, such as material rewards for participation, does not appear to be well-studied within a United States specific context. The focus of studies in the US instead seems to be on indirect economic incentives such as through the structure of payment schemes.

Many waste services charge what's known as a flat rate, with customers essentially paying a single price for a container that is regularly picked up. In this model, the amount you dispose of has no effect on the price that you pay. This also means that even if you divert your recyclables and organic waste and separate it effectively, you pay the same price. An extensive study of multiple communities in China found that, while there is sometimes internal motivation to

separate, flat rate fees can lead to higher levels of waste production and lower levels of sorting compared with other alternatives. Ultimately, they recommend finding ways to reduce fees for customers based on how well waste is sorted (Han et al., 2016). The most common way to do so is by implementing variable pricing in the waste collection payment structure, charging customers based on the amount they throw out with different rates charged for garbage versus recycling and organics. This idea of variable pricing has already been put into practice in many areas, and in the waste sector is most commonly referred to as Pay-as-you-throw (PAYT).

PAYT, also known as unit pricing or variable-rate pricing, is essentially an incentive scheme to promote waste sorting. Residents are charged by the amount of waste they produce, measured in weight, number of bags, or container size. Recyclables and organic waste are then charged at lower rates than garbage disposal. This creates an economic incentive to sort properly, since the amount you're charged decreases as you divert more material away from the more expensive garbage container to the less expensive organics container. The EPA supports this approach to waste management, finding that it promotes equity and sustainability (US EPA, 2016a). On one webpage, the EPA refers to PAYT as the "single most effective" approach to waste diversion, and has even developed a calculator tool to determine whether PAYT is a good fit for their community (US EPA, 2016b) though that page is now archived.

As of 2006, over 7,000 communities in the US used PAYT, meaning about 25% of the US already uses this approach (Skumatz, 2008), resulting in 4.6-8.3 million tons of waste diverted annually (Skumatz & Freeman, 2006). Of these, it seems that richer communities were less likely to adopt PAYT, though areas facing resource and capacity constraints were also less likely to enact the practice. The most common positive community indicators for PAYT implementation were higher education, and being non-rural (Gradus et al., 2019). Interestingly, once

infrastructure facilitating diversion is in place alongside PAYT, people in Sweden seemed to sort to a degree higher than would be expected for motivations based on savings alone. Essentially, there seemed to be strong buy-in to the concept of diversion itself, which was simply facilitated by PAYT and diversion programs (Bartelings & Sterner, 1999). Once adopted, another Swedish study found that while effectiveness varied between cities, on average those with PAYT collected 20% less waste per household (Dahlén & Lagerkvist, 2010). A review study found that PAYT may reduce residential waste going to the landfill by 16-17% (Skumatz, 2008). This is backed up by a national survey of US municipalities finding that the policy led to significant increases in recycling and reduction of waste (Folz & Giles, 2002), as well as a review of European PAYT programs finding similar effectiveness results (Reichenbach, 2008). PAYT is consistently a key aspect of the best performing diversion programs (Skumatz, 2008), and is well worth considering for any waste management program.

While fairly effective at reducing waste, this approach can make waste management more complex. One study that constructed a PAYT program development framework found that pricing, user identification, and measurements of waste are important factors that should be accounted for (Elia et al., 2015). To properly implement PAYT new systems may need to be developed, which in turn can mean a higher baseload of work for administrators. Additionally, the fact that PAYT is effective at driving down waste can mean a reduction in revenue for the management agency given lower waste charges. This can be addressed, however, by introducing a minimum charge to maintain program funding, or by the inclusion of other funding sources (Bilitewski, 2008). With good planning, the system should work out from an administrative cost perspective.

The findings on equity in regards to PAYT were more mixed. While higher educated low-income communities are more likely to adopt PAYT, the program can have an outsized impact on poorer families and even lead to illegal disposal (Gradus et al., 2019). However, PAYT has in some cases been called for directly by citizens in Europe seeking fairness in the face of higher charges. Overall, the costs tend to be lower than under flat fee structures, and the economic benefits from usage of diverted materials can lower the cost further (Reichenbach, 2008). A study in Switzerland found that in general costs to society were overall reduced by PAYT programs, and that concerns over economic impact were unfounded (Manni & Runhaar, 2014). So even in cases where the payment structure might be regressive, the overall cost is likely lower.

Even with potential effects considered, PAYT seems to generally be seen as fair by participants. A study in Sweden found most respondents actually did not think it was fair to pay for someone else to sort waste, and felt that sorting should be their personal responsibility as it is under PAYT (Bartelings & Sterner, 1999). Another study found that while households producing more waste tended to be less favorable of PAYT, in general once someone has experienced PAYT systems they tend to become more supportive of it. In those who valued fairness, PAYT was preferred over other waste systems. The researchers believe this indicates initial resistance is likely to dissipate once the policy is implemented. Ultimately they find that to address concerns, active outreach is likely to see the best effects (Brown & Johnstone, 2014). This adds to a recurring theme throughout the literature of the importance of education and outreach to the success of a given diversion program.

Education and Outreach

For any policy introducing new components and arrangements into the life of residents and commercial groups, education and outreach is vital. For example, one report found that education

to increase household awareness of diversion will be key for countries like Ireland and the Czech Republic to meet their diversion goals (Závodská et al., 2014). A similar study assessing 37 cities in China found that education campaigns were a key component in waste source separation and reduction (Han et al., 2016). In Thailand, the introduction of education and outreach programs increased household organic separation by 17% (Boonrod et al., 2015), even before the introduction of any financial incentives. Another study in Bangkok also concluded that environmental and social education campaigns were an important tool for organic diversion (Sukholthaman & Sharp, 2016). The presence of educational signage alone can also lead to diversion benefits, with one study at Dalhousie University finding that the introduction of signs and labels for collection containers by itself led to a ~19% increase in waste diversion generally (Robinson et al., 2012). In addition to increasing diversion rates, improved waste sorting due to education and outreach can even lead to overall waste reduction (Miliute-Plepiene & Plepys, 2015).

To understand how to perform effective education and outreach to encourage program participation, it's important to understand what motivates people to participate. A survey in Canada found that participants in voluntary diversion programs were primarily motivated by environmental benefits, while the main barriers for non-participants were odor, inconvenience, and cost (Pickering et al., 2020). Similar results were found in studies in both Thailand (Boonrod et al., 2015) and New York State (Oehman et al., 2022). An additional interesting predictor was recognition of anthropogenic climate change (Pickering et al., 2020). This is backed up by a Swedish study, which found that participation in diversion seemed to be strongly influenced by environmental awareness (Miliute-Plepiene & Plepys, 2015). High correlations for participation were also found with information exposure, and environmental knowledge specifically. Routine

information sharing, strong messaging, and leading actors in the community were also important factors (Ruliana et al., 2019). In another study, the strongest predictor for participation was knowledge on the benefits of organic waste diversion. Of note, 42% of non-participants became more likely to participate after receiving educational programming on the benefits of composting (Pickering et al., 2020). Similarly, a review of food waste reduction best practices found that personal interactions with individuals were the most effective at inducing behavior change (Kim et al., 2019). This study used a "social marketing" framework, which explores how to people's behavior with the intent of promoting broader social benefit. This social marketing framework also used in other studies exploring behavior change in relation to waste (Heydari et al., 2021; D. Pearson & Perera, 2018). Based on all of this, it seems education and outreach should consider addressing concerns with odor and inconvenience, provide knowledge on diversion benefits, and consider promoting concern for the environment more generally.

Municipal Case Studies

Most case studies that consider a given city are focused on how the diverted organic material is processed, assessing differences between things like composting and anaerobic digestion (Buratti et al., 2015; Ncube et al., 2021; Pai et al., 2019). Case studies taking a more 'full-picture' view in their assessment of a city's organic waste diversion approach in terms of policy and planning are generally less present in the literature. Those that exist tend to come in the form of reports, master's theses, and dissertations. One of the most directly related to this thesis is a broad assessment by the Department of Urban Studies and Planning at the Massachusetts Institute of Technology, as part of the Urban Sustainability Assessment Project. The report, created by Layzer and Schulman in 2014, consisted of 15 case studies of municipal organic waste diversion management (Layzer & Schulman, 2014). They considered existing data

and studies, web sources, and conducted their own interviews with city officials, haulers, and nonprofits. Their findings were referenced earlier in this literature review, but to summarize their results emphasized the importance of ambitious mandates, capacity for diversion, cooperation with haulers, promoting participation in source separation, and the use of pilot programs. Their list of cities studied included Seattle and Boulder, which we will examine further along with other examples studying these two cities.

Seattle and Boulder

For both Seattle and Boulder Layzer and Schulman mentioned self-imposed Zero Waste goals, which were slightly less ambitious than those set by San Francisco and Berkeley which had the highest diversion rate goals (Layzer & Schulman, 2014). They also found both cities were aided in their implementation by the fact that they already collected yard waste, making other organic collections easier to implement. The also each had a limited numbers of haulers they needed to get on board to the new systems. Both were found to have implemented PAYT, though the report did not comment on the effectiveness of that program. Brief mentions were made of each city's outreach program, with those discussed primarily being online videos posted by Boulder, and a "citizen champions" program for apartments in Seattle. They also noted that both cities built their efforts gradually, beginning with initial pilot programs and scaling up operations from there. Both cities, along with several others, had nonprofits that were engaging in composting before the cities had begun their programs, with EcoCycle in Boulder highlighted as directly inspiring the City of Boulder's recycling and organic collection programs. At the time of the study in 2014, Boulder had seen success with single-family participation, but was struggling with low multifamily rates. Also worth considering is that when this study was conducted, Seattle had only started collecting all organic waste five years earlier. Effectiveness

was measured by overall rate of diversion, with less consideration for the effectiveness of specific policies or programs. Interviews in this case appear to have been more based on fact-finding, whereas this thesis asked for both facts and opinions on effectiveness. It should also be said that Layzer and Schulman only looked at the residential sector, and did not address commercial participation as I will in this thesis.

Other studies also have looked at organic waste diversion in these cities. While not the main focus of the study, a 2011 capstone project for an MA program at University of Washington did assess Seattle's recycling and waste management programs from the perspective of what contributed to these policies being implementation (Thompson, 2011). In a similar vein is a dissertation presented by Lily Polland studying shifts towards sustainable waste systems, which considered Seattle as one of two case studies along with Boston (Pollans, 2017). This study was comprehensive in the aspects of Seattle's policies and programs that it considered, but observations were limited to the span from the 1970's to the early 1990's and was specifically concerned with each city's response to a waste crisis making landfill space limited and expensive. A history of Seattle's initial response is explored including the contentious proposal of using waste incineration as a landfill alternative, before moving to recycling and the composting of yard waste. Success is attributed not just to individual programs, but the system of institutions built up over time to offer an "alternative wasteway" (Pollans, 2017). Neither of these papers gave any special consideration to organic waste, and both were mostly concerned with factors contributing to certain policy outcomes, as well as resulting policy structures, rather than the effectiveness of any given policy or program once it was implemented.

For Boulder, a Master's thesis by Jennifer Thangavelu considered the city as one of two case studies, with a focus primarily on Zero Waste implementation (Thangavelu, 2013). Like

Polland's study of Seattle, Thangavelu gives a detailed accounting of waste management as it developed in Boulder. The discussion is extensive, with only a few sections directly addressing organic waste, but there are findings worth considering. First, was that Boulder as a community was perhaps predisposed to Zero Waste ideals. The city being relatively wealthier was considered as another factor for Boulder being able to pursue Zero Waste successfully, though through analysis of income and taxes they found that the cost of Boulder's programs would likely be relatively low even for another community. They also found that the city used PAYT, which at least initially appears to have led to some customer confusion over the new price arrangement. Beyond that, the effectiveness of the policy was not considered. For organics, they recount how Boulder started their collection as a pilot program in 2005, which allowed for later expansion to all residential customers. No requirement for collection of commercial organics was implemented at the time of publication. The focus of the study ultimately extends beyond the city government to include in depth analysis of haulers, nonprofits, and other levels of governments within broader contexts of policy and cultural change narratives, whereas my thesis considers primarily the city perspective. While much of the research done by Thangavelu overlaps with my work here, it gives less consideration to organic waste specifically and little consideration to factors such as outreach, enforcement mechanisms, and broader environmental and equity impacts. The study also only considers changes up until 2013, which means it does not account for changes made since then such as the Universal Zero Waste Ordinance passed by the City of Boulder in 2015 (City of Boulder, n.d.-c).

When considering this and the other studies presented here that utilize case studies to assess Boulder and Seattle, there are meaningful gaps in their consideration of organic waste management for these cities specifically. Many focus on policy frameworks and what contributes

to the passage of policies, more than the implementation of those policies and related programs. Additionally, many of these analyses focus on more historic timeframes. Studies taking the present context into account, at least for Seattle and Boulder, were conducted in 2014 at the latest, and thus do not reflect any changes in policy or implementation made in the interim. In these respects, I hope to expand on the understanding of organic waste diversion management both generally and for the cities of Boulder and Seattle specifically.

METHODS

I employed a comparative case-study analysis of the organic waste diversion approaches of two cities, Seattle, Washington, and Boulder, Colorado. A case study approach was chosen as it allowed me to "dig down deep" into a few examples (Kanazawa, 2017). This, I hoped, would allow me to observe details that have been missed by more limited studies of city policy in this area. As well, I believed an in-depth look is more suited to the holistic considerations of sustainability and equity I sought to consider in my analysis. Within this case study approach I utilized both textual analysis of policy and planning documents, as well as conducting interviews with management officials. Textual analysis involved the close reading of a text, in this case by applying an initial coding analysis criteria list which was revised throughout the coding process. This consisted of a mix of manifest and latent coding (Hay, 2000). Interviews took a semi-structured approach as elaborated in more detail on page 426 of Research Methods for Environmental Studies (Kanazawa, 2017). The basis of my coding process developed from the initial use of categories found in a framework analysis as outlined by Bardach and Patashnik (Bardach & Patashnik, 2023). With additional consideration of sources from the literature, the coding framework ultimately included a variety of environmental, social, and equity-based criteria. These formed my initial criteria for coding of both texts and interview transcripts, with criteria being adapted based on observed trends within the data. Coding was done within the Atlas.ti software. Trends, similarities, and differences were then assessed through a comparison of findings from both Boulder and Seattle.

Initially I planned to look at four cities in total, two larger and two smaller. However, there were difficulties in attaining interview data from two of these cities. I chose instead to focus solely on two cities in greater depth, those being Boulder and Seattle. While some research

in this area has already been conducted on these cities, as discussed in the literature review, these seem to have either focused more on policy (Thompson, 2011), considered a more historical timeframe (Pollans, 2017), or were conducted long enough ago that follow up research seems warranted given potential changes in the interim (Layzer & Schulman, 2014; Thangavelu, 2013). Seattle has been working towards Zero Waste since at least 1998, including a goal of 50% food waste reduction by 2030 (Seattle Public Utilities, 2023). Boulder adopted a Zero Waste resolution in 2006, with an ongoing goal of 85% overall waste diversion (City of Boulder, 2015). As Seattle has a population of roughly 737,000 (US Census Bureau, n.d.-b) while Boulder has a population of roughly 105,000 (US Census Bureau, n.d.-c), this makes it possible to observe potential differences between smaller and larger cities. They both also are within the Western region of the United States, which maintains some broad regional similarities. Seattle being in Washington can also provide specific insight on reaching high waste goals in the Washington context, as required by the new Washington state laws. Boulder was chosen in part for its relatively smaller size.

The most important factor in choosing cities for this thesis, however, was ensuring that they already have diversion programs with high rates of success. Somewhat challenging for this consideration is that calculations for diversion are generally reported as a combined rate between recycling and organics. The primary number reported as the diversion rate seems to be the tonnage of organic and recyclables divided by the total waste materials produced, including organics, recyclables, and garbage. In 2021, Seattle reported that their overall diversion rate was at roughly 53%, which was slightly down from previous years due to increases in waste production (Schwenger, 2020). Boulder's most recent diversion rate was recorded in 2020, as reported by their Zero Waste Data Dashboard, where they had achieved overall diversion of 53%

(City of Boulder, n.d.-d) coincidentally in line with Seattle's results. It's worth noting that this does not necessarily capture how much of the total organic waste produced specifically is diverted versus going to the landfill, a measure which is more in line with the requirements of Washington State's HB 1799 law. However, with quick estimates using Seattle as an example, a 53% general diversion rate appears to transfer to a roughly 73% capture of food and yard waste based on 2019 data (Seattle Public Utilities, 2023). Considered in tandem with the high rates of overall diversion, this seems to indicate high organic diversion rates are likely for both cities. These levels of diversion for organic waste, and more generally, have led to both Boulder and Seattle being recognized by the EPA as key examples of Zero Waste cities (US EPA, 2013, 2016f).

Data Collection and Approaches

My analysis took into consideration two kinds of data, those being textual sources and interviews. An analysis framework was applied to each, and specific methods of each aspect are detailed below.

Textual Analysis

I chose to limit my textual analysis to all city codes that involved organic waste, or waste generally. While each city has other relevant material such as Zero Waste planning documents, waste characterization reports, and collector contracts among others, I wanted to focus on what had actually been implemented in terms of enacted law. Thus, I focus my textual analysis on the each city's municipal codes as they currently stand as of March 2024, as found on each city's "Municode Library" website. The specific codes subjected to the coding process are listed below, in addition to Seattle's contracts with its two waste hauler companies which were given much more brief consideration. Throughout this thesis any time a code is referenced I will do so by

naming the city code of origin, and then listing the city code in a numbered format as used below. While my coding analysis may not extend beyond these documents, I do still take some of the other documents mentioned into account, and cite them as they become relevant.

Boulder, CO: Municipal Code

As accessed March 2024 from https://library.municode.com/co/boulder/codes/municipal_code

- TITLE 3 – REVENUE AND TAXATION
    - Chapter 10 – Trash Tax
        - *Codes 3-10-1 through 3-10-10*
- TITLE 6 – HEALTH, SAFETY, AND SANITATION
    - Chapter 3 – Trash, Recyclables, and Compostables
        - *Codes 6-3-1 through 6-3-18*
    - Chapter 12 – Trash, Recyclables, and Compostables Hauling
        - *Codes 6-12-1 through 6-12-9*

Seattle, WA: Municipal Code

As accessed March 2024 from https://library.municode.com/wa/seattle/codes/municipal_code

- TITLE 5 – REVENUE, FINANCE AND TAXATION
    - Subtitle II – Taxes
        - Chapter 5.48 – BUSINESS TAX–UTILITIES
            - *Code 5.48.055*
- TITLE 21 – UTILITIES
    - Subtitle III – Solid Waste
        - Chapter 21.36 – Solid Waste Collection
            - *Codes 21.40.010 through 21.40.130*
        - Chapter 21.40 – Solid Waste Collection Rates and Charges

        - *Codes 21.43.010 through 21.43.090*
    - Chapter 21.44 – Standards for Solid Waste Handling
        - *Code 21.44.010*

Seattle, WA: Hauler Contracts

- SPU-RC Solid Waste Contract #17-076-B
- SPU-WM Solid Waste Contract #17-077-B

Interviews

I first prepared an application for the Evergreen State College Institutional Review Board (IRB) for permission to study human subjects, which was approved. I took a key informant interview approach, prioritizing interview subjects involved directly with organic waste management in their respective cities. To find appropriate subjects, I initially looked at city websites for contact information. Where the waste management departments were large enough, I first reached out to the organic waste management lead. I sent emails explaining my project, and asking if they would be interested in participating in an interview process. If they were amenable, I then shared further details as well as a consent form including potential risks and options for anonymity. Both participants signed this form and agreed to the public use of their name and title within this thesis, though I have decided to only share their titles. I then secured a definite agreement to interview and set up a meeting time. At the beginning of the interview, risks and anonymity options were reiterated. Each interviewee asked to see the pre-planned questions ahead of time, and these were shared with both subjects. The pre-planned questions shared with each interviewee are listed below, separated by broader category:

Effectiveness

- In terms of organic waste diversion, are there any specific policies, programmatic tools, or other approaches that have been particularly effective?
    - Any least effective?
- Have diversion programs had any impact on your department's administrative workload and capacity?
    - If so, was this planned for?
- How has the city been measuring success?
    - Have these measurements felt effective?

Planning Process

- If there is coordination between departments or other groups, what does that look like?
    - Does the city's approach to diversion feel cohesive?
- Can you tell me what goals the city has prioritized in their waste diversion planning and process?
    - Similarly, have there been any decision-making criteria that have been prioritized during planning and implementation?

Equity

- Was there a structural process for assessing equity in planning and developing programs?
    - If yes, what did it look like?
    - If not, has equity been considered in other ways? (for example, health and safety requirements for haulers and processers, low-income considerations, or any other city codes, regulations, or programs)

Community Engagement

- Did the development process of diversion programs and policies involve stakeholder or public engagement?

    - If so, what did that look like? How engaged did the community seem?
- Has there been a noticeable response by the community to the implementation of waste diversion programs?
    - What has this looked like? Have there been any common concerns?
- Have there been education or outreach efforts to the community?
    - Has this felt helpful? Any particular approaches that have seemed most effective?

General

- Any challenges or surprises you have run into during implementation? Anything you would do differently?
- Anything you would recommend to administrators looking to implement similar organic waste diversion programs?

Interviews were set for roughly one hour each, and were conducted virtually over zoom. The format was semi-structured, using the list of questions for a basis as noted above. While this list was generally followed, there was flexibility to follow the flow of the conversation. Sometimes one question would be answered while addressing another, and some topics received unequal conversation time between interviews. As it became relevant, I also asked follow-up questions based on something of interest the interviewees may have said. I conducted two interviews in total, one with the Circular Economy Program Manager from the City of Boulder on 3/18/2024, and one with the Organics and Landscape Resource Conservation Planner and Program Lead from the City of Seattle on 3/22/2024. While a consent form agreeing to share their city of employment, official titles, and names was signed by both participants, I have chosen to withhold the use of subjects names in this thesis. I include the use of their titles only to provide potential context on the relation of their role to organic waste management.

These interviews were conducted through the Microsoft Teams software, and built-in functionality was used to record the interviews. Once the meeting was complete, the recording was deleted from the Teams system and downloaded to my personal password-protected device. The video component of these recordings was then removed. The Teams software also created an auto-generated transcript, which I corrected by referring back to the original recording. This corrected transcript was then coded utilizing Atlas.ti software, which was informed by a framework analysis approach. Throughout the results, the interview subjects will be referred to as "a city organic waste manager," and citations will be either in the form of "(Seattle Interview)" or "(Boulder Interview)."

Methods of Analysis

A specific coding strategy was utilized based on an analysis framework as presented by Bardach and Patashnik (Bardach & Patashnik, 2023), with the inclusion of criteria assessing aspects of sustainability and equity. These criteria were drawn from existing literature exploring sustainability assessments (Mathioudakis et al., 2022; Sanjuan-Delmás et al., 2021), Zero Waste frameworks (Zaman & Lehmann, 2013), SWOT analyses (Paes et al., 2019), life cycle assessments (Buratti et al., 2015; Di Maria & Micale, 2014), and studies specifically analyzing the holistic effectiveness of organic waste management systems (Layzer & Schulman, 2014).

These criteria were originally sorted into 3 general categories, those being social viability environment, and equity. As I conducted the analysis, however, these categories made less sense given the information available. Some of the pre-selected criteria, such as access equity, health impacts, or emission rates, appeared rarely or not at all. Other unplanned themes such as how success is measured or addressing cross-contamination emerged during the coding process, and were added as criteria for coding. Ultimately I settled on three broader categories for criteria,

those being how diversion is implemented in practice, the organizational approaches and frameworks utilized, and broader impacts beyond just waste diversion. The individual criteria within each of these categories are listed below:

Diversion in Practice

- Source separation/Collection – voluntary or mandatory
- Enforcement – how is compliance assured
- Payment structure – flat rate, pay as you throw, etc.
- Contamination – issues with, methods to address
- Public reception – any feedback from the community
- Outreach/Education – how they engage/inform their community

Organizational

- Management structure – size and nature of team, program capacity
- Measurements – how is effectiveness monitored, and success determined

Broader Impacts

- Waste reduction – any steps to promote decrease in production
- General sustainability – climate impacts, soil health, circularity considerations
- Equity – considerations across development and implementation

These criteria were used to inform the coding process. Having applied coding to both interview transcripts and the municipal codes for each city, findings for each of these criteria were then organized by theme and observed trends as presented in the results and discussion.

RESULTS AND DISCUSSION

Diversion in Practice

Mandatory vs. Voluntary Source Separation

The City of Boulder does not mandate source separation, though it does require that the infrastructure for recycling and compost collection be provided by waste haulers (Boulder Code 6-12-4), property owners, and business owners (Boulder Codes 6-3-13, 6-3-14, 6-3-15). According to the Boulder organic waste manager the idea is to provide the infrastructure for waste collection, and then "go on an outreach path in order to get people to use them properly." This was the same approach that they took when implementing recycling collection earlier on, stating that "it took a long time, but it worked" (Boulder Interview, virtual, 3/18/24) In contrast, the Seattle city code mandates that everyone must subscribe to both recycling and compost collection as well as participate in source separation (Seattle Codes 21.36.082, 21.36.083). According to the organic waste manager however, this is "very hard to enforce" (Seattle Interview, virtual, 3/22/24).

In practice then, it seems that Seattle may be fairly similar to Boulder, with the mandate mostly serving as a way to require collection infrastructure. However, the Seattle organic waste manager did also say that Seattle's requirements for both residential and commercial customers have led to strong effects (Seattle Interview). While the literature in this area was largely inconclusive, there were some examples such as Maryland that did see positive effects from its organic waste ban, which is equivalent to a separation mandate (Anglou et al., 2023). This could imply that the presence of a mandate for Seattle, even if not rigorously enforced, may have contributed to higher diversion. It is hard to say with certainty though, given the variety of other potential factors that may be at play. For instance, simply providing organic collection services

elsewhere has, in some studies, led to meaningful increases in diversion (Boonrod et al., 2015; Treadwell et al., 2018). But, while important, these policies alone are insufficient for reaching complete diversion.

Enforcement vs. Collaboration

While the extent of each city's requirements may vary, both cities have mechanisms written into their code to allow enforcement by the relevant department. In Seattle, the department director is permitted to inspect the premises of anyone suspected of being in violation of the waste codes (Seattle Code 21.36.114), while Boulder can conduct audits of haulers' records at will (Boulder Code 6-12-8). Both cities allow fines to be imposed in response to violations, with increasing penalties for repeat violators (Boulder Code 6-3-18; Seattle Code 21.36.115). In Boulder, waste haulers, property owners, and business owners must all keep records of collection and disposal that can be inspected by the city to ensure compliance (Boulder Codes 6-12-18, 6-12-6, 6-12-14). If a hauler is in violation in some respect of Code 6-12, city attorneys can pursue an injunction if necessary (Boulder Code 6-12-8). So, for all the aspects of their programs that are mandatory, both cities do have methods of enforcement generally in the form of inspection authority and financial penalties.

However, despite being provided for in the city code, both waste managers said that these enforcement mechanisms are rarely used, and are seen as less effective than other options. Instead, both emphasized the importance of collaboration with customers and contractors to reach compliance, rather than top-down enforcement approaches (Boulder Interview; Seattle Interview). Boulder's organics manager mentioned that while the rules could be useful to point to when pursuing compliance, collaboration was seen as a more significant aspect of implementation (Boulder Interview). Both cities wanted to get people on board with their

approach and, especially for the commercial sector, establish partnerships to hopefully build the investment of participants in the process. This began at the development and planning stages, where both cities engaged the public and key stakeholders such as the commercial sector. This could help to establish a feeling of collaboration early in the process (Boulder Interview; Seattle Interview). The Boulder manager further emphasized the importance of face-to-face interactions, especially for the commercial sector, which has been Boulder's most effective method for achieving compliance (Boulder Interview). In combination with assistance and resources, this may have helped make the required transitions more palatable for those disinclined to participate.

For Boulder, collaboration is especially important given that they rely on self-certification that commercial waste producers are complying with requirements to provide organic waste collection infrastructure. Ultimately this approach, combined with extensive outreach, seemed to work, with a stated compliance of around 96% from the first round of commercial participants. They were even ready to expand to the next round of businesses, though it was around that time that the Covid-19 pandemic derailed their progress leading to "probably less than a 50% compliance rate (Boulder Interview). This success, before it was interrupted by the Covid-19 pandemic, was well aligned with the literature, including several studies concluding that outreach was vital to diversion success (Han et al., 2016; Pietzsch et al., 2017; Závodská et al., 2014). The importance of cooperation with haulers, in addition to commercial partners, was also emphasized in an assessment that considered Boulder and Seattle along with several other cities. This cooperation was seen as easier for cities with limited numbers of haulers, which included Seattle and Boulder (Layzer & Schulman, 2014). Essentially, when there are fewer haulers, or any other stakeholders, to engage, it's easier to get everyone on the same page. So, across sectors, collaboration appears to be important to diversion success.

The collaborative approaches of these cities may be driven by a few factors. The first, I believe, is a matter of practicality. While outreach and engagement can take significant resources, the costs of monitoring for violations and managing enforcement systems would also take significant resources. This may seem especially undesirable given both organic waste managers found these approaches to be less effective (Boulder Interview, Seattle Interview). The second factor is that education and outreach, including approaches like offering technical assistance, seem to have simply been the most effective for both cities (Han et al., 2016; Pietzsch et al., 2017; Závodská et al., 2014). The third factor is that both seem to trust their respective communities.

The decision making behind Boulder's Zero Waste Ordinance, for instance was that the Boulder community would do the right thing if given the proper infrastructure (Boulder Interview). Seattle's community was described by the organics manager as generally having a Zero Waste ethic. Part of why the city focuses on "showing" how to source separate, rather than making people, comes down to the idea that "generally people want to do the right thing, and they do" (Seattle Interview). So, collaboration seems to be pursued not just because it is seen as effective, but also because each city seems to generally trust its constituents. And there is good reason for them to have that trust, given that many studies find simply providing information and explanations leads to significant improvements in diversion results (Miliute-Plepiene & Plepys, 2015; Závodská et al., 2014). Believing that people will engage in diversion once properly informed, or in other words assuming good faith, may be an important element in these collaborative approaches succeeding. This approach, including building connections, can also help to build trust between the community and the government, which can lead to higher

participation in diversion programs (Loan et al., 2017). However, even with good faith assumed, there is still room for issues and challenges to arise.

Difficulties with Contamination

A recurring area of concern throughout the interviews and city codes for both cities were issues regarding cross-contamination of waste streams. Essentially, this refers to waste being put in the wrong disposal container. With organics, the concern is that non-compostable materials are ending up in the organic waste stream. Common items appear to include food packaging, plastic bags and cutlery, and produce stickers among others (US EPA, 2021). Some research finds that contamination of organics can reduce the quality and value of products derived from processes like anaerobic digestion (Arsova, 2010; Hansen et al., 2007). Another study explores in detail the mechanical methods needed to filter out contaminants once the organics had already been collected (Jank et al., 2015), and the need for such technologies can drive up costs for organic waste processers. An EPA report found that in Washington and Oregon, plastic contamination of organic waste was roughly 2.8% by weight. Along with effects on the productivity of organic waste processing technologies, they also shared concerns over the as yet little studied potential health impacts that plastics could present in compost applied to crops (US EPA, 2021). Ultimately, preventing contamination is a key aspect of successful source separation and diversion. Both cities have taken interesting approaches to address these issues, to varying success.

Some of the solutions presented are relatively narrow, such as Seattle's regulations regarding bags containing organic waste. Specifically, organics are not allowed to be put in plastic bags for collection (Seattle Code 21.36.085). This can hopefully prevent those bags from contaminating the compost once it reaches a processing facility. The city also requires that

disposal stations only accept materials if they are relatively free of contaminants (Seattle Code 21.40.080), likely with the intent to minimize the amount of organics and recyclables that need to be thrown away. However, neither of these approaches are fully able to address the larger issue of people putting materials into the wrong bin.

Addressing this seems to be one of the more challenging aspects of diversion. While in their city code Boulder requires that special and temporary events must provide recyclable and compostable collection services (Boulder Code 6-3-15), they stopped enforcing this due to severe issues with contamination. They in fact had to stop collection for any public facing areas, including places like public parks and fast food restaurants (Boulder Interview). While this does seem to indicate the difficulty of implementing source seperation, it's interesting to note that in contrast Seattle still has public facing collections. One potential aspect of this may be that, with difference in size and budget, Seattle is able to conduct more outreach and implement more collection infrastructure more easily.

However, given that the residential and business sectors are generally able to divert effectively, the Boulder manager thinks this issue is likely due to the high number of visitors the city receives that are unfamiliar with their waste systems (Boulder Interview). On the other hand Seattle also receives high numbers of tourists, but does not seem to have the same issues with the contamination from public-facing collections. Data to compare tourism between the cities was difficult to find however. It could be that Boulder receives proportionately higher numbers of visitors, making management more difficult. Alternatively, it may be that Seattle, as a larger city, has greater capacity to implement outreach materials and strategies to improve public-facing collection. It may also be that Seattle's outreach, including adaptive signage, is just more effective at reducing contamination, though its higher budget and staff capacity as a larger city

would be likely to play some role in the observed difference. In general the difference in public-facing contamination in these case then may have less to do with the efficiency of each cities waste systems generally, but perhaps more their ability to handle visitors and tourists specifically.

One challenge with diversion shared by both cities were issues with compostable products, such as biodegradable plastics that might be used for something like serving utensils. An underlying issue is that many of these materials require a more industrialized compost system than what most cities have available, and producers of these materials can often be misleading in their claims. A study found that as a result individuals are left confused over what materials are or are not compostable (Nazareth et al., 2022). This adds more complexity to source seperation for both the individual, and for waste managers. The Seattle manager was unsure if deciding to collect these materials was the right choice, as they seemed to increase "consumer confusion and result in contamination of organics" (Seattle Interview), which aligns with findings in the literature (Nazareth et al., 2022). Boulder faces similar issues, which contributed to the decision of their sole processor, A1 Organics, to stop accepting anything besides pure food and yard waste. As there is no other facility to send these compostable products to, the City of Boulder as a whole had to stop collecting them (Boulder Interview). As it stands, offering to accept these kinds of products may be more trouble than its worth, unless one is willing to contribute a larger amount of time and energy to education and outreach on the topic. This situation could change in the near future however, at least in Washington, as HB 1799 has set regulations on labeling practices for compostable products that could lead to significant changes in this area (*HB 1799 - 2021-22*, n.d.), though we will we have to see.

Issues with these kinds of products contributed, among other aspects of contamination, to the City of Boulder's decision to stop the public facing collection of any organic materials. Instead, they have steered towards greater promotion of reusables and durables over biodegradable single-use items (Boulder Interview). Though Seattle still has public-facing collection, they have similarly steered towards promoting reusables over single-use items even if they are compostable. While they do still allow the collection of compostable and recyclable single-use items, they have, at least for carryout bags, set some regulations and set a "pass-through charge" for the use of any single-use bags (Seattle Code 21.36.100). In any case, it's clear that this aspect of diversion has not been settled for these cities, and is still open for improvement. As with diversion generally, it may be that outreach and education are one of the key methods to move forward in this regard.

Payment Structures and PAYT

Both cities use some degree of a Pay-as-you-throw (PAYT) payment scheme when setting rates for organic waste, with interesting differences. Seattle takes what could be considered a standard approach, while explicitly adopting the term PAYT. For Seattle, residential compost containers are at most roughly a quarter the cost of an equivalent garbage container. However, for use of the larger 90-96 gallon container size, garbage costs roughly $130 in comparison with the organics container only costing roughly $14 (Seattle Code 21.40.050). Pre-paid bags, for areas where containers are always in the right-of-way, must always cost 32% less for organic waste bags versus garbage (Seattle Code 21.40.060). This same rate of 32% lower for compost also applies for containers supplied to commercial customers (Seattle Code 21.40.070). Similarly for "drop box" services, in this case meaning large waste containers that can be loaded and transported for disposal by a collection vehicle (Boulder Code 21.36.012), the cost of organic

waste is set to roughly 50% of the rate for garbage (Seattle Code 21.40.060). And any yard or wood waste brought to a city recycling and disposal station is generally charged $40 less than the equivalent amount in garbage (Seattle Code 21.40.080). So, we can see that Seattle practices PAYT across various collection methods, with some adjustments for each type of collection.

Boulder also practices a form of PAYT, though they never use that name for it, with some interesting distinctions. While Seattle extensively details their various rates, with tables in the city code itself showing prices by bin size, waste stream, and year, Boulder is much more brief in their explanation. First, they detail the amounts of recyclable and organics that collectors must provide free of charge. This includes unlimited recyclables, at least 32 gallons of compostables, 3 bags of leaves, and 3 bundles of branches. Any compostables set out beyond that 32 gallons worth could then be charged at a rate of "no more than [75%] of an equivalent volume of trash service" (Boulder Code 6-12-4). While this means that the provision of these services would cause less impact to the customers, it does mean their financial incentive for collection only truly begins after their 32 gallon garbage container, the smallest the city offers, becomes full. In contrast, Seattle's smallest waste container that they offer is only 10 gallons, after which price differences become steeper (Seattle Code 21.40.050). This means that rate differences come into play sooner, and the financial incentive to separate out organics for diversion can apply to more of the waste produced by an individual or group. While further analysis could clarify if these differences lead to measurable differences in diversion effectiveness, ultimately both PAYT systems do seem to establish meaningful differences in prices between organic and garbage disposal.

It is worth noting that while Boulder does offer a significant amount of organic waste collection free of charge, there is still some cost to this service. This comes in the form of the

"Trash Tax" passed by Ordinance 5343, which the city code describes as an "occupation tax." The tax rate is currently $3.50/month for each residential customer a given hauler has, and "a maximum" of $0.85 for each cubic yard of waste disposed of by commercial accounts (Boulder Code 3-10-2). However, another provision allows for haulers to directly add "Trash Tax" as a line item on their bills to customers (Boulder Code 3-10-7), effectively passing the costs on to consumers. This in effect makes it a consumer tax, possibly structured this way as it removes the need for the city to monitor who should be charged. The intention for the funds is to be used for general operating expenses of the city, "including but not limited to" funding waste reduction programs (Boulder Code 3-10-1). While the code itself does not specify usage further, the city's website reports that uses include funding curbside compost collection, among others (City of Boulder, n.d.-b). So, in effect, there is a payment being made by customers to subsidize that first free 32 gallons of organic waste collection. But, this charge is being placed upon their trash collection only, which in effect raises the rate for trash collection to assist in lowering that rate for organic collection.

Additionally, past studies capture sentiment from haulers that the existence of PAYT within Boulder's system led to more work and costs for companies to manage it than it would have for the city due to complications with equipment retrieval and customers changing residencies (Thangavelu, 2013). If costs are passed on to the consumer, it would similarly seem to contribute to different rates within PAYT. While slightly complicated, this does still seem to fit within a PAYT framework, though it is unclear if the differences in structures would lead to any changes in the incentives of the program. Seattle also has a similar tax that, while having no dedicated use for its funds, does still tax disposal of garbage while excluding organics (Seattle

Code 5.48.055) which could also be seen as contributing to variable rates that contribute to PAYT's economic incentives to divert.

Generally, we can see that having some form of PAYT is important to both cities, given their specific inclusion in the city codes. While we did not happen to touch on this topic in the course of the Boulder interview, the organic waste manager from Seattle was able to share their thoughts on the efficacy of the practice. They found that PAYT strongly incentives creating less waste, with the introduction of a monetary incentive being a key component for why the payment structure is so effective (Seattle Interview). This aligns well with literature analyzing PAYT, which consistently finds that implementation of PAYT systems have led to increased rates in diversion and can even lower waste production in general (Dahlén & Lagerkvist, 2010; Pietzsch et al., 2017; Skumatz, 2008).

The manager also brought up another perspective I had not come across in the literature, with the idea of a competitive social incentive resulting from PAYT described as a social marketing aspect of the program. Essentially, when someone separates more efficiently and wants to pay for less waste, they get a smaller waste bin. This is a very visible difference that can be observed among neighbors, and was described as becoming something like a "badge of honor… or walk of shame" depending on your bin size (Seattle Interview). Basically, when someone goes from a larger to a smaller waste bin and it is observed by neighbors, this could have the potential to ignite a competition-based incentive to participate in source separation. This provides another reason, along with financial incentives, of why implementing PAYT is well worth consideration by cities seeking to address organic waste diversion.

Public Reception

The diversion and Zero Waste policies in both cities seem to generally be approved of by the public. The Boulder manager described the Boulder community as being generally progressive, and aligned with the goals of the city government. When the policies were enacted, some businesses had in fact already met the new requirements (Boulder Interview). Looking at the website of their non-profit community partner Eco-Cycle, this makes some sense. According to their history, Eco-Cycle seems to have developed their own recycling program in 1976 that predates any curbside collection by the city (Eco-Cycle, n.d.). In this case, it seems there was active community advocacy working towards Zero Waste before the city adopted these goals.

Similarly in Seattle, as mentioned earlier, the organic waste manager mentioned that there was generally a Zero Waste ethic in the community. Further, they said these policies exist to begin with partially because members of the community advocated for them (Seattle Interview). This seems to have been driven in large part by responses to a plan to implement a waste-to-energy incineration facility in the 1980's, which galvanized a strong community response regarding how diversion should be handled (Pollans, 2017). This also seems to have included advocacy by the group known as Zero Waste Washington, at least according to the group's website, which as an organization continues to support Zero Waste efforts in Seattle and the state at large (Zero Waste Washington, n.d.). While such advocacy does not necessarily tell us the degree of public agreement with city policies, the presence of such groups, along with comments from the interviews, could be indicative of broader support. While the size and extent of groups in Seattle are less clear, groups like Pace and Eco-Cycle in Boulder are well-established and can provide stronger evidence for this claim. As seen in previous research of Boulder, Seattle, and other cities, involvement of such groups can play a significant role in the development and

success of diversion programs and policy (Layzer & Schulman, 2014). Regardless, the presence and engagement of such passionate organizations seems like it could only be beneficial for increasing diversion.

While public acceptance and advocacy were certainly helpful in contributing to the development and success of each cities' policies, it could make analyzing the success of these policies more difficult. If a community is already willing to embrace diversion and Zero Waste, then it becomes harder to tell if the success of any given approach as discussed above may be transferable to other cities with less preexisting support. For instance, while providing collection infrastructure without a mandate has led to good results for Boulder, it's possible that same approach wouldn't work as well for a community not already desiring those changes. Additionally, the median incomes for both Seattle and Boulder are respectively roughly $14,000 and $45,000 higher than the national average (US Census Bureau, n.d.-a, n.d.-c, n.d.-b). Higher income in has in some studies been correlated with higher diversion rates (Treadwell et al., 2018) which could further predispose these two cities to success in terms of diversion, though it should be said this link is disputed and may not have a causal relationship (Pollans et al., 2017; Treadwell et al., 2018). This all may limit the generalizability of the approaches of Seattle and Boulder, especially when considering cities that are responding to external pressure such as financial stress or state mandates rather than internal community-based pressure for change.

However, I would argue that while that is likely true to an extent, this line of thought only goes so far. As the Seattle manager puts it, under Nancy Lee's social marketing framework, people fall into three categories of "tell me, show me, make me" (Seattle Interview). Meaning, some people only need to be told what to do, some need to be shown, and some need to be made to do something. Both cities, even while having generally receptive communities, still have

people that need to be shown, and need to be pushed to change. Their solutions to addressing these groups would likely be transferable. This is especially true of the approach prioritized most by both cities, namely, education and outreach.

Education and Outreach

For each city, it was clear that education and outreach were prioritized. Seattle has invested quite a lot into their outreach, especially around source separation. When asked if outreach had been helpful, the Seattle manager responded that "it's not even a question." Human behavior was seen as a critical component of waste conveyance systems, and their education efforts were considered to have been quite effective especially for the commercial sector (Seattle Interview). This concern with outreach appears to be have been consistent since the initial development of diversion programs, with the leader of Seattle's public utility requesting in 1987 a "huge budget for communication" (Pollans, 2017), indicating an early dedication to outreach. A similar sentiment is reflected in Boulder finding that, while it can be difficult, "outreach and education are paramount. They're just so important to do" (Boulder Interview). This makes particular sense given Boulder's reliance on voluntary source separation generally, and their self-reporting approach in regards to commercial compliance. This agrees with findings in the literature that informing and engaging citizens is essential, both for Zero Waste generally (Pietzsch et al., 2017) and organic diversion specifically (Han et al., 2016; Závodská et al., 2014).

Even with good intentions, it would be difficult for people to participate in these systems without the knowledge of how to do so (Boulder Interview). As the Seattle manager put it, "if we are expecting all of the people who live and work in Seattle to do this behavior properly… it is incumbent upon us to figure out how to effectively communicate" with them (Seattle Interview). But while outreach and education are seen as vital, the Boulder manager also cautions that they

are “hard to do,” (Boulder Interview) which frames them as both challenging and necessary tasks. Both cities have gone about meeting these challenges in a variety of ways, with some similarities and differences.

Dedicated and Connected Teams

In both cities, there are people dedicated to Zero Waste outreach and education. Seattle has a whole staff dedicated to outreach, both to conduct outreach and provide technical assistance for their Zero Waste programs. Commercial customers are the primary target of this assistance, as diversion is more complicated for that sector (Seattle Interview). Seattle also places many outreach requirements in their contracts with waste collectors, including material development, technical assistance, and education program delivery (SPU-WM Solid Waste Contract #17-077-B, Section 1310; SPU-RC Solid Waste Contract #17-076-B, Section 1310). While Boulder seems to have less in-house staff capacity, and only utilized their collectors for distribution of education materials, outreach is still a large part of the city’s focus. In the initial implementation phases for diversion compliance, directed again primarily at the commercial sector, managing the self-reporting program was a large part of the Boulder organics managers work plan. They also employ the assistance of nonprofit outreach partners, PACE and Eco-Cycle, which were described as effectively being the “outreach arm” of the City’s Zero Waste efforts. Ultimately, this combination of efforts allowed them to achieve a 96% compliance rate in a targeted portion of the commercial sector, though this rate later fell to roughly 50% likely due to the Covid-19 pandemic (Boulder Interview). Whatever the composition, an outreach team seems to be a necessary component of the diversion programs for both cities.

It also seems to be important that members of these teams have connections with the communities they are reaching out to. For example, the Seattle manager said that their staff team

tries to have a variety of language skills and familiarity with various cultural and ethnic communities. They continued that this both helps with culturally considerate outreach, and also allows them to more effectively conduct outreach by engaging with Seattle's many diverse communities (Seattle Interview). Boulders outreach partners also seem to have community connections. One of their partners, Eco-Cycle, was described by the organics manager as having a network of volunteers that would distribute information in their neighborhoods, churches, gyms, and in general serve as a resource for the communities in which they are already members. This includes face-to-face connections, and the distribution of materials such as a yearly "Eco-Cycle guide" partly funded by the City of Boulder. Similarly, another partner, the University of Colorado's Environmental Center, utilizes students to engage in peer-to-peer outreach (Boulder Interview). This matches a correlation found in the literature between the presence of community leaders, such as Eco-Cycle, and high diversion participation rates (Ruliana et al., 2019). Teams were further found to be important to effective diversion in a broad case study assessment of several cities (Layzer & Schulman, 2014). In addition to having a team, the ability for that team to connect and relate to the communities they are attempting to inform and assist appears to be vital.

Assistance, Connection, and Meeting People Where They're At

Both cities engaged in many similar approaches to outreach and education, with some variation. For example technical assistance, such as for commercial customers or building owners attempting to implement waste collection infrastructure, was mentioned as being important by both managers. For Seattle, while technical assistance was useful for residential customers, it was described as "very helpful" for the commercial sector in particular. Assistance mentioned included both cultural and language-specific outreach, help setting up accounts,

detailing how to set out bins, partnering on store specific source separation graphics, and more (Seattle Interview). Boulder emphasized the importance of such approaches, and how attempting to enforce requirements is "received much better" by the public "when you provide them the assistance and resources to be successful" at the required task (Boulder Interview). Essentially, people are more willing to support requirements made of them when the system sets them up with the best chance of successfully meeting those requirements.

A few approaches to technical assistance, and to outreach generally, stood out in particular. Face-to-face interactions appeared to be highly valued by the Boulder manager as an important aspect contributing to the success of their outreach efforts, with the phrase "face-to-face" being mentioned repeatedly throughout the interview. Their community partner PACE would go directly to businesses and provide "information, resources, [and] one-on-one face-to-face advising around how to manage their waste systems" (Boulder Interview). This affirms the findings of another study which found personal interactions to be an important factor for inducing behavior change (Kim et al., 2019). PACE also seems to serve as an outreach arm not just for waste, but all aspects of climate sustainability planning (Boulder Interview). This makes it easier for customers to know where to go, and presents a simple avenue to address waste with customers that may have initially been seeking assistance in relation to a different aspect of sustainability. Altogether, along with a targeted self-compliance campaign, this appears to have contributed to their reported ~96% compliance rate among their initial commercial targets, at least until the Covid-19 pandemic derailed these efforts (Boulder Interview). So, these approaches seem to be largely successful, and are likely worth emulating.

The Boulder organic waste manager related their outreach approach to the idea of social marketing, attributed to Doug McKenzie-Mohr (Boulder Interview), which was also mentioned

by Seattle, attributed to Nancy Lee (Seattle Interview). This was described by Boulder as the idea that the "only way to make people change their behavior is to meet them where they are and talk to them face-to-face" (Boulder Interview). The Seattle organic waste manager seemed to share similar sentiments, but focused more on Seattle's efforts with translations and culturally competent outreach as part of "meeting the customers in a culturally responsive way." Additionally, they mentioned the importance of explaining "why is that important?" Especially given that food waste in particular can be perceived as "icky," helping people understand the reasons for diversion was seen as a meaningful way to increase buy-in. The main point of emphasis was climate change, and how "diverting food waste from the landfill is actually one of the most powerful things we can do as individuals" to affect climate change (Seattle Interview). And several studies do in fact cite awareness of environmental impact as a positive driver of diversion (Miliute-Plepiene & Plepys, 2015; Pickering et al., 2020; Ruliana et al., 2019). It was acknowledged, however, that this might not be the right angle to reach everyone (Seattle Interview), again adding to the theme of using different messaging to best reach different audiences. Taken altogether, all of this seems to be in service of the broader idea valued by both cities of meeting people 'where they're at' which seems to generally inform their approaches and attitudes to outreach. This mindset fits with both cities' broader preference for collaboration and may be an important step in building connections and partnerships with stakeholders and community members.

Materials, Signs, and Distribution

Approaches to the content and implementation of outreach materials, and signage in particular, are interesting and varied. The Seattle manager for instance reported that the city translates their signs into around four languages, and materials like brochures into maybe

eighteen languages. This also includes what was labeled as “transcreation” which in addition to translation involves adaptation of the message to a new cultural context. They also will tailor the imagery of their materials, such as working with a restaurant so that waste separation signs show images of the exact foods and containers used at that establishment. This can get expensive, especially when paying for graphic design services (Seattle Interview), though some of this production cost may be offset by requirements for collectors to produce some of these materials themselves (SPU-WM Solid Waste Contract #17-077-B, Section 1310; SPU-RC Solid Waste Contract #17-076-B, Section 1310). Generally, though, Seattle seems to find context-specific signage helpful for reaching their customers in a culturally responsive way, an approach which they also see as simply being more effective at achieving diversion compliance (Seattle Interview). The importance of signage can be seen in the literature, with implementation of signs at Dalhousie University leading to a ~19% increase in waste diversion generally (Robinson et al., 2012). Taken together we can see that signage can be important for achieving compliance in front-facing collection, especially across diverse situational and cultural contexts.

The Boulder manager also acknowledged the benefit of signs, but had some reservations. While they have extensively developed and redeveloped their signage over time, they found that some people just don’t look at the signs (Boulder Interview). So while signage seems generally important to have and can lead to good results, there is the potential that high investment could still lead to little improvement. Interestingly, while the Seattle organic waste manager shared less reservations regarding signage, they also shared another approach which could reduce the need for them. By consistently having the three collection bin types across as many contexts as possible including work, school, community events, and other spaces, sorting behavior should become “second nature” (Seattle Interview) which means over time the community could

become less reliant on signage for instructions. Regardless, investment in signage seems generally worthwhile, though perhaps should be considered strategically in balance with other approaches that may prove more effective. And while not explicitly endorsed as effective, the fact that managers for both cities mentioned using pamphlets and other materials seems to imply an assumed benefit to the practice.

Of course for such materials to have an impact, they need to reach those that they seek to educate. This was done in a few different ways. The Boulder city code mentions that hauling companies are required to distribute materials to their customers upon request by the city (Boulder Code 6-12-7). While not mentioned in Seattle's city code the city does place outreach requirements in their contracts with waste haulers, including requirements to provide, and even produce, educational materials such as posters, signage, and instructional flyers to both residential and commercial customers (SPU-WM Solid Waste Contract #17-077-B, Section 1310; SPU-RC Solid Waste Contract #17-076-B, Section 1310). Boulder being an open system likely has less leverage over hauler behavior (Layzer & Schulman, 2014), which may prevent them from implementing similar requirements. While the effectiveness of these requirements was not touched on in the interviews, it seems like it would be a relatively efficient way to increase each cities' reach using existing channels in the form of a given hauler's collection routes and connections with their customers.

Other groups were also utilized for distribution. For instance in Boulder, it is mandatory for property owners to provide information to their tenants or occupants (Boulder Code 6-3-13), with the same requirements applying to business owners in regard to their employees (Boulder Code 6-3-14). The Boulder manager cautioned however that these policies can be difficult to enforce without a whole team in place to contact property management companies. In addition,

their community partner Eco-Cycle will distribute yearly "Eco-Cyle guides," as mentioned previously, among other materials (Boulder Interview). In a sense these approaches can allow cities to take advantage of the existing distribution pathways other entities and groups may already have in place, which the city would otherwise have to create themselves. While the effectiveness may be variable depending on the partner utilized, especially regarding business and property owners, it seems relatively low risk to the city. While there is a chance that a hauler or building manager doesn't follow through on such requirements, this does seem to be a risk that would diminish as partnerships with these groups strengthen over time.

Multifamily Sector Difficulties

The multifamily sector appears to be a more difficult area for outreach and education to achieve results in. Boulder was seen to have been struggling with multifamily compliance in a report from 2014 (Layzer & Schulman, 2014). Difficulties with organic diversion for multifamily residents seems to have continued to the present, with the Boulder organic waste manager saying they have had to even ease back on requirements for providing collection to multifamily structures (Boulder Interview). There are, however, some attempts to address this issue by both cities. The Seattle manager indicated that a "disproportionate amount of resources" may need to be directed towards the multifamily sector to achieve compliance (Seattle Interview). This may be reflected in the fact that the multifamily sector has the lowest diversion rate of any category for both cities (Cascadia Consulting Group, 2020; City of Boulder, n.d.-d). In Boulder, as previously mentioned, property owners are required to provide information on how to use the on-site system to any new tenants or occupants and provide them with annual updates (Boulder Code 6-3-13). The manager for Boulder mentioned that while some property owners do engage voluntarily, others are harder to convince. Multifamily complexes seem to be particularly

challenging in this respect given the large number of tenants and frequency of turnover, which requires further work from property owners. The organic waste manager mentioned this can be "especially hard" due to being in a college town, with the implication of more frequent resident turnover. This is complicated further by specialty "concierge" collector services some places hire, separate from general collectors, who also need to be reviewed for compliance. Again as mentioned before, without a "whole team of people" contacting property management companies, these education requirements were described as "nearly impossible to enforce" (Boulder Interview). So, this approach may be less appealing for cities with limited outreach capacity.

A different tactic can be found in Seattle's contracts with their waste haulers, where they stipulate requirements for multifamily outreach by the haulers. Required services specifically for multifamily structures include production and delivery of signage and instructional materials, providing "onsite technical assistance" by a designated specialist, delivering educational programs, and training several property managers a year (SPU-WM Solid Waste Contract #17-077-B, Section 1310; SPU-RC Solid Waste Contract #17-076-B, Section 1310). While it seems promising to have dedicated outreach in this area, the manager reported that multifamily still has the lowest compliance (Seattle Interview). This seems in line with a recent Toronto study, where outreach and other strategies such as implementing chutes for organic waste were seen to have little effect (Maclaren et al., 2022). In general, multifamily outreach seems to be a particularly difficult area for either city to achieve diversion in, and no clear solutions seem to present themselves. This may simply be due to the more complicated collection pathways presented by a multi-unit building. Or, given that apartment households have a lower median income than the national average (National Multifamily Housing Council, n.d.), it could be that income

differences somehow play a factor which would be worth investigating from an equity perspective. Generally, this seems to be a prime area for further research and experimentation.

Management Structures and Partnerships

Across the board, staff capacity seems to be an important aspect of these programs. The Seattle manager communicated that along with their own position the city has the rest of the solid waste management team including someone dedicated solely to solid waste policy, and a full team of outreach staff to develop materials and provide technical assistance. The city also runs its own transfer stations, which require even more staff. For the aspects of waste management the city contracts out, including collection and processing, setting up and managing those contracts is complicated and can require further capacity (Seattle Interview). Boulder, while having less in-house capacity, also engaged with several community partners, which allowed them to function with an expanded capacity (Boulder Interview). Even then, they described implementation as a "heavy lift." For their commercial self-reporting approach, they had to develop the systems and forms, implement them, and after all that ensure compliance across a variety of scenarios. Even with broader support, the Boulder manager had to review each form submitted, and managing this program was a large part of the manager's work plan for the first year. This stress did seem to be alleviated by the choice to roll out their implementation in stages, focusing to begin with on only a subsection of the commercial sector (Boulder Interview). In general then, each city emphasized the need for a full team to properly conduct outreach and implement their diversion and Zero Waste plans (Seattle Interview; Boulder Interview).

In this context, community partnerships seem like a particularly effective tool. Regarding Eco-Cycle, the Boulder organic waste manager stated how "you can't say enough about their

effect on… where Boulder is now," having "basically been partners in the whole Zero Waste thing for 47 years." One of the described benefits of having a community partner was that the partner has built-in connections with the community (Boulder Interview) which may make things easier than a city trying to build these connections on their own. Additionally, the elements that are more peer-to-peer based, such as neighborhood or campus outreach, may simply be more effective. While a study regarding campus peer-to-peer programs found inconclusive results, they did consider the approach to be promising though the literature seems inconclusive on this subject (Erickson, 2010). Ultimately, community partners can free up city staff capacity to conduct further outreach or engage in other aspects of implementation.

In addition to working with community groups, the organic waste managers also spoke to involvement with other local and regional governmental structures. The Seattle manager pointed to an example of how multiple departments came together to coordinate the development of an update for the city's Food Action Plan (Seattle Interview). They also discussed helping other departments to achieve compliance with new policy, such as the requirements set by HB 1799 requiring that Washington cities procure local compost when possible (Seattle Interview; *HB 1799 - 2021-22*, n.d.). There was also regular coordination with other departments, with examples of focus including "sustainable landscaping practices and education" (Seattle Interview). It would seem that priorities for this kind of coordination primarily revolve around planning in regards to cross-sector issues such as food, as well as in response to policies that require action by different departments.

The City of Boulder interestingly seems like it may have stronger interconnections between departments. Part of this was attributed by the organic waste manager to the nature of a public utility touching on issues such as water that affected everyone. But they have also seen

that “over the years… other departments are realizing that what we do needs to be part of what they do in a very integrated sense.” This seems to have happened especially in regard to meeting climate goals, as the climate initiatives department the interview subject was part of was seen as “the experts in it” (Boulder Interview). This more strongly expressed interconnection by Boulder could be due to a difference in approach in planning or policy. Boulder for instance more actively embraces Circular Economy approaches, which promote interconnections (Kirchherr et al., 2017). However, it may also simply be that given Boulder is a smaller city, such connections are easier to establish and maintain as there are less people for them to communicate with. Regardless, both cities do seem to value interdepartmental connections in working towards various diversion and sustainability goals.

Equity Consideration

As part of considerations for a ‘just transition’ from landfills towards more sustainable waste systems, it was important to consider aspects of equity that may have been taken into consideration. The most relevant categories of equity found in this study were regarding the processes of plan and policy development, as well as consideration for various impacts that might result from implementation of diversion approaches. These are explored below.

Health and Environment

In this category, there was not an extensive amount of information from which to make a judgement. Boulder’s policy did indicate concern for impacts, stating that all of their waste collection policies are intended to protect public health, safety, and welfare (Boulder Code 6-3-1). Seattle had similar rules, stating that any waste delivered to a receiving facility must comply with all federal, state, and local laws, rules, and regulations relating to environmental health (Seattle Code 21.36.113). In Seattle, there were also exemptions from curbside disposal for those

with physical disabilities, in addition to reduced costs for backyard collection (Seattle Code 21.40.050). While for both cities there were health regulations in regard to leaving waste out, as well as standard safety and health requirements made of collectors, the only aspect related specifically to organic waste was Boulder's rules on compost piles. Namely, that on-site composting could not be allowed to become a health nuisance (Boulder Code 6-3-6). Generally, it seems that both cities rely on existing city, state, and federal laws and codes around health without further expansion, at least relating to waste collection and organic waste specifically.

The lack of rules relating to facilities is perhaps to be expected, as the primary impacts of organic waste are further downstream. The main impacts of organic waste collection come into play at the processing level, and the composting facilities that Boulder and Seattle send their organics too are not located within the boundaries for either city. By a rough estimation, A1 Organics and Cedar Grove Composting in fact seem to be located in more rural parts of their respective counties meaning they will likely have less impact on city centers generally, though a full analysis would be needed to say anything with certainty. Cities generally only have control of the processing aspect through their contracts, and neither Boulder nor Seattle are the only customers of the organic waste processors they respectively utilize. In both cases organic processing facilities seem to be managed on a more regional basis, which municipalities will have less control over. This also means cities have less control over some of the major health and environmental impacts of organic waste management.

Economic Consideration

While the economic impacts of source separation seem to have been taken into account by both cities at the planning stage, impact equity was only directly apparent in the Seattle code. Seattle in its requirement had various carveouts related to those with lower incomes, primarily in

the form of exceptions to charges for customers already on benefit systems. This includes not applying pass-through charges for bags to anyone on WIC, TANF, SNAP, or FAP (Seattle Code 21.36.100). Those on LIRA were exempt from $10 new account charges, with small charges to LIRA (Seattle Code 21.40.50). While these rules indicate a consideration for economic impacts to low-income communities in particular, the amounts saved by these codes are not generally large. However, while not directly observed in the parts of the city code being studied, the Seattle organic waste manager did mention that they have customer assistance programs for those having trouble paying their bills (Seattle Interview). This seems likely to be referring to the Seattle Utility Assistance Program, which offers assistance to low-income individuals and households for their broader utility bill, which includes waste collection (Seattle, n.d.). Assistance in this way could help to offset any impacts from changes in utility costs due to new diversion policies. Of course, not all cities may be able to offer assistance programs to the same degree as Seattle given differences in resources.

However, negative economic impacts in this area may not actually be a major area of concern. For organics collection in Boulder and Seattle, the main source of economic strain would come through rate changes related to Pay-as-you-throw payment systems. In the literature, we actually see that some research has found that PAYT, once implemented, tends to either be neutral in cost to the consumer, or even drive rates down (Reichenbach, 2008). Another study backs up this claim of reduced costs, and goes on to say that concerns over economic impact of PAYT are unfounded (Manni & Runhaar, 2014). This is further supported by a Swedish study where PAYT was seen as a fair system by disposal participants, seeing sorting as a personal responsibility that shouldn't be put onto others (Bartelings & Sterner, 1999). It seems reasonable

to conclude that inequitable economic impacts may not be too significant of a concern in regard to organic waste diversion.

Process and Development Considerations

Information from the two organic waste managers on the development process for their respective diversion and Zero Waste policies was indirect, as neither was personally involved in that initial process. However, the Boulder manager knew someone that was, and was able to relay that information. The shared that the city engaged with key stakeholders, including business owners and waste haulers, whose involvement they saw as necessary for successful implementation. This was also a way to address any concerns around impacts to business and property owners. Community groups such as Eco-Cyle were also involved, as well as the general public. During this process, according to the manager, financial impacts on the community were taken into account. In general, the process was described as "very robust," and similar to what most municipalities would do (Boulder Interview). Based on how this was framed, it seemed that the city felt this process was important for their diversion program to work effectively.

Seattle appears to have also had extensive community involvement in their development processes. While the Seattle manager was not able to speak extensively about the development of the initial Zero Waste and diversion policies, given they were first implemented in the 1980's, other sources can give us some insight into this topic. The dissertation by Pollans exploring this early development in the 1980's found, for instance, that the public was able to influence the scope and preferred options of the 1986 Solid Waste Management Study: Policy and Development plan, among others. Additionally, citizens were able to provide extensive input during an energy recovery project EIS, as well as more informally sending messages and comments that were fully taken into consideration by the city government. They concluded that

this constituted “meaningful participation” and that the public were included at “all points in planning and practice” (Pollans, 2017), indicating strong community participation early in the development process for Seattle.

Engagement by citizens in the development of more recent plans, policies, and programs was explained by the Seattle organic waste manager. Like Boulder, they mention that there are standard requirements and processes for engagement that most cities would follow. Additionally, the manager shared that it is a “point of practice” by Seattle to engage the public and various stakeholders (Seattle Interview). In general, it seems there is a process in planning that considers how a program will affect different communities differently, as wells as considering how the city will reach these different communities. As an example, they gave the new waste prevention plan currently in development, where engagement is being done through interviews and stakeholder groups (Seattle Interview). So, the participatory nature found in the early stages of development appears to have carried through to the present.

Seattle also has formalized structures to integrate equity into the development and planning process. For example, the city utilizes a formalized process known as the Racial Equity Toolkit, which was developed as part of the Race and Social Justice Initiative created by executive order in 2004 and officially enacted as city code in 2023 (Eastman, 2023). While it was not clear the exact waste policies this has been applied to, it does seem to have been utilized in the waste diversion context (Seattle Interview). This may be reflected in the city’s approach to signage and outreach with waste, including the employment of culturally knowledgeable staff, wide translation of materials, and adaptation of materials to specific social and cultural contexts (Seattle Interview). Regarding waste specifically, Seattle also has a Solid Waste Advisory Committee (SWAC) made up of community members, as required by state law since 1984,

covering most of the time Seattle has been engaged in diversion efforts. The SWAC provides input and oversight for any policies and programs being developed, and is meant to ensure the representation of "a balance of interests including… citizens, public interest groups, business, the waste management industry, and local elected officials" (RCW 70A.205.110, n.d.). This ensures a guaranteed level of community participation in the planning and development process. While the efficacy of these approaches in achieving their goals would be worth considering further, their presence seems indicative of Seattle's commitment to equity in the processes of planning and development.

To summarize, both cities seem to have taken part in meaningful stakeholder and community engagement during the development of their policies and programs. The inclusion of various stakeholders and the broader community seems to have been central for waste planning more generally, and such engagement is more broadly valued by each city. In this vein, the built-in consideration of various cultures and communities in Seattle was described as not only the morally correct thing to do, but also just more effective (Seattle Interview). The more people you can reach after all, the more people are properly engaging in diversion. Given that the literature suggests that engagement across sectors is important for improving waste diversion (Walia & Sanders, 2019), it seems very likely that these processes contributed to the success of the diversion programs by facilitating meaningful community buy-in to diversion and Zero-Waste programs.

Broader Sustainability

Waste Reduction

Aligned with efforts to reach Zero Waste, waste reduction appears to be an increasingly important issue for both cities and is even prioritized above diversion. Boulder has taken a Zero

Waste approach for a long time, starting with a Zero Waste Resolution in 2006 and a Master Plan for Waste Reduction established that same year. This continued in 2015 with the adoption of the Universal Zero Waste ordinance that amended Boulder Revised Codes 6-3-13, 6-3-14, and 6-4-15 (City of Boulder, n.d.-c). This was followed by a Zero Waste Strategic Plan in that same year, which set a goal of 85% diversion by 2025 (City of Boulder, 2015). For Seattle, the organic waste manager spoke of an intention expressed of "moving away from these single-use items" and to "create less altogether." This can be seen by the managers interest in having a "right to repair law" which would allow items to stay in circulation for longer, thus reducing demand (Seattle Interview). Seattle's valuation of Zero Waste is further reflected in the recent 2021-2026 strategic plan of the Seattle Public Utility, which outlines Zero Waste as one of three main aspects of the departments overall mission (Seattle Public Utilities, 2021). The city's relation with Zero Waste dates back to the 1998 Seattle Solid Waste Comprehensive Plan where Zero Waste was adopted as a "guiding principle," which has been reaffirmed several times since (URS Corporation et al., 2007). This together demonstrates strong dedication by both cities to Zero Waste goals and approaches, which appear to predate and inform efforts focusing on organic waste.

In the context of this study, several examples of these Zero Waste principles in practice were observed. The examples from the Seattle organics manager included bans on single-use materials with a "disproportionate environmental impact" including Styrofoam. Plastic bag and straw bans were also mentioned, as well as pass-through charges for single-use bags (Seattle Interview). These bag fees were detailed in the city codes of both Seattle (Seattle Code 21.36.100) and Boulder (Boulder Code 6-15-3). For Boulder, 40% of the fee is retained by the store, and the remaining 60% goes to city activities promoting Zero Waste (Boulder Code 6-15-

3). In Seattle single-use materials at restaurants were required to be compostable or recyclable (Seattle Code 21.36.086) which could be incorporated into the individualized educational signage employed by Seattle. In practice however the manager related that any single-use or takeaway item used for food services would have to be compostable, as items covered with food can't be recycled. Though, as mentioned earlier, they did find that the use of compostables in this area can contribute to contamination (Seattle Interview), and the contamination from these items in Boulder has apparently contributed to the decision stop public-facing collections (Boulder Interview). So 'compostable' replacements of single-use disposable items as a method of waste reduction, especially when used for anything food related, may come with drawbacks.

While Seattle is still allowing compostable products, there seems to be a preference in both cities to move towards reuse and waste reduction more generally. The Seattle organic waste manager mentioned prioritizing waste reduction, including specifically preventing food "from being wasted in the first place" as well as broader "waste prevention" (Seattle Interview). Boulder in their city code also mentions the intent for their policies to decrease the amount of solid waste generally (Boulder Code 6-12-1). The Seattle organic waste manager gave several examples of how waste reduction could be put in practice including efforts to promote reusable items, such as through a pilot program with "R Cup" to promote reusable, washable cups in places like theaters and concert venues. They plan to expand the program to include "durable plates and cutlery" at places like community festivals, and the manager expressed interest in engaging in other similar pilot programs (Seattle Interview). Boulder similarly is promoting the use of reusables and "durables." and the manager spoke of providing incentives for switching away from single use items. (Boulder Interview). While the details of these incentives weren't specified, use of incentives has seen success in areas such as increasing diversion rates (Xu et al.,

2015). Depending on the success of these reusable programs, it may be that 'compostable' replacements of single-use materials may not even be necessary. Cities that prioritize reusables then may have the dual benefits of both reducing waste generally, and avoiding the complications that come with compostable products.

Another approach to addressing waste seems to come in the form of taxation. This includes Boulder's Trash Tax, as mentioned earlier, which taxes disposal of garbage to generate funds that can support waste reduction efforts, as well as other city operation expenses (Boulder Code 3-10-1). Seattle, which also taxes garbage while excluding organics and recycling, does not seem to have any specific dedicated uses for their funds (Seattle Code 5.48.055). According to the city website, uses of Boulder's tax fund seem to include switching to single-stream recycling, purchasing land for the "Center for Hard-to-Recycle Materials," as well as offices and spaces for other recycling and waste reduction groups such as Eco-Cyle and Resource Central. In total, the City of Boulder reports the tax as generating $1.8 million a year for such uses (City of Boulder, n.d.-b). Essentially, funds go to activities that seem geared towards improved reuse and recycling, both of which can reduce waste by keeping materials in circulation for longer timeframes. While the tax is likely passed on to customers, at $3.50/month for residents and $0.85/cubic yard for commercial customers, the impact seems relatively minimal given the apparent value generated for waste reduction efforts (Boulder Code 3-10-2). While a more in-depth economic analysis may be required to judge effectiveness more accurately, it seems well worth considering for cities seeking ways to fund their waste reduction efforts.

Sustainability and Circularity

Both cities seem to be concerned with broader sustainability impacts, as well as promoting more circular systems. In Boulder this can be seen by their requirements that any compost

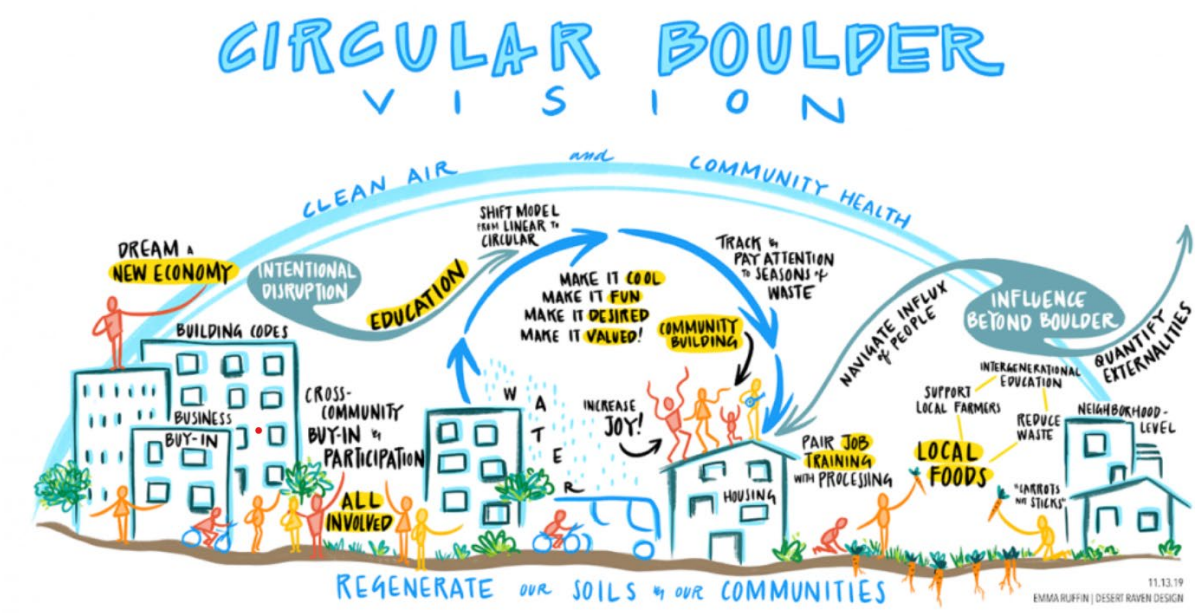
facility that haulers deliver to must be able to certify that materials are converted into compost or biogas products. Alternatively, haulers can also deliver to a facility using the materials to create another beneficial product altogether (Boulder Code 6-12-6). That is to say, the city builds in requirements that a sustainable product is being created, which can keep the organic material in circulation whether as a soil amendment or some other product. The subsequent use of products such as compost and digestate as soil supplements was explicitly tied to ideas of sustainability in ecological and social systems. The Seattle organic waste manager, for instance, referred to compost use as a way to "build healthy soils and sustainable landscapes" (Seattle Interview). The Boulder organic waste manager similarly described "trying to create a circular organic system" where they can "keep that resource within our boundaries," with the resource being organic materials and their nutrients. Plans toward this end include expanding the local composting capacity by increasing the number of processing facilities, as well as promoting more distributed, individualized composting by businesses and individuals. Altogether the goal would be to help "create healthier soil and grow more nutritious food," allowing Boulder to become more "self-reliant as a municipality," which can in turn contribute to community resilience (Boulder Interview). We can conclude that organic waste diversion for these cities is not just a way to address climate and landfill impacts, but also is being taken as an opportunity to build and strengthen ecological and social sustainability more generally.

Along with these considerations of broader sustainability, both cities also make use of the Circular Economy framework. While not mentioned directly in the Seattle interview, the idea of building soils mentioned earlier fits within the framework. Additionally, the 2021 strategic plan adopted by Seattle Public Utilities explicitly calls for building a "circular and inclusive economy" as part of their Zero Waste mission (Seattle Public Utilities, 2021). The Boulder

manager mentioned being part of the "Circular Economy team" (Boulder Interview), which is most likely an outgrowth of the City's "Circular Boulder Vision" that has its own page on the city website (City of Boulder, n.d.-a), and is visualized in Figure 4. The city also commissioned a report exploring steps to achieving circularity which was explicitly linked with Zero Waste and climate neutrality goals (Kennedy & McCue, n.d.). Circular Economy then seems to be intertwined with other sustainability goals such as climate and Zero Waste, and may even be seen as necessary to achieve those visions.

Figure 4.

Circular Boulder Vision Diagram



Note. Diagram taken from Circular Boulder page located on the City of Boulder website, displaying a visualization of the City's community-based envisioning of a Circular Economy system (City of Boulder, n.d.-a)

This embrace of Circular Economy seems to go even further in Boulder. The organics manager went so far as to say that circular economies are "just the way life works." In their description "ecosystems are circular economies just by their nature," and they find it necessary to embrace more naturally-based systems in order to achieve broader sustainability (Boulder Interview). This seems to go beyond average definitions of Circular Economy which are less often concerned with environmental quality (Kirchherr et al., 2017), and may be more aligned with a conception of economy as a subsystem of natural systems as presented by Raworth and Daly (Raworth, 2019). Boulder then seems to be embracing the aspects of Circular Economy which require systemic shifts in our mindsets and systems that is often left out of other definitions (Kirchherr et al., 2017). In any case, the embrace of Circular Economy as a framework, at least in Boulder, is seen not just as a way to increase diversion and economic outcomes, but even potentially as a goal in itself to build more sustainable systems.

There appears to be significant amounts of engagement by each city with Circular Economy ideas, especially in the case of Boulder, and it is worth considering how these ideas are put into practice in terms of organic waste diversion. This primarily takes the form of waste managers of both cities spending time to promote and establish end-use markets for organic waste products such as compost (Boulder Interview; Seattle Interview). This would be to help grow the demand for compost, in order to further incentivize the production of compost and thus hopefully drive further need for stable and ongoing organic waste collection. As part of this promotion and advocacy for compost the organic waste manager for Boulder has joined the regional Colorado Composting Council as a co-chair. One of the manager's goal is to use policy and regulations to enable more compost facilities and production to be developed (Boulder Interview), which could further grow the organic waste market.

Boulder, as mentioned earlier, also made room for other products and uses to be considered beyond compost and similar soil amendments (Boulder Code 6-12-6). While currently a singular composter appears to be the only option for the city, this does leave room for further markets to develop such as anaerobic digestion. This is important as more regional governments are considering new methods of utilizing organic waste streams, as can be seen by the Washington State Legislature commissioning a report on circularity and symbiosis including consideration of methods such as anaerobic digestion and combined heat and power (Roth et al., 2023). Generally, the success of Boulder and Seattle in building effective Circular Economy systems for organic waste was hard to assess within the framework of this study, and could warrant further exploration including a deeper assessment of potential material uses, flows, and connections.

Measuring Success

When implementing any of the policies, programs, or strategies covered so far in this thesis, it is necessary to know how cities will measure if these efforts are effective or not. More detailed measurements can help to illustrate the effectiveness of specific aspects of a policy or program, and inform attempts at improvement moving forward. The Seattle organic waste manager spoke to the importance of granular data broken down by customer sector in particular. For example, in the area of food waste, single families appear to be doing well, commercial is doing the best, but multifamily is struggling. Knowing this allows them to determine where to best direct their resources, in this case towards multifamily units. Measurements such as this were described as very helpful for thinking creatively about tactics to reach customers and achieve goals (Seattle Interview). In short, the more data the better. While not explicitly stated to the same degree, the apparent excitement of the Boulder organic waste manager when discussing various data and measurement approaches spoke to a similar valuation of data by Boulder as

with Seattle (Boulder Interview). While collecting data was also described by the Seattle manager as being "sometimes expensive- and difficult," it was still ultimately valuable to making "informed decisions" (Seattle Interview). Both cities appear to place high value on good data even if it comes at cost, though the exact nature of what is being measured can take a variety of forms.

Diversion rates, measured as the percentage of organic waste that doesn't go to the landfill, are a basic measure of success in the diversion field, including for Boulder and Seattle. For example in the case of Washington State's 75% organic waste diversion goal the basic metric of diversion is built into the goal itself. In Seattle this basic use of diversion rate had been "the overall metric" for "a long time" (Seattle Interview). Boulder also uses this measure (Boulder Interview), even going so far as to display a "diversion dashboard" on their website displaying current and historic diversion of organics and recyclables (City of Boulder, n.d.-d). In Boulder gathering these measurements are accounted for by requirements that haulers must submit annual reports on tonnage of trash, recyclables, and compostables collected broken down by commodity type (Boulder Code 6-12-4). While this approach was described as "at best an estimate," these measures are still able to inform the numbers displayed on their dashboard (Boulder Interview), which also includes breakdowns by housing type (City of Boulder, n.d.-e).

While still important, it appears that both cities are deprioritizing diversion rates as a way of measuring success in favor of other criteria. Seattle was moving towards more waste reduction-oriented measures. Currently they're considering capture rate, which is how much of a given item generated in the city, like cans, is actually captured through the organic waste or recycling systems. Essentially, making sure they're capturing what they want to be capturing, and that material is not being missed. Additionally, they are considering measurements of waste

generation per person, broken down by material type, as well as measures of food waste prevention and recovery (Seattle Interview). With an eye towards better measuring emission impacts, Boulder believes that "consumption measures" can give a more accurate assessment of the 'whole picture' of waste systems, though it was cautioned that such measures are still considered estimates. This was described as a more holistic approach that looks at everything that comes into the city, is used in the city, and disposed of by the city. To this end they hired a group called Metabolic to run an "urban metabolism study," which appears to use a consumption-based analysis of material flow through the city. Through this process consumption-based emissions were found to exceed all other sources (Boulder Interview). This would further place an emphasis on the importance of waste reduction and reuse, which more directly affect the earlier stages of consumption and production, rather than diversion. This seems indicative of the value these new measures can provide in terms of fresh insights into how to best move towards Zero Waste and diversion goals, with data that may be more aligned with the current priorities of each city.

A large part of why these new measurements are being considered seems to be due to shifting priorities. Boulder's organic waste manager detailed how concern with circularity, for instance, is leading the city to move from a linear to a circular model of waste, which "takes diversion away as the greatest way to measure" success. This appears to be because the more "holistic and circular" view the city has taken has led to a higher valuation of waste reduction over waste reuse or other aspects of diversion. So, diversion can't serve as the primary measurement of success, because it only accounts for the lesser prioritized "back end" of circular waste management. Beyond that, circularity is a complex framework to worth within, and diversion "isn't enough" to provide a more holistic picture. The manager acknowledged this does

make success “much more complicated to measure” (Boulder Interview). Similar ideas are found in at least one study in the literature, which attempts to establish a more detailed “Zero Waste Index” that considered more holistic measures beyond diversion or even reduction rates (Zaman & Lehmann, 2013). Seattle has even begun adding more goals in addition to diversion, such as food waste prevention and recovery, as well as the measurements of resource capture mentioned above (Seattle Interview). These shifts in goals, and their resulting complications, seem to have driven the experimentation by both cities with the new measurements discussed earlier.

For cities just beginning their efforts, it seems valuable to consider exploring the use of similar measurements, as well as the frameworks that drive them. The Boulder manager in fact urged those considering their own approaches to diversion to also “think about upstream and not just downstream.” They reflected that to “start a program such that it’s creating less waste to begin with through reuse programs [and] education around consumption… might be a better place to start” rather than focusing primarily on managing waste on the “back end” once it’s already been generated (Boulder Interview). Essentially, while diversion is necessary, programs that prioritize waste reduction from the start could be more effective than those that don’t. This ties into Boulder’s use of the Circular Economy model, and the importance they place on taking “a more holistic and circular” view (Boulder Interview). This can help not just to reduce the amount of organic waste produced in the first place, but can also help to achieve broader goals of sustainability and circularity. Given that Boulder and Seattle are now considering these kinds of broader systemic changes to help make further progress towards their organic diversion and Zero Waste goals, it may make things easier for newer cities to consider such approaches and frameworks from the start as they begin to plan and develop their organic waste diversion policies, programs, and implementation strategies.

CONCLUSION

There are always going to be byproducts of any process, natural or artificial. The question is how we value those byproducts, which call we waste, and what we choose to do with them. As it stands many byproducts produced by humans are currently considered useless, or even harmful. This waste end up polluting the environment, or sitting in landfills where it create negative impacts such as increasing emissions among other impacts (Danthurebandara et al., 2013). Increasingly, communities and governments are using frameworks like Zero Waste and Circular Economy to change how we view waste, and shift how our systems of material flow are structured (Korhonen et al., 2018; Zaman, 2015). Due to the release of methane and resulting climate impacts, organic waste is one of the top priorities in this field (US EPA, 2022). This is leading to changes such as Washington State's HB 1799 which is pushing local governments to reach high levels of diversion by 2030, a relatively short timeframe. Local governments like those in Washington are increasingly considering how best to approach organic waste diversion.

This informed the creation of this thesis which has sought to answer what approaches to policy and implementation are most effective at the city level, with considerations for broader sustainability and equity impacts in line with a 'just transition' approach. To answer this question, I explored the literature, and constructed an analysis framework that accounted for diversion and Zero Waste goals, as well as broader sustainability and equity criteria. This framework was then applied to two case studies, Seattle, Washington, and Boulder, Colorado, where I analyzed the city codes as well as the transcripts of interviews I conducted with a member of the organic waste management team for each city. Ultimately, I have found there are a broad range of viable policy and implantation approaches that are within even a smaller city's

ability to enact, and that these approaches can have significant impacts on organic diversion rates. And in general, most approaches do seem to carry over between a larger and smaller city.

Recommendations

Taken altogether, I believe there are several recommendations based on this research that can be made to cities. First is that while mandates can be helpful, collaboration with communities and key stakeholders such as haulers and commercial disposers are preferred by both Boulder and Seattle. While there are requirements and mandates around source separation and the provision of collection infrastructure, collaboration and engagement were preferred and seen as more effective by both cities. Engaging and collaborating with the community and key stakeholders such as haulers and commercial disposers was seen as important throughout the process from initial planning and development to the actual implementation of policies and programs. In this context, a Pay-as-you-throw system was seen as particularly effective, and highly recommended by the Seattle organic waste manager. In contrast, it may be preferable to avoid 'compostable' products, and focus instead on promoting reusable and durable items.

Once the implementation stage is reached, it appears best to take this work in stages. Seattle and Boulder both utilized pilot programs to help test out methods, and showcase effectiveness to the community (Layzer & Schulman, 2014). This seems especially important for smaller cities with less resources such as Boulder, whose initial limited outreach to a subsection of the commercial sector was still considered a "heavy lift" (Boulder Interview). Taking on smaller sections of diversion at a time can ensure that a city's capacity is not overwhelmed, while allowing diversion programs to be expanded over time. This expansion will likely require significant energy be given to outreach and education efforts. If a city is struggling to dedicate enough research to outreach, looking for community partners can be a good way to expand

capacity. Groups such as Eco-Cycle and Pace in Boulder are great examples of effective nonprofit partners, which have the benefit of being embedded and connected with the community. Notes could also be taken from Seattle's contract stipulations, which require haulers to create, distribute, and engage in their own outreach materials and programming. Effective practices for outreach according to these cities include face-to-face interactions, integration with existing sustainability programs and the creation of a 'one-stop-shop,' as well as signage and outreach that accounts for language and cultural differences. Further support may be found from county and state governments, such as the Washington Center for Sustainable Food Management established by HB 1799 in Washington State. This includes the recent addition through HB 2301 of grants which can support collection and outreach (WA Department of Ecology, n.d.-a).

It also seems worthwhile for cities to engage at more regional levels. The decision of an organic waste processor can have a large impact on what a city is able to implement in terms of collection. This is a limiting factor for city control over diversion rates, such as seen with Boulder and A1 Organics. Participation in regional coordination efforts such as Boulder's organic waste manager co-chairing the statewide Colorado Composting Council, or Seattle having a solid waste policy staff advocate, is one way to have a greater say in the management and implementation of more processing facilities. There may also be room at this level for coordination around issues of organic waste diversion, reduction, and other aspects of Zero Waste and Circular Economy frameworks.

A focus on waste reduction was advocated for by both Seattle and Boulder, generally within Zero Waste and Circular Economy frameworks. Focusing on reduction was seen as reducing the need for diversion in the first place, and was increasingly prioritized by both cities along with reuse. This can include promotion of end-use markets for organic waste products,

especially around compost. It also extends to how each city measured success, where both were experimenting with new measurements that were more holistic than basic organic waste diversion metrics. While diversion is important and necessary, it is only one part of a large picture of waste management. It is likely a good strategy for cities to focus on waste reduction from the beginning of policy and program creation, rather than just diversion.

Limitations and Future Directions

For this study, I only did a full analysis of the city codes, but there are many other relevant documents that may have yielded further information including strategic plans and various collection contracts. While these were looked over briefly, a deeper analysis may have revealed further relevant information. Similarly, I only conducted interviews with city officials overseeing organic waste management. Further interviews with waste collectors, organic waste processors, and various community groups may provide a more complete picture especially regarding the effectiveness of various education, outreach, and implementation strategies. This can be seen in regard to equity, where a full analysis of policy and program impacts would require further data such as interviews with customers that are lower-income or otherwise vulnerable. In future research exploring organic waste diversion, I would want to get the perspective of other stakeholders, and focus more heavily on education and outreach efforts given their importance within this study.

It should be made clear that not everything that works in one place will necessarily work in another. Boulder and Seattle both seem to benefit from populations that are generally already supportive of Zero Waste policies. Cities without such existing, and often active, support may face more challenges implementing the same policies and programs as Boulder and Seattle. And as one dissertation noted when considering Seattle, it is the development of "multiple institutions

of the alternative wasteway" over time that have contributed to success in diversion and waste reduction (Pollans, 2017). As Pollans argues, simply replicating policies and programs may not be enough to achieve the same results as Seattle, since the approach to Zero Waste by cities like Seattle, and I would argue Boulder as well, come from building Zero Waste values and principles into their systems over time. In this context, it seems that cities should consider not just which programs, policies, and implementation strategies they would like to adopt, but also consider incorporating sustainable waste values into their institutions and culture. From there broader systems of management can be built with consideration of specific contexts, and in collaboration with the community and key stakeholders. That being said, there are already a wealth of existing policy and program options with records of success in Boulder, Seattle, and beyond which cities can draw from when developing their own approaches. While goals such as Washington State's 75% diversion of organics by 2030 are ambitious, there are plenty of strategies on the table to make a strong start. From there, we can begin realizing the climate and environmental benefits that organic waste diversion, and prevention, can entail.

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