The Massachusetts Commercial Food Waste Disposal Ban:
A Case Study of the Effectiveness and Implementation of the Ban and the Waste Stream for Colleges and Universities

A thesis submitted by
Alexandra Raczka

in partial fulfillment of the requirements for the degree of Master of Arts
in
Urban and Environmental Policy and Planning

Tufts University
May 2018

Advisor: Penn Loh
Reader: Timothy Griffin

Abstract

This thesis assesses the effectiveness and implementation process of Massachusetts' Commercial Food Waste Ban, with particular emphasis on the influence of the ban on the waste generated by colleges and universities. This thesis considers the ban's overall effectiveness in increasing food waste diversion, the large-scale benefits to society as a result of the ban, and its influence on a particular category of waste generation. It reviews academic literature as well as government and nonprofit reports on food waste, data on waste generation and diversion in Massachusetts, and analyzes stakeholder interviews. The waste stream for colleges and universities is highlighted through four case studies with colleges and universities of different sizes, locations, and management of dining operations. Since the implementation of the ban, the amount of food waste diverted in the state has increased, as has the infrastructure to support diversion, successes that can partly be attributed to the long stakeholder process as part of developing the ban. Colleges and universities throughout Massachusetts have not necessarily adopted food waste diversion practices since 2014, when the ban was made effective, as many institutions throughout Massachusetts began implementing diversion practices well before the ban was officially enacted. The results of the ban have however provided resources to support further development of food waste reduction and diversion goals at the college and university level and have benefitted some stakeholders in the processing of food waste. The main areas for improvement are to increase resources for enforcement of the ban to ensure that generators out of compliance are aware of their behavior

and can take the steps to rectify their actions, better understand the impact of the ban on other categories of food waste generators, particularly those in the food processing, manufacturing, and distribution sectors, and to assess the role of source reduction in complying with the ban.

Acknowledgements

This thesis is the result of support and guidance from so many individuals.

To my thesis committee, Penn Loh and Tim Griffin, thank you for your guidance and thoughtful feedback throughout this entire process. I am so appreciative of all of your help!

To the eighteen professionals engaged in different aspects of the food waste stream – from policy to generators of waste to farmers – thank you for taking the time to share your knowledge, expertise, and data with me. This thesis would not have been possible without your interest and willingness.

Finally, to my friends and family for encouraging me over the past nine months, thank you for asking me about my thesis and supporting me as I stressed over deadlines. Your support means so much to me!

From the bottom of my heart, thank you!

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

Wasted food is a significant problem with many environmental and social implications; each year nearly 40 percent of the food that is produced in the United States is wasted at some point in the food system (USDA, n.d). Much of this wasted food is wasted beyond the farm gate, including about 30 percent at the retail and consumer level (USDA, n.d.). Within Massachusetts, food and other organic materials account for 25 percent of the state's waste stream, making it the largest category of waste (MassDEP, 2015).

Waste generation is a particular concern to Massachusetts as the capacity of the state's landfills continues to decline. Massachusetts' most recent Solid Waste Master Plan, the plan for 2010-2020, sets the goal of reducing the amount of waste generated in the state by 30 percent (MassDEP, SWMP, 2013). In order to meet this goal wasted food must be addressed, since it makes up such a large portion of the state's overall waste. The current Solid Waste Master Plan addresses wasted food through methods of waste diversion, with the intention to reduce wasted food by 35 percent by 2020 (MassDEP, SWMP, 2013).

Although consumer-generated food waste makes up a substantial portion of the total wasted food, regulating and reducing consumer-generated waste at the household level would be an arduous process. Instead, focusing on large-scale generators of food waste – restaurants, grocery stores, institutions, etc. – offers a more feasible scope to ameliorate the problem. Focusing on large waste

generators allows the state to maintain the necessary level of oversight to enact change.

In order to achieve the reductions in food waste targeted in the Solid Waste Master Plan, Massachusetts introduced the Commercial Food Waste Disposal Ban in 2014, which added organic waste produced by institutions and other businesses in excess of 1 ton per week to the list of materials already banned from the waste stream in Massachusetts. The ban requires businesses such as restaurants, hospitals, colleges, and supermarkets that produce at least 1 ton of food waste each week to redirect the wasted food to other channels including food rescue, composting, anaerobic digestion, and livestock feed (MassDEP, 2017).

In addition to Massachusetts, four other states – Vermont, Connecticut, Rhode Island, and California – have developed food waste bans to reduce the amount of wasted food that is generated. The goals of these bans share many similarities, though their reach varies. Currently, Massachusetts has one of the most widespread regulations; only Vermont (with a significantly smaller population than Massachusetts) has a more rigorous regulation. Over time, many of the bans in other states will increase their reach to include lower level waste generators and in some circumstances even households. Connecticut, which has the oldest regulation enacted in January of 2014, preceded Massachusetts by a couple of months (Jones, 2017). Since all of these bans are still in their infancy, states have not had the opportunity to conduct in-depth analyses yet or learn from the successes and challenges that other states have had.

This thesis will assess the effectiveness and implementation of the Commercial Food Waste Disposal Ban, with particular focus on the waste stream for food waste generated by colleges and universities. Nearly all colleges and universities in Massachusetts are subject to the ban, as a result of producing at least 1 ton of food waste each week, and they have been targeted for voluntary food waste diversion by the Massachsuetts Department of Environmental Protection and the Environmental Protection Agency since before the ban was implemented in 2014 (Beling, 2018; Fischer, 2017).

In addition to stakeholder interviews with members of government agencies and nonprofit organizations related to the ban, four case studies of the waste stream of colleges and universities in Massachusetts – Massachusetts College of Art and Design, Smith College, the University of Massachusetts Amherst, and Wheaton College – are included in this thesis. These case studies detail the history of food waste diversion practices at each institution and the role of the Commercial Food Waste Disposal Ban in the institutional practices. The case studies also document the businesses involved in diverting food waste from each institution, including their history and experience with receiving food waste and how the ban has impacted or influenced their operations.

Data from the Massachusetts Department of Environmental Protection, Region One of the Environmental Protection Agency, and RecyclingWorks Massachusetts on food waste generation and diversion is also analyzed to examine the overall quantity of food waste being diverted, the growth of food

waste diversion categories, interest in technical assistance, and participation in voluntary programs.

Chapter 2 details the methodology and research questions for this thesis, as well as notes the limitations of the methodology. Chapter 3 provides a literature review of the waste stream, particularly with relation to food waste, state-level food waste regulations across the country, and methods of food waste diversion. Chapter 4 introduces Massachusetts' Commercial Food Waste Disposal Ban, including the history and impetus of the ban, its enforcement, and compliance. Chapter 5 presents case studies for the food waste streams of four colleges and universities in Massachusetts, as well as outlines initial findings from the case studies. Chapter 6 applies the findings from the case studies, and the data analysis, to the overall impacts of the Commercial Food Waste Disposal Ban on colleges and universities and presents recommendations for improving the ban and other states implementing a food waste ban. The final chapter, Chapter 7, presents opportunities for further research on the Commercial Food Waste Disposal Ban.

Chapter 2: Methodology

Overview

Currently, seven states throughout the United States have adopted food waste bans. This analysis of Massachusetts' Commercial Food Waste Disposal Ban is a case study of statewide regulations on food waste. I am interested in Massachusetts' capacity to reduce commercial food waste, in order to lessen the burden on the state's solid waste facilities. The success of the Commercial Food Waste Disposal Ban not only depends on the regulation itself, but on the relationship between stakeholders within the food waste sector and the ability for the state to enforce the regulation and hold the appropriate parties accountable for their actions. This thesis will assess the overall effectiveness of the ban and its implementation, with specific focus on the influence of the ban on food waste diversion in the waste stream for waste generated by colleges and universities.

In December of 2016, ICF published a report detailing the economic impacts of the Commercial Food Waste Disposal Ban (ICF, 2016). This report largely focused the direct and indirect impacts of the ban, including job creation and revenue across food waste sectors. ICF's analysis was based on stakeholder interviews and a survey of stakeholders to collect information on the revenue, employment, and investments of their businesses. The main purpose of the ICF analysis was to

> *[…] analyze the recent trends in the Massachusetts organics waste industry as well as potential impacts of implementing the Commercial Food Waste Disposal Ban*
>
> - ICF, 2016, 4

Although the ICF analysis intended to examine the impacts of the ban, it only included the economic impacts, and furthermore only the economic impacts for food waste haulers and processors. This thesis will build off of the ICF study to assess the impacts of the ban on the waste stream, businesses throughout the food waste sector, and the government bodies regulating the ban. This thesis includes a literature review, secondary research of the Commercial Food Waste Disposal Ban, and 15 interviews with 17 stakeholders to collect qualitative and quantitative data on the implementation and effects of the ban.

Focus was placed on the waste stream for colleges and universities because nearly all colleges and universities in Massachusetts are subject to the ban, these institutions account for some of the largest food waste generators in Massachusetts, and many institutions engage in a variety of diversion and reduction practices. Four universities – Massachusetts College of Art and Design, Smith College, the University of Massachusetts Amherst, and Wheaton College – and their subsequent waste stream stakeholders, were included in case studies on the waste stream for waste generated by colleges and universities and the impacts of the ban. Research Questions

My main research question is: how effective has the Commercial Food Waste Disposal Ban been in increasing food waste reduction and diversion at colleges and universities since it was implemented in 2014.

My supplementary research questions are:

1. What have been the results of the Commercial Food Waste Ban since it was implemented in 2014?
    a. How much wasted food has been diverted from the waste stream [in terms of a single business and in general]?
    b. How many facilities are there to receive diverted wasted food?
    c. What are the economic impacts of the ban [in terms of a single business in general]?
2. How have business operations regarding food waste at colleges and universities changed since the Commercial Food Waste Ban went into effect?
3. To what extent were colleges and universities and other waste stream stakeholder businesses implementing food waste diversion practices before the ban was enacted?
4. How do colleges and universities decide what methods of food diversion to pursue?
5. Do businesses and institutions in the waste stream feel that the resources and support are available to effectively comply with the ban?
6. Where have been successes and challenges of the ban and what might be done to improve its effectiveness?

The literature review will provide context for food waste regulations. Chapter 4 will touch on all of the research questions, through analysis of existing data and documents and stakeholder interviews. Stakeholder interviews will be especially instrumental for answering questions 2 through 6. Chapter 5 will also address question 6, in recommending improvements to the Commercial Food Waste Disposal Ban to increase its effectiveness in Massachusetts, or other states looking to implement similar regulation.

Literature Review

I conducted a three-part literature review in Chapter 3, to provide context for this thesis. Since the Commercial Food Waste Disposal Ban is still in its first couple of years of implementation, and due to the relative newness of food waste

bans in general, there is no peer-reviewed literature on the ban. Thus, the literature review includes non-scholarly sources that contextualize the ban. Sources such as newspaper articles, government documents, and non-profit reports are included in this review.

The first section is focused on solid waste disposal in general, highlighting the growing pressures on the solid waste stream and the main categories of waste that make up the waste stream. The second section focuses on food waste bans throughout the United States. Currently there are 5 statewide food waste regulations in the country, and each one is unique in both its parameters and its state context. The analysis included in this thesis does not compare the Commercial Food Waste Disposal Ban to regulations in other states, but it is important to contextualize Massachusetts' ban in the current landscape of food waste regulations. The final section of the literature review addresses types of food waste diversion including source reduction, food donation, animal feed, anaerobic digestion, and composting. This section provides background on each method of food recovery, indicating environmental, economic, and social impacts and potential for each method. The colleges and universities included in the case studies each have different approaches to food waste diversion, so it is important that each type of diversion is clearly described to support the case studies.

Document Analysis

Existing and publicly available documents were used to analyze the effectiveness of the Commercial Food Waste Disposal Ban; this analysis is

included in Chapter 4. MassDEP, the government body responsible for the ban, has a number of documents available on its website, including the regulation, information for businesses in compliance of the ban, the economic impacts of the ban, resources on food waste diversion, and data on food waste generators in Massachusetts. The documents, which range in format from individual datasets to completed reports, help to depict the environments of food waste in Massachusetts both before the ban went into effect and more recently.

Though the Commercial Food Waste Disposal Ban impacts stakeholders across food waste sectors, the MassDEP website is largely targeted to businesses that generate food waste and must comply with the ban. The website does, however, provide resources for food waste haulers and processors, as well as provide context on the establishment of the ban. The only outside study that has been conducted on the Commercial Food Waste Disposal Ban was conducted by ICF, a consulting firm based in Cambridge, MA, and focused on the economic impacts of the ban. This study was conducted for MassDEP. Annual reports from RecyclingWorks were also included in the document analysis. RecyclingWorks is a program operated by the Center for EcoTechnology and funded by MassDEP to support waste generators, haulers, and diversion facilities in adhering to Massachusetts' waste ban and support waste reduction and diversion overall.

Additionally, reports and data were collected from colleges and universities and food waste diversion facilities to provide a historical context to food waste diversion programs and quantify the scale of diversion and its economic and environmental impacts. These reports include studies and reports

published by colleges and universities, as well as data on food waste hauling and food waste generation.

I did not collect primary data to verify any of the data presented in documents from the MassDEP or the individual institutions I examined. This thesis was largely focused on analyzing existing quantitative data in conjunction with qualitative data gathered from stakeholder interviews.

Stakeholder Interviews

Stakeholder interviews were a central component of this thesis, to provide perspectives on the Commercial Food Waste Disposal Ban, as well as contextualize food waste diversion in the college and university sector and provide a history of these efforts. Interviews focused on the waste stream for food waste generated by colleges and universities, and included professionals representing different aspects of the waste stream and compliance in general.

The purpose of the interviews was to 1) understand the food waste diversion practices occurring at colleges and universities and the history of these practices, 2) provide insights into the role that the Commercial Food Waste Disposal Ban has had on food waste diversion for the college and university waste stream, and 3) listen to professionals in the waste stream, and otherwise involved with the ban, speak to the successes and challenges of the regulation and how it can be improved. I asked all interviewees about their professional role and engagement with food waste diversion and the Commercial Food Waste Disposal Ban, including successes, challenges, and opportunities. All interviews were voluntary and were recruited to represent a variety of institutions – with respect to

size, geographic location, and dining operations – and means of food waste diversion. An outline of interview questions can be found in Appendix A.

I interviewed 16 different stakeholders in 14 different interviews over an eight-week period, from February 1, 2018 through March 23, 2018. Three of the interviews took place in person at the perspective offices of the interviewees and the other nine interviews took place over the phone. The interviews lasted between 20 and 65 minutes. After the interviews I transcribed the interview recordings and analyzed them to identify themes and perspectives pertinent to my research questions. Quotes from the interviews were selected and included in the analysis to accurately convey the perspectives of the interviewees.

The government agency employees I interviewed included one at MassDEP, two at the Massachusetts Department of Agricultural Resources (MDAR), and one at Region 1 of the Environmental Protection Agency (EPA). The Commercial Food Waste Disposal Ban is regulated by MassDEP as are commercial composting operations, which are directly related to the ban. MassDEP interviewees provided breadth and depth on the ban's history, implementation, and impacts thus far. MDAR has an agricultural composting program supporting farms that receive off-farm compostable materials as an additional facet to their business. The department's Division of Animal Health is also involved with animal feed, which some food waste is diverted to. The EPA has a number of priorities and programs related to waste reduction – including food waste – such as the EPA's Food Recovery Hierarchy and the Food Recovery Challenge. Though these programs and initiatives run parallel to the Commercial

Food Waste Disposal Ban, the businesses and institutions in Massachusetts that engage in the EPA's programming are often subject to the ban, and both the MassDEP and EPA are working towards similar goals of addressing food waste.

Among nonprofit agencies, I interviewed one employee at RecyclingWorks Massachusetts, a MassDEP funded program through the Center for EcoTechnology that works to help businesses comply with the different waste bans in Massachusetts, including the Commercial Food Waste Disposal Ban. Because of RecyclingWorks' unique role in being directly linked with both a government agency and businesses that need to comply with the ban, this interview provided insights on enforcement and compliance as well as successes and challenges faced by individual businesses.

Among colleges and universities I interviewed employees representing four different colleges and universities in Massachusetts: Massachusetts College of Art and Design (MassArt), Smith College, University of Massachusetts Amherst (UMass Amherst), and Wheaton College. These institutions were selected because they reflect the diversity in college and university dining operations, including privately run and contracted dining operations; schools of various sizes – from fewer than 2,000 students to more than 30,000 students; rural, urban and suburban geographies; and diversion practices including source reduction, donation, composting, and animal feed. Two of the institutions have dining services operated by the institution, UMass and Smith College, while Wheaton College's dining services are operated by Aramark and MassArt's dining services are operated by Chartwells. I interviewed three employees of

MassArt, who represent the campus facilities, sustainability operations, and dining services; two employees of Smith College, who represent sustainability operations and dining services; two employees of UMass Amherst, who represent the campus facilities and dining services; and two representatives of Wheaton College, who represent dining services. Each of these interviewees provided valuable information on the history of food waste diversion at their respective institution, the motivations behind diversion, successes and challenges, and their perspectives on the ban.

For each of the colleges and universities I interviewed, I also interviewed, or emailed, the facilities involved in diverting the bulk of each institution's food waste. This included an interview with a farm that started a compost operation to process organic waste from one institution, an interview with the largest commercial compost operation in Western Massachusetts, an interview with a pig farm that feeds food scraps to their pigs, and an email exchange with a waste hauler that has an organics diversion operation and related facilities. These interviews contributed to understanding the process of diverting food waste to other uses, as well as impacts that the ban has had on the operations. I did not include interviews with any food rescue organizations because the scale of food rescue at the colleges and universities included in this thesis is rather small. Here is a list of the 17 interviewees:

<u>Government Agencies</u>

John Fischer
Massachusetts Department of Environmental Protection
Branch Chief of Commercial Waste Reduction and Waste Planning
Boston, MA

Christine Beling
US EPA, Region 1
Project Engineer, Assistance and Pollution Prevention Unit
Boston, MA

Sean Bowen
Massachusetts Department of Agricultural Resources
Agricultural Compost Coordinator
Boston, MA

Michael Cahill
Massachusetts Department of Agricultural Resources
Director, Division of Animal Health
Boston, MA

Nonprofit Organizations

Lorenzo Macaluso
Center for EcoTechnology
Director of Client Services
Northampton, MA

Colleges and Universities

John Pepi
University of Massachusetts Amherst
General Manager, Office of Waste Management, Moving, & Surplus
Amherst, MA

Brittany Florio
University of Massachusetts Amherst
Senior Sustainability Coordinator, UMass Auxiliary Enterprises
Amherst, MA

Andrew Cox
Smith College
Director of Dining Services
Northampton, MA

Emma Kerr
Smith College
Campus Sustainability Coordinator
Northampton, MA

Matthew Thompson
Aramark
Culinary Director, Higher Education
Philadelphia, PA

Scott O'Rourke
Aramark
Director of Dining, Wheaton College
Norton, MA

Claudine Ellyn
Massachusetts College of Art and Design
Sustainability and Environmental Health and Safety Officer
Boston, MA

Howard LaRosee
Massachusetts College of Art and Design
Executive Director of Facilities Planning
Boston, MA

Kory Laznick
Chartwells, Compass Group
Director of Dining Services for Massachusetts College of Art and Design, Wentworth Institute of Technology, and Massachsuetts College of Pharmacy and Health Sciences
Boston, MA

Food Waste Haulers and Diversion Facilities

Peter Montague
Bridgmont Farm
Farm Owner
Westhampton, MA

Adam Martin
Martin's Farm
Farm Owner
Greenfield, MA

Brian Plante
Plante Brothers Farm
Farm Owner
Norton, MA

Michelle Lee Guiney[1]
Total Recycle Program Manager
Waste Management of New England

Limitations

Although the methods for this thesis have been successful in identifying the impacts and effectiveness of the Commercial Food Waste Disposal Ban, there have been some shortcomings. The availability of studies is quite limited, partly because food waste disposal bans are still relatively new and are only in effect in a handful of states across the country. The reports that are available are based on projections of potential impacts of food waste diversion rather than showing the results that bans have had.

A limitation related to the stakeholder interviews and case studies included in this thesis is that the case studies provide a small sampling of perspectives. While the case studies were chosen to represent institutions that varied in size, geographic location, food waste diversion practices, and dining operations, they may not accurately reflect all colleges and universities subject to the ban in Massachusetts. Additionally, the case studies included were dependent on people's willingness to participate in an interview. This may have caused selection bias with institutions interested in food waste diversion and sustainability and with successful programs more likely to respond than others.

Another limitation is that many of the employees in dining service operations and sustainability departments were relatively new to their positions, many beginning work at their respective institution within the past three years. Because

[1] Correspondence was only via email

of this some of their perspectives were based on anecdotal information rather than personal experience. This is especially challenging because the Commercial Food Waste Disposal Ban went into effect before many of the employees began their current jobs and as a result they could not speak to diversion practices and motivations before the ban compared with after the ban.

Chapter 3: Literature Review

Overview:

This chapter reviews peer-reviewed journal articles, government documents, investigative journalism articles, and reports and documents created by nonprofit and business stakeholders to frame the issue and scale of food waste. This chapter is broken into three sections relating to the impetus for food waste regulations, existing food waste regulations throughout the United States, and methods of food waste diversion. The first section, Solid Waste Disposal, outlines solid waste infrastructure and practices, especially the role that organic waste, specifically food waste, has in the waste stream. Food Waste Regulations, the second section, will review regulations in other states to illustrate the similarities and differences in priorities, feasibility, and courses of action. The final section, Means of Food Recovery and Diversion, will document the different types of food recovery included in the Commercial Food Waste Ban – source reduction, donation, composting, animal feed, anaerobic digestion, and other commercial uses.

Solid Waste Disposal

Solid waste disposal is not an issue unique to an individual state, or even country; however the burden of waste disposal can be significantly greater in some areas because of socioeconomic and environmental factors and physical limitations. Waste as phenomena of society is related to both wealth and

education, causing areas with higher median incomes or education levels to often times produce greater levels of waste (Jones, 2017). There are also challenges associated with the disposal of waste once it has been created. Disposing waste can lead to contamination and greenhouse gas emissions, which can cause environmental degradation and harm to public health. Perhaps even more limiting than concerns on the impacts of waste disposal are the physical limitations placed on disposal facilities, especially landfills. Massachusetts is an example of a state where this array of concerns for and limitations of solid waste disposal are visible and create a degree of uncertainty when looking at the future.

Solid Waste Disposal in Massachusetts

Until the tail end of the 20th century solid waste was largely disposed of in municipal landfills, which lacked liners and other safeguards protecting environmental and public health (MassDEP, SWMP, 2013). According to the Massachusetts Department of Environmental Protection, the state's landfill capacity is quickly declining. It is estimated that four of the landfills in the state that are currently in use will reach capacity by 2021, and total capacity will decline to 600,000 tons (MassDEP, SWMP, 2013). In addition to landfill capacity declining, combustion facilities are operating near capacity; in 2016 combustion facilities were operating at 91 percent of their permitted capacity (MassDEP, 2018). Permitting new landfill and combustion facilities is a long and challenging process, especially because of limitations on where they can be located and public concerns over constructing new facilities. The state does not have control over where waste is disposed of, whether it is in Massachusetts or exported to another

state; waste haulers choose the most economical option. Massachusetts can however support food waste diversion facilities and infrastructure in Massachusetts through the Commercial Food Waste Disposal Ban (Serreze, 2017). In 2015, Massachusetts produced 5.51 million tons of waste, of which approximately 25 percent is disposed of in landfills in the state, 60 percent is disposed of in combustion facilities in the state, and 16 percent is exported to other states for disposal (MassDEP, Solid Waste Update, 2015). Though Massachusetts has one of the highest recycling rates in the country, the state's present waste management system cannot be maintained, even in the near future (MassDEP, SWMP, 2013). In order to adapt to the reality of the limited capacity of solid waste disposal in Massachusetts, MassDEP outlined target goals to reduce waste disposal, ultimately targeted towards zero-waste.

In the 2010-2020 Solid Waste Master Plan, MassDEP established short and long term goals targeted at waste reduction. The state aims to reduce solid waste disposal by 30 percent by 2030 and 80 percent by 2050, in comparison to waste levels of 2008 (MassDEP, SWMP, 2013). While this goal is based in the state's need to adjust its waste disposal for the reduced disposal capacity, it is also directly tied to the state's existing commitment to reduce greenhouse gas (GHG) emissions; by law, Massachusetts is required to reduce GHG emissions by 25 percent by 2020 and 80 percent by 2050, when compared to 1990 GHGs (MassDEP, SWMP, 2013). Solid waste disposal has a number of negative environmental consequences, ranging from the transporting of waste, which can include long distances across state lines, to the physical disposal. The two primary

means of solid waste disposal, landfills and combustion facilities, present unique environmental issues.

Landfills produce methane gas, which is a powerful GHG, 25 times more potent than carbon dioxide. Although most landfill facilities capture methane as a source of energy, it is not possible to capture all of the methane emitted, especially when waste products break down at different rates and thus produce methane at different times (EPA, GHG, 2017). In addition to methane production, landfills can leach toxins and chemicals into groundwater causing contamination that is a risk to human health and the environment at large. This is especially a problem for older municipal landfills that are now out of commission, as it was not standard practice to include liners in their construction (Christenson & Cozzarelli, 2003).

Combustion facilities account for the majority of waste disposal in Massachusetts. Though they produce energy, which can be used as an alternative to energy from coal or natural gas, combustion facilities also have negative environmental impacts as a result of their waste products. Aside from energy, combustion facilities produce carbon dioxide and airborne pollutants, including nitrogen oxides, sulfur dioxides, lead, mercury, and dioxins, which can have environmental and public health impacts (EPA, MSW Combustion, 2016).

Solid Waste Diversion in Massachusetts

Through current practices, including the lengthy list of items that are banned from the solid waste stream, Massachusetts has been able to divert waste from landfills or combustion facilities in favor of practices such as recycling and

composting. Since 1990 Massachusetts has banned certain items from the waste stream, such as yard waste, tires, cathode ray tubes, and aluminum, metal, and glass containers (MassDEP, Overview, n.d.). Because of these practices the state diverted almost 5 million tons of waste in 2009, slightly less than the 5.8 million tons of waste disposed of in that year (MassDEP, Solid Waste Update, 2015). This significant diversion of waste prevented GHG emissions and saved energy and natural resources, while also reducing the amount of money spent on tipping fees at landfills and combustion facilities. While the state's achievements in solid waste disposal provide environmental and financial benefits, the limitations of solid waste disposal infrastructure highlight the need for more restrictions of items for disposal.

Food Waste in the Waste Stream

Food waste places a burden on the environment and the economy. In the United States over $200 billion is spent annually throughout the process of growing, processing, transporting, and disposing of food that never eaten (Spoiler Alert, 2017; ReFED, Roadmap, 2016). In addition to the financial impact, a significant amount of energy is used to power the sectors of the food system as they handle food that will ultimately be wasted; approximately 2 percent of the energy used in the United States in 2007 was used for wasted food (Cuéllar & Webber, 2010). The process of producing, transporting, and disposing food that was never eaten uses many other natural resources and inputs, including water, fertilizer, fossil fuels, and soil, and can cause air and water pollution while degrading the environment.

United States

Nationally, food waste accounts for a significant portion of the total waste discarded each year. While food waste only contributes to 14.5 percent of total municipal solid waste created, it is the largest component (21%) of what is discarded (EPA, MSW, 2012). In 2012, 87 million tons of waste were diverted through recycling and composting; however only 2 percent of the diverted waste was food waste. The 1.74 million tons of food waste that were diverted from landfills and combustion facilities in 2012 only represents 5 percent of the total food waste that was generated that year (EPA, MSW, 2012). The organic nature of food waste makes it a suitable input for waste diversion practices such as composting and anaerobic digestion, both of which have far lower environmental burdens than the traditional waste stream (EPA, Food Recovery Hierarchy, 2017). The measly 1.74 million tons of food waste that was composted in 2012 had significant environmental benefits; diverting this waste from the landfill prevented the equivalent of 1.4 million metric tons of carbon dioxide from being released into the atmosphere (EPA, MSW, 2012).

In an effort to reduce the amount of food that is disposed of, the United States Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) set a national food waste reduction goal in 2015, to achieve a 50 percent reduction by 2030 (Spoiler Alert, 2017). In conjunction with this effort, the EPA has published a hierarchy for diverting food waste, which emphasizes practices based on their resource intensity and benefits (EPA, Food Recovery Hierarchy, 2017).

Massachusetts

The amount of food waste produced in Massachusetts largely follows national trends. According to the state's 2010-2020 Solid Waste Master Plan, organic materials – food waste and yard waste – make up over 20 percent of total municipal solid waste, accounting for over 1 million tons of waste each year (MassDEP, SWMP, 2013). Compared to Massachusetts' high recycling rate, less than 10 percent of the food waste produced in Massachusetts is diverted from landfills and combustion facilities (MassDEP, SWMP, 2013). Though only a small percentage of food waste in Massachusetts was regularly diverted, the grocery sector played a large role in diversion. MassDEP and the Massachusetts Food Association established the Supermarket Recycling Program Certification in 2003 "to encourage the recycling and reuse of organics and other materials" (MassDEP, Overview, n.d.). Since the program was established over 200 stores, including six major chains have become participants, and have experienced significant cost savings while preventing organic waste and other waste from being disposed of. At least 6,000 tons of waste are diverted from disposal each year across the more than 200 participating stores (MassDEP, Overview, n.d.).

In order to achieve its goal of reducing total solid waste disposal by 30 percent by 2020 and 80 percent by 2050, organic waste, including food waste, must be addressed since it accounts for such a large portion of the state's total solid waste (MassDEP, SWMP, 2013). In line with the state's existing goals and timeframes, MassDEP set a goal to reduce the total amount of food waste

disposed of by 35 percent by 2020, increasing the amount of diverted food waste by approximately 350,000 tons per year (MassDEP, SWMP, 2013).

Food Waste Regulations

National Scale

While there are currently no national regulations of food waste, the EPA has set a goal of reducing the amount of food waste that is disposed of by 50 percent by 2030. In order to do this both commercial generators of food waste and individuals will need to adopt behavior changes. The EPA Food Recovery Hierarchy serves as a guide for food waste generators, especially commercial generators, to determine how to divert their food waste. The hierarchy identifies and ranks categories of food recovery and diversion based on their environmental, economic, and social benefits. The highest tier of the hierarchy is source reduction, emphasizing a reduction in the amount of food purchased and used, which prevents food from being unnecessarily wasted. The middle four tiers provide ranked options of recovery and diversion using food as a resource for other people, animals, or processes. The final tier of the hierarchy includes traditional means of solid waste disposal, landfills and incinerators; these means of dealing with food waste lack environmental, social, and economic benefits and are thus considered to be a last resort (EPA, Food Recovery Hierarchy, 2017).

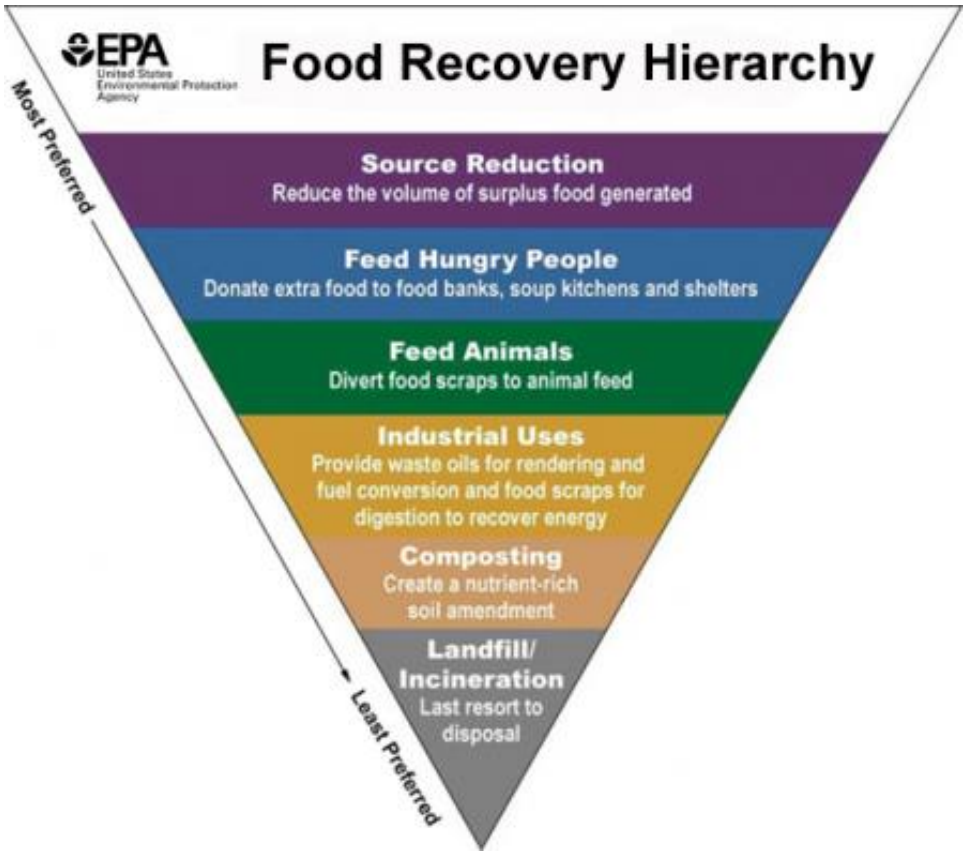


Figure 1: EPA Food Recovery Hierarchy (EPA, 2017)

In conjunction with national interest in diverting food waste, food waste regulations have been adopted at a more local level throughout the country, Currently, five states have implemented food waste bans – Connecticut, Vermont, Massachusetts, Rhode Island, and California. Largely, existing bans target commercial generators of food waste, which account for approximately 49 percent of the nonfarm generated food waste in the country (Jones, 2017).

State Level

The food waste bans in each of the five states vary on the food waste generators included in the regulation, preferred means of diversion, and other

characteristics. The following section provides an overview of the state-level bans that exist outside of Massachusetts. Table 1 outlines the current state-level food waste bans.

Table 1: Statewide Food Waste Bans

State	California	Connecticut	Massachusetts	Rhode Island	Vermont
Population	39,536,653	3,588,184	6,859,819	1,059,639	623,657
Population Density (people/sq. mi)	239.1	738.1	834.1	1018.1	67.9
Median Household Income	$65,783	$71,755	$70,954	$58,387	$56,104
Ban Adopted					
Ban Enacted	April 1, 2016	January 1, 2014	October 1, 2014	January 1, 2016	July 1, 2014
Generators Currently Subject to Ban	Food waste generators producing at least 4 cubic yards (~0.93 tons) of organic wate per week	Food waste generators producing at least 104 tons of source separated organic material per year (2 tons per week) AND located within 20 miles of a food waste recycling facility	Food waste generators producing at least 1 ton of food waste per week	Food waste generators producing at least 52 tons of organic waste per year (1 ton per week) AND located within 15 miles of a food waste diversion facility	Food food waste generators producing at least 18 tons of food waste per year (~0.35 tons per week)
Future Phases	January 2019: Business that generate at least 4 cubic yards of solid waste per week Summer/Fall 2020 (if demed necessary): Businesses the genrate at least 2 cubic yards of solid waste per week	2020: Threshold reduces to 52 tons of source separated organic material per year	N/A	N/A	July 2018: All waste haulers must offer food waste collection July 2020: All food waste, inluding household waset subject to the ban

Data Sources: 2017 Population Estimates Program (U.S. Census Bureau, 2017); 2010 Resident Population Data (U.S. Census Bureau, n.d.); Platt, 2016; Spoiler Alert, 2016; VT DEC, n.d.; Jones, 2017; Brinkley, 2016; Shafer, 2017; CalRecycle, 2017; MassDEP, Guaidance, 2016

Connecticut

In 2010, Connecticut conducted a study of the state's solid waste stream and found that food waste made up a significant portion of municipal solid waste, organic waste amounted to about a third of the state's landfill waste each year (Platt, 2016). The state set a lofty goal to reduce food waste by 60 percent by 2024 (Hladky, 2016). In order to effectively accomplish this goal, Connecticut adopted the first state-level legislation (Public Act 11-217) to regulate and reduce food waste disposal in 2011 and expanded in 2013 (CT DEEP, 2017).

The ban went into effect in January of 2014 and targeted commercial food waste generators, defined as wholesalers, distributors, industrial food manufacturers or processors, supermarkets resorts, and conference centers. Commercial food waste generators that produce at least 104 tons of organic waste each year and are located within 20 miles of an authorized food waste diversion facility that has the capacity to accept the waste, are required to separate their organic waste and send it to a diversion facility. Over time the ban will become stricter, reducing the waste generation threshold for compliance to 52 tons of organic waste per year by 2020 (Platt, 2016; Spoiler Alert, 2016).

Since the ban was enacted, one of the major hurdles has been building the necessary infrastructure for diverting food waste, specifically anaerobic digestion facilities, which are intended to have a significant role in reaching the state's diversion goal (Spiegel, 2016; Jones, 2017). In the time before and after the ban was adopted, five anaerobic digestion facilities were slated to be built, yet by 2016 – more than two years after the ban went into effect – none of the facilities were open, or even being built (Spiegel, 2016). This not only poses a challenge for the state as a whole in accomplishing its goals, but also for the companies seeking to establish anaerobic digestion facilities. In a news article from 2016, one company, Quantum Biopower, explained the challenges of waiting more than two years for permits, especially when communicating with lenders who are funding a project that is continuously delayed (Spiegel, 2016).

Vermont

Following the action of Connecticut, Vermont enacted legislation on food waste in 2012 through the Universal Recycling Law, which went into effect in July of 2014. Under this law, three different categories of waste are regulated, including food scraps (VT DEC, n.d.). Similar to the ban in Connecticut, Vermont's ban includes phases of compliance based on the scale of food waste generators and their location. When the ban was first enacted, commercial food waste generators producing at least 104 tons of food waste per year were required to divert the waste to a food recovery facility within 20 miles. As time went on the threshold for compliance halved each year through 2016, and further decreased to 18 tons per year by July of 2017. The law requires that by July of 2018 all waste haulers offer food waste collection and by July of 2020 all food waste, including waste generated at the household level, be banned from the landfill (VT DEC, Timeline, n.d.; VT DEC, n.d.; Spoiler Alert, 2016). Vermont prioritizes food waste recovery methods very similarly to the EPA, preferring source reduction, followed by using food to feed people or animals, and finally producing compost and energy (VT DEC, n.d.).

Currently, all businesses generating at least 18 tons of food waste per year must comply with the ban (VT DEC, n.d.). While composting is a common means of diversion for businesses, many businesses have followed the state's recommendations for food recovery and have donated food that can still be eaten to food banks throughout the state. Between 2015 and 2016 the amount of food donated to food banks in Vermont increased between 30 and 40 percent (VT

DEC, n.d.). Not only has the quantity of food donations increased, but the quality of donated food has also improved; significantly more fruits and vegetables have been donated than were previously (VT DEC, n.d.; Mugica, 2017; VT DEC, Status Repot, 2016). The impact on hunger organizations was unexpected when the ban was established but has provided many social and economic benefits in addition to the environmental benefit of keeping food waste out of landfills.

Unlike Connecticut, which intends on significantly reducing the amount of food waste that is disposed of through anaerobic digestion, Vermont will focus on composting as a primary means of diverting food waste (Jones, 2017; VT DEC, n.d.). The rural geography in Vermont requires an infrastructure that includes facilities in each county to make composting accessible, as all residents will be required to divert their food scraps by 2020 (VT DEC, n.d.). Though residents are not yet required to compost food scraps, towns have begun establishing infrastructure to support residential composting. However, while the infrastructure exists it is unclear if people are diverting their food waste; in many communities throughout the state, very few people have brought food scraps to their local transfer station. The Recycling Coordinator with the Southern Windsor/Windham Counties Solid Waste Management District noted, though, that transfer station data might not be the best representation of compliance as many households may partake in backyard composting (Hongoltz-Hetling, 2017).

Vermont's rural geography and small population size provide different challenges and opportunities than the other states that have implemented such

bans, allowing it to pursue the most rigorous food waste disposal ban in the country.

Rhode Island

Rhode Island became the most recent state in New England to implement a ban on food waste through amending the Refuse Disposal laws in June of 2014 and enacting a ban on food waste, which went into effect on January 1, 2016. A study prior to the ban taking effect found that approximately 16 percent of the waste disposed of in the Rhode Island Resource Recovery Corporation Landfill each year could be composted or anaerobically digested (Brinkley, 2016; Spoiler Alert, 2016). Rhode Island's ban on food waste applies to "commercial wholesaler or distributors, industrial food manufacturers or processors, supermarkets, resorts or conference centers, banquet halls, restaurants, educational or religious institutions, research institutions, military installments, prisons, corporations, hospitals or other medical care institutions, and casinos" that produce more than 104 tons of organic waste per year (Brinkley, 2016). Similar to the bans in Connecticut and Vermont, the ban in Rhode Island is also phased; the threshold of compliance decreased to 52 tons of organic waste per year in January of 2018 (Jones, 2017; NEWMOA, 2017). Generators are only required to comply with the ban if they are located within 15 miles of a composting or anaerobic digestion facility with the capacity to accept the waste. In addition to the geographic exemption, food waste generators may be waived

from compliance if the tipping fees for said composting or anaerobic digestion facility exceed that of RIRRC (Brinkley, 2016; Spoiler Alert, 2016).

Information is not readily available on the initial response of businesses in the food waste sectors was or what the effects and challenges of the ban have been since it was implemented in 2016.

California

California was the most recent state to implement a food waste ban; a statute requiring mandatory recycling of commercial organic waste was signed into law in October of 2014 and the law went into effect in April of 2016 (Spoiler Alert, 2016; CalRecycle, 2017). This statute stems from the state's existing actions towards reducing its greenhouse gas emissions and increasing recycling. A 2014 assessment of California's waste stream found that over 37 percent of the waste stream is comprised of organic materials, of which more than 18 percent is food, which illustrates the significant potential for food waste to be diverted from landfills and incineration (CalRecycle; 2015; CalRecycle, 2017).

Beginning in April of 2016 this ban required businesses that generate at least 8 cubic yards, approximately 1.85 tons, of organic waste per week to recycle it, namely through composting and anaerobic digestion (CalRecycle, 2017; Spoiler Alert, 2016; EPA, 2016). The ban entered its second phase in January of 2017, under which businesses producing at least 4 cubic yards, approximately 0.93 tons, of organic waste per week must be in compliance (Spoiler Alert, 2016; EPA, 2016). In January of 2019 the ban will broaden to include "businesses that generate at least 4 cubic yards of commercial solid waste per week" (CalRecycle,

2017). Following this phase CalRecycle will determine if the state has sufficiently reduced its food waste, decreasing 50 percent or more from 2014 levels by 2020. If this goal has not been achieved, a final phase will be implemented in 2021 to include businesses that generate at least 2 cubic yards of commercial solid waste each week. Though the ban increases in scope over time, it does include an exception for rural counties (CalRecycle, 2017).

As the ban is still in its relative infancy there is not much information available on the effects it has had, nor is there readily available information on people's reactions to the ban when it was first implemented. CalRecycle intends to conduct its formal review of the ban in the fall of 2018 (CalRecycle, 2017). Much of the information currently available is at the local level, signaling efforts taken in individual towns.

New Jersey

While New Jersey has yet to implement a food waste ban, the state enacted a law in the summer of 2017 establishing a goal to reduce the state's food waste by half by the year 2030. Currently, the state's Department of Environmental Protection is developing a plan to meet the goal, which could include implementing a food waste ban (Rosengren, 2017).

Means of Food Recovery and Diversion

Efforts and regulations to reduce food waste provide a number of possible means of diversion including source reduction, donation, feeding animals,

composting, anaerobic digestion, and other commercial uses. The economic and environmental costs and benefits of each practice vary, making some practices more attractive than others depending on the circumstance.

Food Waste Prevention: Source Reduction

According to the EPA's Food Recovery Hierarchy, source reduction is the most preferred method for reducing food waste disposal. Instead of diverting food waste from the landfill or incineration, source reduction reduces the amount of waste generated, thus preventing the problem of food waste and contributing to significant economic, environmental, and social benefits; "prevention creates three times the societal net Economic Value of recovery and recycling combined" (ReFED, Roadmap, 2016; EPA, Source Reduction, 2016). Source reduction practices can be adopted throughout the consumer-targeted food waste sector, and include behavior changes, such as decreased plate size, consumer education, policy changes, and assessments of waste generation (ReFED, EPA, WARM, 2015). Preventing food waste has the potential to divert 2.6 million tons of food from the waste stream in the United States each year (ReFED, Roadmap, 2016).

Source reducing also has significant environmental benefits; according to the EPA, source reduction has the largest impact on decreasing greenhouse gas emissions when compared to other means of diversion (EPA, WARM, 2015; EPA, Source Reduction, 2016). This practice reduces emissions throughout the entire food system and waste stream. Reduced demand for food products decreases the amount of food that needs to be produced, decreasing the amount of resource-intensive fertilizers and pesticides needed at the farm level. As a result

of source reduction, waste disposal emissions also decline. As previously mentioned, decomposing food waste creates methane gas, which is not always trapped by energy-generating technology at landfills. In preventing food from being wasted, greenhouse gas emissions at the waste stream can also decline (EPA, Source Reduction, 2016).

Nearly all of the food waste regulations that are in place focus on commercial food waste. While individual businesses cannot necessarily lead the charge in all strategies of food waste reduction, they can partake in two strategies with the largest diversion potential -- consumer education and waste tracking, the latter of which can directly relate to waste generated by businesses (ReFED, RoadMap, 2016). The process of analyzing and tracking waste generation includes an inventory of food purchases, measuring waste, assessing food storage, reviewing menu items (EPA, Source Reduction, 2016). While initiating waste tracking and analysis can be time intensive and costly to establish, in the long run it has significant potential to reduce food waste and thus save money. According to ReFED, a non-profit organization focused on decreasing food waste, food businesses in the United States can increase their profits by over $1 billion each year and divert over 570 tons of waste through tracking the amount of food that they purchase and waste; food waste prevention efforts across the food system have the potential to divert more than 2.5 million tons of waste with an economic value of $7.7 billion (ReFED, Roadmap, 2016).

Though preventing food waste through source reduction provides many economic and environmental opportunities, it can only account for a fraction of

the food waste that has the potential to be diverted; ReFED estimates 2.6 million tons of food waste can be diverted each year through source reduction, while the total amount of food waste that can be diverted annually is almost 13 million tons (ReFED, Roadmap, 2016).

Food Waste Diversion: Donation

Unlike source reduction, which prevents food waste from being created, donation practices offer a form of food recovery, utilizing food that would otherwise be wasted to feed people. This means of food diversion provides environmental, economic, and social benefits as food is being used for its highest possible use, feeding people. Food recovery has the ability to tackle to significant challenges facing the food system – food waste and hunger. In 2016, over 40 million people in the United States lacked resources to provide enough food for their households (EPA, Food Recovery Hierarchy, 2017; EPA, Feeding Hungry People, 2017). While not all wasted food can be diverted through donation because of the nature or quality of the food, food donation is a viable mechanism for non-perishable and unspoiled perishable foods, including prepared foods that meet food safety guidelines.

Commercial generators of food waste are ideal donors because of the scale of their operation. Grocery stores commonly participate in food donation programs, though food processors, restaurants, institutions, and farms can also adopt this means of food diversion (ReFED, Roadmap, 2016). Though organizational support and infrastructure are commonly seen as limiting factors preventing businesses and institutions from donation food, there has been a surge

in food rescue organizations connecting generators of wasted food to hunger relief organizations. In the Boston area for instance, organizations including Food for Free, the Boston Area Gleaners, Lovin' Spoonfuls, and Rescuing Leftover Cuisine rescue food from grocery stores, restaurants, hotels, farms, and many other food businesses and distribute it to hunger relief programs in the region (Food for Free, 2017; Boston Area Gleaners, n.d. ; Lovin' Spoonfuls, n.d. ; Rescuing Leftover Cuisine, 2018). In addition to the physical infrastructure fostering food donation, the Bill Emerson Good Samaritan Food Donation Act provides liability protection for food donors, so long as they do not act with negligence or intentional misconduct (U.S. Congress, 1996).

Food donation programs can recover significant amounts of food. At a company-wide scale, Kroger donated 56 million pounds of fresh food in 2015, while Lovin' Spoonfuls' regional recovery network in the Boston area recovers enough food to feed 35,000 people each week (EPA, Feeding Hungry People, 2017; Lovin' Spoonfuls, n.d.). Not only do food rescue programs increase the quantity of food donated, but also the quality. Since the Universal Recycling Law went into effect in Vermont, food banks have seen significant growth in food donations and an improvement in the quality of the food being donated, including fresh food (Mugica, 2017).

Aside from the social benefits of food donation and the environmental benefits of diverting wasted food from the landfill or incinerator, businesses that donate food can also reap economic benefits from donation. A 2015 change to the tax code allows all businesses or organizations to receive enhanced tax deductions

if they donate food to a 501(c)(3) organization to feed people who are ill, needy, or infants (Blazek et al., 2016). Providing a tax incentive for food donations helps to make food donations an economically viable form of food waste diversion when compared to other strategies. Outside of the existing support for food donation, ReFED notes that standardizing donation regulation at the federal level has the potential to increase food donations by nearly 200 million tons pear year. Currently, donation regulations may vary by state or even city depending on the rules of the health department, which makes food donation especially challenging for businesses that operate in multiple jurisdictions and may prevent them from participating in food donation (ReFED, Roadmap, 2016). In addition to policy changes, support for donation infrastructure, education, and value-added processing have the potential to significantly increase the amount of food that is donated each year and contribute billions of dollars in economic value (ReFED, Roadmap, 2016).

Food Waste Recycling

Food waste that cannot be donated to feed people can be diverted from landfills in a number of different ways. Each of the methods outlined below has different environmental and economic costs and benefits. Figure 2 illustrates the potential capacity for food waste diversion through different methods.

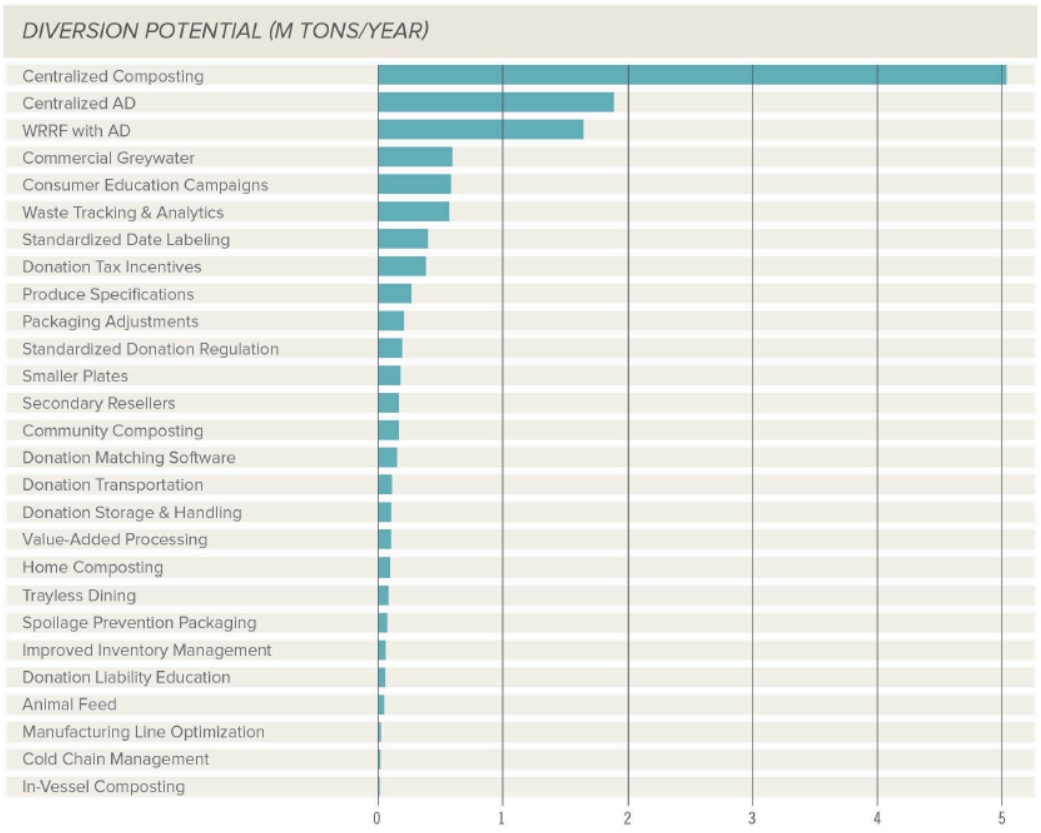


Figure 2: Food Waste Diversion Potential (ReFED, Roadmap, 2016)

Animal Feed

The EPA deems that using food waste to feed farm animals is the third most preferable method of food waste reduction and diversion (EPA, Food Recovery Hierarchy, 2017). Feeding animals is generally considered to be a higher use than composting, anaerobic digestion, or other industrial uses, as it is less energy intensive and uses food waste in its available state as a resource (BSR, 2014, EPA, Food Recovery Hierarchy, 2017). Food waste diverted to animal feed is often suitable for human consumption but is also appropriate for feeding animals. Food scraps produced in restaurants, grocery stores, or processing facilities, for instance do not have a value for feeding people but can easily be used to supplement traditional animal feed; a 2013 study of food manufacturers

found more than 85 percent of the food waste that was diverted went to animal feed (BSR, 2014). The amount of food waste created across sectors varies, as does the means of diversion. According to a 2014 study conducted for the Food Waste Reduction Alliance, more than a 25 percent of food waste diverted by retail and wholesale sector respondents is diverted to animal feed (BSR, 2014). In contrast to manufacturing, retail, and wholesale sectors which divert large percentages of food waste to animal feed, the same study reported that the restaurant sector diverts 0.1 percent of food waste to animal feed (BSR, 2014).

Using food waste to feed farm animals provides environmental benefits in that it is not very energy intensive, especially when food scraps are directly used for feed and do not need to be processed or altered beforehand. Feeding animals with food waste also reduces the demand for food crops grown solely for animal consumption. Animal production, especially meat production, is especially resource intensive when considering all of the inputs – pesticides, fertilizers, water, etc. – required to produce feed crops which are then used to feed animals (Broad Leib et al., 2016).

While the feasibility of diverting food waste to feed animals depends on local and state regulations, the practice can divert significant amounts of food waste from the landfill or incineration while also providing a feed source for animals (EPA, Feeding Animals, 2017). Rutgers University began implementing a food diversion program in the 1960s, sending food waste from the campus's dining facilities to Pinter Farms, a local hog and cattle farm. On average, the university sends over a ton of food waste per day to the farm, providing feed for

the farm's livestock. As a result of this partnership, the university has experienced financial benefits, saving hundreds of thousands of dollars in hauling costs and labor (EPA, Rutgers, 2015).

Diverting food waste to animal feed presents opportunities for businesses, but the feasibility of expanding animal feed diversion beyond its current scope depends highly on the scale of food waste production, the location of both food waste generators and animal operations, the need to treat food waste to be used for animal feed and the costs of doing so, and the availability of suitable food waste that is not already diverted to composting, anaerobic digestion, or another process (ReFED, Animal Feed, n.d.). An analysis by ReFED estimates that using food waste for animal feed has the potential to divert nearly 50,000 tons of food waste per year nationwide and decrease GHG emissions by 34,000 tons per year, but has a negative economic value of over $-52 per ton, especially because of the treatment process to make food scraps suitable for animal consumption (ReFED, Animal Feed, n.d.).

Industrial Uses: Anaerobic Digestion and Fats, Oil, and Grease

Though the EPA lists industrial uses towards the bottom of its food recovery hierarchy because of their energy and resource intensity and need to alter food waste in order to make it a valuable resource, they are heavily used means of food waste diversion. The two main categories of industrial uses included in the EPA's hierarchy and most frequently used are anaerobic digestion and industrial use of fats, oil, and grease (EPA, Food Recovery Hierarchy, 2017).

Anaerobic digestion is the process of breaking down food waste with microorganisms, in an anaerobic environment to create biogas, which can be used as a source of energy, and digestate, which can be applied to agricultural operations as a liquid fertilizer or composted (ReFED, Roadmap, 2016). The energy produced through anaerobic digestion is versatile in its use; biogas can be used to provide heat or electricity, enabling it to power alternative-fuel vehicles, run stoves, heat homes, as well as other energy uses (EPA, Anaerobic Digestion, 2016). Unlike the other diversion methods previously discussed, anaerobic digestion can divert food waste and other organic waste, such as yard trimmings, animal manure, and sewage sludge (ReFED, Roadmap, 2016; EPA, Anaerobic Digestion, 2016). Of all of the means of food waste diversion, anaerobic digestion accounts for a significant amount of current, or proposed diversion, in states with food waste bans; both Connecticut and Massachusetts estimate that the capacity for anaerobic digestion will surpass the capacity for other types of diversion (Jones, 2017).

While anaerobic digestion is not one of the highest possible uses of food waste, it is a sustainable source of diversion. A 2011 study by Levins and Barlaz conducted a life-cycle assessment of commercial-scale food waste treatment facilities and processes, including anaerobic digestion, composting, and landfills. Though the study found that the environmental impact of food waste treatment facilities can vary greatly depending on what the treated output is replacing and the energy captured by the facility, anaerobic digestion showed the greatest environmental benefits. According to their model, anaerobic digestion has the

lowest global warming potential, lowest SO_2 emissions, lowest NO_x emissions, and lowest net energy use (Levins & Barlaz, 2011).

According to ReFED, expanding centralized anaerobic digestion facilities has the potential to divert nearly 2 million tons of food waste each year nationwide, with an economic value of $40 million (ReFED, Roadmap, 2016). Anaerobic digestion has the most potential for development in areas with high energy prices and high waste disposal rates, such as the Northeast (ReFED, Roadmap, 2016; Jones, 2017). Beyond the realm of food waste, anaerobic digestion also has the potential to expand at the farm level, especially on livestock farms with high levels of manure output. Establishing and expanding anaerobic digestion does include some barriers, namely the financial resources necessary to construct facilities and the network requirements to ensure sufficient and consistent feedstocks for the facilities to process. Furthermore, policy barriers, especially related to the classification of anaerobic digestion facilities and where they can be sited must be addressed for the potential of anaerobic digestion as a means to divert food waste to be reached (ReFED, Roadmap, 2016).

Industrial uses for food waste in the form of fats, oil, and grease can take a number of forms, including rendering the waste into cosmetics, soap, and other products, generating biodiesel fuel, and anaerobically digesting the waste in wastewater treatment facilities (EPA, Industrial Uses, 2017). Diverting fats, oil, and grease to industrial uses is a significant type of food waste diversion, especially in the restaurant industry, which produces an average of 0.5 pounds of food waste per meal served (RecyclingWorks, Food Waste Estimation, n.d.). In

the Food Waste Alliance's 2011 study of food waste survey participants from the restaurant sector identified that over 70 percent of the food waste that the sector diverts is "used cooking oil recycling" (BSR, 2014).

Composting

Composting is the breaking down of organic material, including food scraps, to create compost, a valuable agricultural resource that can improve soil quality, boost plant growth, reduce pollution in the air, water, and soil, and sequester carbon (EPA, Composting, 2017). In addition to the benefits of compost itself, composting organic material rather than disposing of it in a landfill can prevent greenhouse gas emissions; according to RecyclingWorks, "composting 5 gallons of food scraps is equivalent to not burning one gallon of gasoline" (RecyclingWorks, Food Waste, n.d.). Though composting provides many environmental benefits, it is ranked at the bottom of the EPA's food recovery hierarchy because it provides fewer environmental, social, and economic benefits than the other means of food recovery (EPA, Food Recovery Hierarchy, 2017). That being said, however, composting is a valuable and effective way to divert food waste that cannot be reduced or diverted through a more preferred method because of economic barriers, the quality of food waste, or other restraints (EPA, Composting, 2017; ReFED, Roadmap, 2016). When compared to other means of food waste recycling, centralized composting facilities present the greatest potential for food waste diversion. Many states with food waste bans emphasize the role of composting in meeting waste diversion goals. Composting is assumed to account for the majority of food waste diversion in Vermont and currently

accounts for the majority of diversion in Massachusetts (Spoiler Alert, 2016; Jones, 2017; Fischer, Progress Report, 2017).

ReFED's 2016 Report on ways for the country to reduce food waste estimates that centralized composting could divert more than 5 million tons of organic waste each year (ReFED, Roadmap, 2016). The economic value of composting varies by region, depending on waste disposal fees and the demand for compost. In some parts of the country, especially the southern portion of the country, the economic value of composting is lacking, with a negative economic value associated with composting. However, much of the Northeast, Pacific Northwest, and Eastern Midwest are viable markets for composting, with an economic value ranging from net zero to more than $25 per ton (ReFED, Roadmap, 2016). Overall, ReFED estimates that centralized composting has a net economic value of $18 million. The challenges and opportunities of different methods of food waste recycling, especially composting and anaerobic digestion show that while composting has the potential to divert significantly more waste, a difference of more than 3 million tons per year, anaerobic digestion has an economic value more than $20 million greater than composting (ReFED, Roadmap, 2016). In areas where composting has a positive economic value, developing the infrastructure necessary to support the sector's growth through policy changes, especially related to the citing of composting facilities. The success of large-scale composting infrastructure also depends on the availability of organic materials high in carbon to create compost (ReFED, Roadmap, 2016).

Conclusion:

The increasingly limited capacity of solid waste disposal facilities, as well as the environmental, economic, and social consequences of disposing of wasted food illustrate the importance of food waste diversion. Diverting food waste is a complex process, especially when considering the economic, political, and physical feasibility of implementing different methods of diversion. State and federal goals to reduce food waste, especially through statewide bans of food waste disposal have begun to show the varied benefits of diversion both at different scales and through different types of facilities. The newness of these regulations however makes it necessary for collaboration across multiple sectors, including government, industry, technology, and non-profit organizations, to support implementation.

Chapter 4: Massachusetts' Commercial Food Waste Disposal Ban

History and Context

Massachusetts became the third state to enforce regulations limiting food waste disposal in 2014, with the Commercial Food Waste Disposal Ban becoming effective in October of that year (Spoiler Alert, 2016). Unlike the regulations in other states, Massachusetts' ban was not the result of a legislative statute, but rather initiative by MassDEP. Developing and implementing the ban was part of a long-term process; the possibility of a ban had been considered since 2000, more than a decade prior to the ban's establishment. In order to effectively implement a ban on food waste MassDEP decided that the infrastructure to support the ban needed to be developed before the ban was enacted. During this time MassDEP worked with supermarkets and grocery stores and colleges and universities to support food waste reduction and diversion, including the Supermarket Recycling Program Certification. The 2010-2020 Solid Waste Master Plan included the establishment of a food waste ban, which was to be implemented in 2014 (Fischer, 2017). Beginning in 2011, MassDEP engaged stakeholders across the waste stream in conversations about the structure and implementation of the ban. At the same time MassDEP also assessed existing policies and regulations relating to food waste and developed a program to aid businesses in compliance (Fischer, 2017).

Another important factor for political favorability and ease of adoption was the threshold of food waste that would require compliance. It was important to MassDEP to establish a threshold that was not economically burdensome and was potentially economically beneficial to businesses subject to the ban. John Fischer, the Branch Chief of Commercial Waste Reduction and Waste Planning at MassDEP noted,

> *There are a lot of factors that go into the cost of managing wasted food, so this cost will vary from one business to another. But, generally speaking, businesses that dispose of a ton or more of food material per week can typically at least break even or maybe save money by diverting that material from the trash to other alternatives. This is dependent on making adjustments to their trash service to lower their disposal costs.*
>
> - Fischer, 2018

In addition to making sure that the threshold is not economically onerous for businesses, the one-ton threshold allows MassDEP and the food waste diversion facilities to focus on the quality of food waste being diverted, while also targeting a significant portion of the total quantity generated. By restricting the ban to this threshold, food waste is more likely to be traced to its generator and contamination can be managed so that the highest quality end product can be produced (Fischer, 2018). In addition to setting the threshold of one-ton of food waste per week, MassDEP also decided not to use a phased implementation approach because it was thought that the ban could be at least economically neutral for businesses above the threshold, as well as to reduce confusion among waste generators and haulers and to prevent a regulatory burden (Fischer, 2018)

The Ban

The Commercial Food Waste Disposal Ban is an extension of the state's existing ban of materials from the waste stream. Under this regulation, businesses that produce at least one ton of organic waste per week are required to divert their waste from the landfill or combustion facility (MassDEP, Guidance, 2016). In some cases, the one-ton of food waste per week threshold is not at the individual business level; the ban assesses food waste generation based on how waste disposal is contracted. For instance, if multiple businesses use the same dumpster or one waste disposal contract covers multiple venues on the same campus, then the amount of waste generated is based on the total (MassDEP, Guidance, 2016). In order to be subject to the ban, businesses do not need to consistently produce an excess of one ton of food waste each week, but rather businesses must comply with the ban each time they generate over a ton of food waste in a weeklong period (MassDEP, Guidance, 2016).

Of the over 7,000 food business in the state, this ban impacts approximately 1,700 businesses (Spoiler Alert, 2016). A 2011 dataset created by MassDEP provides estimates of food waste generation for healthcare facilities, independent schools, colleges and universities, correctional facilities, resorts and conference facilities, supermarkets and grocery stores, and restaurants (MassDEP, Generators, 2011). While some food manufacturers, processors, distributors, and wholesalers were included in the dataset, they were largely omitted because of the diversity of operations and the difficulty to characterize them (Fischer, 2018). In total, the institutions and businesses included in this dataset that were estimated to

produce at least 52 tons of food waste per year, generated nearly 328,000 tons of food waste annually. This is approximately 68 percent of all of the commercial food waste generated by facilities included in the dataset (MassDEP, Generators, 2011).

In conjunction with the implementation of the Commercial Food Waste Disposal Ban, MassDEP revised regulations to make it easier for composting and anaerobic digestion facilities to be permitted. Rather than be permitted as solid waste facilities, the Site Assignment Regulations for Solid Waste Facilities (310 CMR 16.00) were amended in 2012 to consider composting and anaerobic digestion facilities as recycling facilities (MassDEP Organics Action Plan, 2017; MassDEP 310 CMR 16.00). Unlike some other states with food waste bans, such as Vermont, Massachusetts did not adopt a hierarchy of food recovery (VT DEC, Universal Recycling, 2018). Instead, the state supports all means of reduction and diversion, allowing businesses to make decisions that make the most sense for them. That being said, it is anticipated that composting and anaerobic digestion will be the primary modes of diversion, with the latter serving a significant role in diverting large quantities of organic waste (Jones, 2017). Because of changes in regulation and a clear permitting pathway, composting and anaerobic digestion infrastructure in Massachusetts has significantly expanded as a result of the ban. Currently there are 45 off-site composting and anaerobic digestion facilities permitted in the state, with a capacity of about 465,000 tons per year. In addition to the current facilities there are additional ones, namely for anaerobic digestion, being developed and will expand the capacity (Fischer, 2018). Though the overall

capacity for food waste diversion in Massachusetts exceeds the current goals of the Commercial Food Waste Disposal Ban, there are some areas of the state where it is much more challenging to locate a diversion facility. According to a 2017 map of food waste diversion facilities in Massachusetts, there is only one facility located on Cape Cod, an area of the state with more than 100 food waste generators subject to the ban (MassDEP, Diverted Food Material, 2017). This misalignment of waste generators and diversion facilities can pose logistical challenges coordinating food waste diversion for waste generated in areas not near a diversion facility.

Enforcement

Since the Commercial Food Waste Disposal Ban is a part of the MassDEP Waste Disposal Bans it is enforced in the same manner as the other bans. MassDEP inspectors visit solid waste facilities and transfer stations and inspect a certain number of loads of waste based on the scale of the facility. In 2017 6,252 loads of waste were inspected through 178 inspections (Fischer, email, 2018). Inspectors do not physically sort through the waste, but rather look for materials that are included in the waste disposal bans. One of the challenges of identifying food waste in loads of waste is that it is not necessarily visible;

> *Cardboard is highly visible and easy to observe in a load of trash. By contrast, food material is often harder to see in a load as it is more dense and often placed inside trash bags. Food material may also liquefy in a load which makes it more difficult to observe and account for.*
>
> - Fischer, 2018

Although food waste can sometimes be identified because of the uniqueness of how it settles in containers or if trash bags are clear, the current inspection process is not always conducive to identifying food waste.

Unlike the other materials included in the Waste Disposal Bans, commercial food waste is banned at a certain threshold, which makes enforcement of this ban more challenging. MassDEP places the responsibility on itself to determine if commercial food waste generators are exceeding the threshold level, rather than requiring businesses to submit data on their food waste generation. Because of this, MassDEP is more cautious in identifying noncompliance for this ban than for some of the other materials that are banned in any quantity (Fischer, 2018). Another challenge in enforcing the ban is identifying the generator of food waste that is in noncompliance. Depending on the size of the business, one packing truck may contain waste from 20 to 40 different businesses, making it very challenging to identify if the waste that exceeds the ban was generated by one business or multiple businesses, as well as make it difficult for the hauler to identify exactly which business the waste in question may be from.

If businesses are identified as being in noncompliance with the ban, they receive a warning letter from MassDEP and, if the situation requires, a Notice of Noncompliance (NON) and/or a penalty (Fischer, 2018). Because of the challenging nature of enforcement of the Commercial Food Waste Disposal Ban, there is likely more noncompliance than MassDEP has identified; through December of 2017 15 NONs and one penalty had been issued for the ban, significantly fewer than those issued for other banned materials, such as

cardboard (Fischer, 2016). However, it is still assumed that compliance is relatively high, especially among the large food waste generators, those generating more than 5 tons per week (Fischer, Progress Report, 2017; Fischer, 2018).

Compliance Assistance

In order to aid businesses across the waste stream, especially waste generators and waste haulers, MassDEP contracted with the Center for EcoTechnology to establish RecyclingWorks Massachusetts, a program that assists businesses in complying with the different waste bans, including the Commercial Food Waste Disposal Ban, and reducing waste in general. RecyclingWorks Massachusetts was established in 2011 prior to the implementation of the Commercial Food Waste Disposal Ban, providing generators of food waste with sufficient time and resources to change practices to comply with the ban when it was implemented in 2014. Between fiscal year 2013 and fiscal year 2017 RecyclingWorks received over 3,600 requests from businesses, institutions, haulers, and processors (RecyclingWorks, FY2013, 2013; RecyclingWorks, FY2014, 2014; RecyclingWorks, FY2015, 2015; RecyclingWorks, FY2016, 2016; RecyclingWorks, FY2017, 2017). Processing these requests can include helping waste generators locate waste haulers, providing technical assistance, and holding events allowing businesses within the waste stream to learn from each other.

While RecyclingWorks does not focus solely on food waste, much of the assistance that businesses seek relates to the ban, especially because the other bans predated the establishment of RecyclingWorks. In fiscal year 2017, nearly 85 percent of the waste, by weight, diverted as a result of requests to RecyclingWorks, was food waste; with 84 percent of the total waste being composted, anaerobically digested, or used as animal feed and less than one percent of the total waste donated to food rescue organizations (RecyclingWorks, FY2017, 2017). While food waste generators are a key part of the waste stream for compliance, RecyclingWorks provides assistance to businesses across the waste stream to help to support the wider infrastructure necessary to improve compliance. For instance, RecyclingWorks provides technical assistance to composting operations to improve the facility's ability to process food waste and other compostable materials, thus increasing the overall diversion potential (RecyclingWorks, FY2017, 2017; Macaluso, 2018). By supporting facilities that receive and process diverted waste, RecyclingWorks ensures that food waste is not simply separated out by the generator, but effectively diverted and turned into a resource.

In addition to MassDEP's efforts to support compliance through RecyclingWorks, the EPA has programming that supports waste reduction and diversion as well. While this programming exists throughout the country, in a state such as Massachusetts that has a Commercial Food Waste Disposal Ban, the WasteWise and Food Recovery Challenge help to engage and educate businesses on issues of waste, particularly related to food waste, which support compliance.

The Food Recovery Challenge began in 2011 and is a voluntary program for businesses that want to reduce and divert their food waste in line with the EPA's Food Recovery Hierarchy. Through the program participating businesses can receive technical assistance and grants to implement programming and infrastructure, and can also be recognized for their work at the regional and national levels (Beling, 2018).

Impact

Since the ban was implemented in October of 2014, the amount of food waste diverted has increased, nearing the state's goal of 350,000 tons of food waste diverted annually by 2020, as well as the number of facilities to process diverted waste, both of which have had positive economic impacts throughout the state. In 2016, 260,000 tons of food waste were diverted to off-site facilities, a significant increase in diversion, while also below the capacity of diversion facilities (Fischer, Progress Report, 2017). MassDEP calculates food waste diversion levels largely based on the operating volume of food waste diversion facilities.

As a result of the ban and the increase in food waste diversion, anaerobic digestion facilities and depackaging facilities have experienced significant growth. Changes in the waste stream market as a result of the ban have warranted innovative approaches to increasing food waste diversion, particularly for products that are more challenging to divert, such as large pallets of food or other forms of packaged foods. At the time that the ban went into effect, infrastructure to compost and anaerobically digest food waste existed within the state, but the

growth of diversion led to the establishment of depackaging facilities. There are currently six such facilities throughout the state with additional facilities in the process of being built (Fischer, Progress Report, 2017). In addition to growth in facilities to process food waste, haulers have experienced growth as well; between 2014 and 2016 customers of food waste haulers increased by 56 percent (Fischer, Progress Report, 2017). Though not a primary form of diversion, food rescue has also grown in popularity; between 2014, when the ban was implemented, and 2016 the amount of fresh and perishable foods donated to food rescue organizations increased by more than 33 percent (Fischer, Progress Report, 2017). In line with this growth RecyclingWorks has received more frequent requests regarding food donation, and as a result has worked to better educate businesses on issues of food safety, liability, and other issues of interest (Macaluso, 2018; Fischer, Progress Report, 2017).

Aside from an increase in the quantity of food waste being diverted and the available infrastructure, the growth in diversion has also led to job creation and other economic gains. A study conducted by ICF for MassDEP found that employment across all segments of the waste stream increased by 150 percent between 2010 and 2015; in 2015 there were more than 900 jobs in organic waste hauling, processing, and food rescue in the state. In addition to growth in employment, businesses throughout the organics waste stream contributed $5.4 million in tax revenue and experienced $175 million in industry activity in 2016 (ICF, 2016).

While the implementation of the Commercial Food Waste Disposal Ban has been effective in increasing the amount of food waste diverted and provides economic benefits to the state, the role of the ban in food diversion efforts is not necessarily consistent across sectors of food waste generators. The following section focuses on the food waste generated by colleges and universities, including case studies of four universities and their food waste diversion practices, and the role that the ban has had on these practices.

Chapter 5: College and University Case Studies

Colleges and Universities in Massachusetts' Food Waste Stream

There are 102 colleges and universities in Massachusetts that serve more than 340,000 full-time and part-time students (College Simply, 2018). MassDEP's 2011 dataset on food waste generators included 87 different higher education institutions, and estimated that these institutions generate a cumulative 19,246 tons of food waste annually (MassDEP, 2011). Of these 87 institutions the vast majority of them are subject to the Commercial Food Waste Disposal Ban; according to the 2011 estimates, at least 71 of the institutions produced 52 tons of food waste or more each year. Since college and universities largely operate around a nine month academic calendar it is likely that even more than 71 institutions are subject to the ban; the amount of waste that institutions generate is not consistent each week and as a result institutions with annual generation below 52 tons may still have weekly generation above the 1 ton threshold during the academic year (MassDEP, 2011).

In addition to the majority of colleges and universities needing to comply with the ban, these institutions are some of the largest waste-generating businesses in the state. In MassDEP's 2011 dataset the top seven food waste generating businesses were colleges and universities (MassDEP, 2011). While it is important to note that this dataset did not include businesses involved in the manufacturing, processing, or distribution of food, which are significant sources of food waste, the impact of colleges and universities on the food waste stream is

still evident. Colleges and universities are also an important sector to highlight because of the long history of efforts to promote food waste diversion across the sector. MassDEP established voluntary programs for colleges and universities well before a waste ban was implemented as a part of the development process, and the EPA's Food Recovery Challenge began with a focus on colleges and universities in 2011 (Fischer, 2017; Beling, 2018).

The following section details the food waste diversion practices at four higher educational institutions in Massachusetts – the Massachusetts College of Art and Design, Smith College, the University of Massachusetts Amherst, and Wheaton College. The universities vary in size, geographic location, dining services management, and interests in food waste reduction and diversion. Though only four institutions are included in the case studies, they reflect the variations across colleges and universities in Massachsuetts. The current food waste reduction and diversion practices, and the history of these programs, in addition to the off-site diversion facilities and processes are outlined. Table 2 provides an overview of the different case study institutions.

Table 2: Case Study Colleges and Universities

College/University	Location	Student Body	Dining Management	Food Waste Reduction & Diversion Practice
Massachusetts College of Art and Design	Boston, MA	2,070	Contracted - Chartwells	Anaerobic Digestion
Smith College	Northampton, MA	2,450	Run by Smith	Menu planning, pantry coordination, composting, food donation
University of Massachsuetts Amherst	Amherst, MA	30,000	Run by Umass Amherst	Menu planning, source reduction, food donation, composting, no trays, dining hall design
Wheaton College	Norton, MA	1,650	Contracted - Aramark	Menu planning, source reduction, animal feed

Massachusetts College of Art and Design

Boston, MA

Background

The Massachusetts College of Art and Design (MassArt) is a public university located in Boston, Massachusetts with a student body of 2,070 students in undergraduate, graduate, and continuing education programs (MassArt, 2017). MassArt is a part of the Colleges of the Fenway consortium and shares some resources and facilities with other institutions in the consortium, including the campus' dining services which is run by Chartwells, which also runs dining programs at the Massachusetts College of Pharmacy and Health Sciences and Wentworth Institute of Technology (Elkin, LaRosee, & Laznick, 2018).

Issues of environmental sustainability are very important to MassArt's campus culture, and are evidenced through course offerings, student groups, and overall student, faculty, and administration interests (Elkin, LaRosee, & Laznick, 2018). As a result of these interests, MassArt began implementing food waste diversion practices in 2012 with composting in the back of the house – composting pre-consumer food waste largely resulting from trim, food prep, and overproduction – and expanded the practices to front of the house composting, the composting of post-consumer food waste, in October of 2014 (Elkin, LaRosee, & Laznick, 2018; RecyclingWorks, MassArt, 2016).

Food Waste Diversion Practices

As a company, Chartwells is interested in environmental sustainability, seen through its initiatives on sustainable food sourcing and waste reduction (College of Fenway, 2018). While Chartwells manages the dining programs in a number of institutions in the Colleges of the Fenway consortium, and students are able to able to purchase food at different schools in the consortium, the food waste diversion operations vary from institution to institution, based on individual interests and priorities (Elkin, LaRosee, & Laznick, 2018). When MassArt implemented the initial phase of its composting program in 2012, all food scraps from preparation were separated out into a composting bin, as well as separating recyclable materials from trash. Prior to this effort the dining staff already recorded data on the amount of food waste that was being created in the back of the house (RecyclingWorks, MassArt, 2016). In order to divert the food waste that was now separated out, MassArt contracted with a waste hauler that could provide trash, recycling, and organic waste services (RecyclingWorks, MassArt, 2016).

Over time, MassArt wanted to expand its food waste program to the front of the house to include diversion of post-consumer food waste. The dining hall at MassArt is different than that of some other colleges and universities in that all food is served on disposable or to-go containers. Because of this there is no dish room to sort out compostable food scraps from waste that is meant to be recycled or is trash. Instead students are responsible for sorting their waste, a step that is crucial to maintaining a high quality organics waste stream (Elkin, LaRosee, &

Laznick, 2018; RecyclingWorks, MassArt, 2016). In order to prevent as much contamination as possible from the post consumer food waste, MassArt created shadow boxes above the 'compost,'[2] recycling, and trash bins identifying which products from the cafeteria should be disposed of in each bin. In addition the college created signage throughout the dining hall and conducted student outreach to explain the new waste sorting procedure. As a result of these efforts contamination in post-consumer food waste is quite low (Elkin, LaRosee, & Laznick, 2018). Since the food served in the cafeteria is served with disposable service ware the college took the initiative to source as much compostable and recyclable serviceware materials as possible to reduce the amount of trash that was generated (Elkin, LaRosee, & Laznick, 2018; RecyclingWorks, MassArt, 2016).

Because of the growth in composting, the college needed to change their waste collection infrastructure, which is an especially challenging task for an urban campus. The campus currently has a 15yd compacting dumpster for organic material and a 30yd split dumpster for trash and recycling, all of which are color-coded with the same scheme used throughout the dining hall. Throughout the nearly four years that the college has been composting from the front and back of the house the amount of food waste that is diverted has increased. In 2017 MassArt diverted more than 55 tons of food waste, through a contract with Waste Management (WM) (Waste Management, January-June, 2017; Waste

[2] MassArt uses the term 'compost' to signify food waste diversion; it is a well understood term and concept compared to creating signs and educational campaigns around separating food waste for anaerobic digestion. This is considered to be a catchall industry term for food waste diversion. According to RecyclingWorks, 'compost' can include diverting food waste to composting, anaerobic digestion, or animal feed (Macaluso, 2018).

Management, July-December, 2017). The food waste diverted from MassArt is sent to WM's CORe facility in Charlestown, MA where it is converted to an organic slurry and then anaerobically digested to produce biogas (Guiney, 2018; Waste Management, CORe, n.d.; Elkin, 2018).

Smith College

Northampton, MA

Background

Smith College is an independent, liberal arts women's college located in Northampton, MA and has a student population of 2,450 students studying on campus (Smith College, 2018). While Smith has a relatively small student population, its dining system is quite unique and expansive. The college privately operates its dining services program and has 13 kitchens, which feed 12 dining rooms and one campus café (Cox, 2018; Kerr, 2018). Originally, Smith began implementing food waste diversion practices as a result of student interest. In 2005 students worked with the college's grounds manager and facilities department to begin small-scale composting – collecting food waste in five-gallon buckets and delivering them to a farm at a local vocational high school for composting (Kerr, 2018). Over time, the college became interested in expanding the scale of composting because of both environmental and financial benefits of diverting food waste. By 2012 composting was institutionalized in each of the dining rooms and kitchens on campus and in the spring of 2018 post consumer composting was implemented in the campus café (Kerr, 2018).

Food Waste Diversion Practices

On average, Smith produces 240 pounds of food waste per student each year, which is nearly 100 pounds more than the national average from the EPA of 141.25 pounds per year (Cox, 2018). Of this waste, more waste is produced in the

back of the house than in the front of the house (Cox, 2018). The high volume of food waste warrants a number of different approaches to reducing and diverting food waste. Each year the amount of food waste diverted on campus grows; in 2017 Smith diverted 307 tons of waste (Kerr, 2018). Compost accounts for the majority of diversion; for about a decade Smith has contracted with Bridgmont Farms, a grass-fed beef farm in Westhampton, MA for composting services. Three times a week, two Smith staff members collect toters of pre-consumer and post-consumer food waste from each of the dining facilities and deliver them to Bridgmont Farms, totaling about 12yds of food waste each week. Up until this year Smith also delivered manure and bedding, which serves as a compost bulking material, from the college's equestrian facilities (Montague, 2018; Cox, 2018; Kerr, 2018). In addition to composting food waste, Smith and Bridgmont Farms worked with RecyclingWorks to receive technical assistance to enable the composting of compostable serviceware, especially utensils and to-go containers (Montague, 2018; Cox, 2018; Kerr, 2018). From an institutional sustainability perspective using compostable containers and serviceware is very important to achieve zero waste goals, especially at events, but these compostable products are more challenging to compost than food waste (Kerr, 2018; Montague, 2018).

While a relatively small component of Smith's food waste diversion practices, the college has a student run chapter of the Food Recovery Network that collects leftover food from the kitchens across campus and delivers it to MANNA Soup Kitchen in Northampton, MA. Each week students collect about 100 pounds of food that has been frozen from five to seven kitchens across

campus and deliver it to the soup kitchen. In addition to the food rescued by the student group, Smith's dining services works to reduce on-campus food insecurity with leftover food. The dining services department creates frozen individual portions with leftover food and collects sandwiches from the grab-and-go sandwich station each Friday – these foods are made available in a campus freezer and refrigerator (Cox, 2018).

While programs supporting food waste diversion are valuable, Smith is also interested in reducing food waste from the start. In the summer of 2017 Smith piloted Phood Solutions, a food waste tracking software, to collect data on overproduction and other pre-consumer food waste in one kitchen. Although this tracking software has not been continuously implemented because of some departmental challenges, the hope is that over time it can help Smith to identify opportunities for source reduction, resulting in cost savings. Based on the per student average of food waste and the EPA's estimated average cost of food waste of $1.17 per pound, Smith currently wastes about $750,000 in food each year (Cox, 2018). In addition to tracking pre-consumer waste, Smith has also implemented changes related to menu planning to reduce the amount of waste created. Some of these changes include made to order foods such as salads, sandwiches, and burritos and conducting inventories of each of the kitchens and how ingredients can be moved between them to maximize efficiency (Cox, 2018).

University of Massachusetts Amherst

Amherst, MA

Background

The University of Massachusetts Amherst (UMass Amherst), located in Amherst, MA, is the main location the University of Massachusetts institutional network and has more than 30,000 students in undergraduate and graduate programs, 21,000 of whom are on the campus' meal plan (UMass, 2018; Florio, 2018). By revenue, the university operates the largest campus dining program in the county and serves over 6 million meals each year in four dining halls and over two dozen cafes and express style eateries (Florio, 2018; UMass Dining, n.d.). Because of the scale of university and its dining operations, UMass Amherst has an extensive system for reducing and diverting food waste, which includes practices that date back more than 20 years (Pepi, 2018).

In 1997 the university began diverting food scraps from the wastewater treatment plant, where they were previously sent through the garbage disposal, by collecting pre-consumer food scraps from the dining halls and composting them on campus in composting vessels (Pepi, 2018). Shortly thereafter, the scale of the food waste that was being collected exceeded the composing infrastructure and the university sought out other options for composting the waste. To improve the composting process and increase capacity the university constructed a composting system, which was in place until about 2001. As a result of waste stream pressures, site limitations and capacity for the university, and cost constraints, UMass Amherst began contracting with a local farm for off-site composting

services (Pepi, 2018). Over the past two decades the university has continued to compost food waste off-site, paying tipping fees less than what they would be at a solid waste facility, while also expanding food waste reduction and diversion practices (Pepi, 2018). Economic interests motivated this initial adoption of food waste diversion practices, though environmental interests and the goal of becoming an industry leader have supported the growth of the campus' food waste diversion practices.

Food Waste Diversion Practices

Each year UMass Amherst produces about 1,200 tons of food waste, of which 60 percent is post-consumer waste and 40 percent is pre-consumer waste, including trim which accounts for 15 percent of total food waste and overproduction which accounts for 25 percent of total food waste (Florio, 2018). While the amount of waste generated is substantial, as a percentage of food purchased it is significantly lower than industry averages. Food waste accounts for 9.42 percent of the university's overall food budget, compared to an average of 30 to 40 percent across the industry (Florio, 2018). UMass Amherst is a member of the EPA's Food Recovery Challenge, and as a result, the university follows the EPA's Food Recovery Hierarchy, prioritizing source reduction and donation over other means of diversion (Florio, 2018; EPA, FRC, 2018).

Composting accounts for the largest method of food waste diversion. Both pre-consumer and post-consumer waste are collected in the dining locations across campus. In each of the four dining halls on campus food waste is sorted and collected by dining services employees in the back of the house, while the

other dining facilities on campus rely on diners to sort their plate waste into source-separated bins, which increases the likelihood of contamination (Florio, 2018; Pepi, 2018). The university also offers composting at about 90 percent of the events held on campus, though the implementation and effectiveness largely depends on the scale of the events (Pepi, 2018; Florio, 2018). Currently, UMass Amherst contracts with Martin's Farm in Greenfield, MA – the largest commercial composting operation in Western Massachusetts – for composting services (Martin, 2018). The facilities department at the university collects toters of food waste from the dining facilities across campus and delivers them to Martin's Farm (Pepi, 2018).

While contamination of food waste is a challenge, especially with regard to post-consumer waste, Martin's Farm has been largely tolerant of contaminants in UMass Amherst's food waste because of its composting process and ability to screen out contaminants (Pepi, 2018; Martin, 2018). That being said, Martin's Farm does inspect loads of food waste when they are delivered and will refuse waste with significant contaminants (Martin, 2018). The increased prevalence of compostable and biodegradable packaging and serviceware has become a challenge for composting facilities such as Martin's Farm. These products have grown in popularity as a result of zero-waste goals as well as the benefits they provide to compost collection, such large compostable bags, and as a result are more common in loads of food waste, both from UMass Amherst and other businesses. The synthetic makeup of these products prevents them from being Certified Organic, and as a result compost that includes these materials cannot be

certified Organic. Martin's Farm recently lost its organic certification because of this challenge (Martin, 2018; Pepi, 2018).

In addition to composting, a portion of wasted food is diverted through donation. UMass Amherst has a student chapter of the Food Recovery Network, which collects food from two of the campus' dining halls daily and delivers the food to Craigs Doors, a homeless shelter in Amherst. The group works with the dining services staff to collect and package prepared, pre-consumer food waste and maintain food safety throughout the food's transit. Though food donation only accounts for a small percentage of food diversion, over 40 pounds of food are diverted to donation each day (Florio, 2018).

Aside from diverting food waste, UMass Amherst is interested in reducing the amount of food waste generated, especially from a cost-saving perspective. The university implemented LeanPath software to track the pre-consumer waste that was produced, as well as identify the reason for the waste and the environmental and economic impacts associated with the waste. Because of the data collected by LeanPath UMass Amherst was able to identify significant avoidable sources of pre-consumer waste, which led to $750,000 in food cost savings over a three-year period. While the adoption of LeanPath software solely addresses pre-consumer food waste, other changes consider post-consumer waste as well (Florio, 2018).

In 2013 Hampshire Dining Commons, one of the four main dining halls on campus reopened after a two-year renovation that included changes to facility's layout to reduce the amount of pre-consumer and post-consumer waste. The

Hampshire Dining Commons was reconfigured to have a circular layout. This circular design reduces lines throughout the dining hall, which reduces plate waste; longer lines are generally associated with students taking more food than they need. In addition, the design places the cooking stations in the dining hall – kitchens are largely used only for food prep – so food is less likely to be overproduced when staff cooking the food can see how quickly it being depleted (Florio, 2018). Across all of the dining halls the dining services chefs engage in menu planning to reduce food waste. Efforts have been made to create bite-sized portions, especially for deserts, increase the amount of made to order foods, and use measured serving utensils to serve food to students (Florio, 2018). Additionally, in the summer of 2009 all of the dining halls on campus went trayless; a successful effort to reduce plate waste, which has result in a 30 percent reduction (Florio, 2018).

Wheaton College

Norton, MA

Background

Wheaton College is a small, liberal arts college, located in Norton, Massachusetts, and has a student population of 1,650 students (Wheaton College, n.d.). Throughout the campus there are two dining halls and two cafes, all of which are run by Aramark (O'Rourke, 2018). As a company, Aramark is interested in environmental sustainability and seeks to be a leader in the industry. In line with this goal Aramark is engaged in food waste diversion and reduction practices following the EPA's Food Recovery Hierarchy (Thompson, 2018). In addition to Aramark's interest in sustainability, both Wheaton's administration and student body are interested in environmental issues. Wheaton began implementing its food waste diversion practices roughly 15 years ago, through a partnership with Plante Brothers Farm, which is also located in Norton, MA. Through this partnership, Wheaton donates the campus' food waste to the farm where it is used to feed pigs (O'Rourke, 2018; Thompson, 2018).

Food Waste Diversion Practices

Wheaton's practices of food waste diversion have stayed consistent over time. In the kitchen, all trim and other types of pre-consumer food waste are separated into containers that will go to the farm, while staff in the dish room separate post-consumer plate waste from plates and other types of waste. This process eliminates the need for students to sort their waste, which decreases the

risk of contamination in the food waste that will be donated (O'Rourke, 2018). Each week nearly all pre-consumer and post-consumer waste generated in the campus' dining venues are sent to Plante Brothers Farm. The only restriction that the farm has for receiving food waste is that all forms of meat must be cooked before they can be fed to animals. In the kitchens at Wheaton staff will cook raw meat scraps before they are placed in the food waste bins (O'Rourke, 2018). As an additional safeguard, Plante Brothers Farm steam cooks all of the donated food waste before any of the scraps are fed to their pigs (O'Rourke, 2018).

In addition to diverting the food waste that is created on campus, Wheaton's dining services works to reduce waste from the source in the kitchen through the use of software and menu planning and through educating the student body (O'Rourke, 2018). Wheaton, like all Aramark-operated college dining services, has LeanPath software in the kitchens to track the amount of pre-consumer food waste generated as a result of preparation, overproduction, etc. (O'Rourke, 2018; Thompson, 2018). LeanPath not only provides metrics on the amount of food waste that is generated, but it tracks how the waste is diverted or disposed of, who processed the waste and used software, and the environmental and economic costs associated with that level of food waste (O'Rourke, 2018). In addition to tracking all pre-consumer waste, Wheaton's dining services looks at particular menu items and compares the amount of food that was prepared with the amount of food that was left over to reduce future waste by better planning for those meals when they are on the menu again (O'Rourke, 2018).

Each semester Wheaton's dining services collaborates with a special interest house on campus to educate the student body on the amount of food waste generated and help them to better conceptualize the impact of their decisions. Over the course of one day each semester all post-consumer food waste is collected in a clear container in the dining halls and weighed. This visual and quantitative display reminds students to not take more food than they need (O'Rourke, 2018). As a company, Aramark also has education and outreach materials on its efforts to increase sustainability, which are displayed in the dining hall for students to engage with and learn about food waste and some of the other efforts Aramark is making to reduce its environmental impact (O'Rourke, 2018).

Initial Findings

Similarities across Case Study Institutions

Influence of the Commercial Food Waste Disposal Ban on Practices

Although the colleges and universities and food diversion facilities included in the case studies differed in scale, geographic location, and management there are some common themes related to food waste diversion and the Commercial Food Waste Disposal Ban. One of the largest similarities was the timing of the adoption of food waste diversion practices across the case study institutions. Each of the institutions established a food waste diversion program before the Commercial Food Waste Disposal Ban went into effect in 2014, with the oldest dating back to 1996 at UMass Amherst, and the most recent at MassArt in 2014.

In each of the case study interviews it was expressed that the implementation of the ban did not spur the adoption of diversion practices, and it generally did not change the trajectory of initiatives at the individual universities. Emma Kerr, the Campus Sustainability Coordinator at Smith College noted, *"because we had a strong composting program in place already, when the ban came it didn't make us need to change anything because we were already prepared and had been sort of compliant with that for many years"* (Kerr, 2018). John Pepi, the General Manager, Office of Waste Management, Moving, & Surplus at UMass Amherst echoed similar sentiments, in that the food waste ban did not motivate the work that the university was doing, especially since food waste diversion practices had been going on for nearly two decades before the ban

(Pepi, 2018). Because these institutions were largely in compliance with the ban before it went into effect it was not necessarily something that they were cognizant of at the time. Howie LaRosse, the Executive Director of Facilities Planning at MassArt mentioned he was not aware of the ban at the time it went into effect (Elkin, LaRosee, Laznick, 2018).

While the implementation of the ban did not result in significant changes in the food waste reduction or diversion practices at the case study institutions, the existence of the ban did help institutions advocate for expansion of existing initiatives. Andy Cox, the Director of Dining Services at Smith College, explained that when he started working at Smith some compostable materials, including bones and compostable serviceware and containers, could not be composted at Bridgmont Farms. He used the presence of the ban to push for the expansion of Bridgmont Farms' composting infrastructure to include these compostable items (Cox, 2018). It is also important to recognize that even though the ban did not go into effect until October of 2014, it was something that MassDEP was considering for more than a decade and working to establish the infrastructure and support for the ban to be successful and effective. Though it is difficult to document, the MassDEP support - both formal and informal - of food waste diversion, in addition to a growing national interest in food waste may have had an influence on some of the food waste diversion practices that were adopted by the case study institutions, especially initiatives adopted in the mid 2000s through up until the ban was put into effect.

The Commercial Food Waste Disposal Ban and Market Demand

Institutions and businesses across the food waste stream have benefitted from the ban and opportunities it has led to in the market. A number of colleges and universities included in the case studies stressed the importance of using biodegradable and compostable packaging, serviceware, and to-go containers to achieve goals of zero waste. While the use of this type of packaging, and the need to divert it from landfills and combustion facilities is not a part of the ban, the compostable nature of these products fall in line with food waste diversion practices. Because of the requirements on restaurants, institutions, and other food businesses in Massachusetts, and other states with similar food waste bans, there is a growing demand for biodegradable and compostable packaging and products. John Pepi from UMass Amherst explained that *the food waste bans in Massachusetts and elsewhere "helped create an environment where there's enough demand out here for biodegradable packaging […] it eased the way for people to develop more biodegradable packaging alternatives […] [that] wouldn't have been [available] otherwise"*(Pepi, 2018).

Aside from increased demand for reengineered products that enter the waste stream, the establishment of the Commercial Food Waste Disposal Ban has created an increased customer base for food waste diversion facilities. Since the ban additional food waste diversion facilities have been established and other existing facilities have expanded. Martin's Farm has been in operation as a composting facility since 1987, when it was one of the first farms in the state permitted for food waste composting. Over the past thirty years the business has

grown as more businesses and institutions become interested in diverting their food waste to compost. Because of the ban the customer base is slowly growing, and as a result the farm recently increased its permitted capacity with MassDEP from 15 tons of food waste per day to 22 tons per day (Martin, 2018).

Importance of Food Waste Diversion Infrastructure

The importance of infrastructure to support food waste diversion practices was stressed by a number of the institutions included in the case studies. Establishing goals to reduce and divert food waste at an institutional level are important, but without facilities to process the diverted food waste, diversion is not possible. In talking about Wheaton College's food waste diversion practices of donating food waste to a local pig farm, Scott O'Rourke, the Director of Dining at Wheaton College explained that,

> *We're fortunate enough to be able to divert to a pig farm, if we were an institution and we weren't near a pig farm, how could we divert our food? It would be a different model I guess, we would have to figure some things out. I hear a lot of people talking about composting, but it's challenging to compost the amount of food that that we go through during a school year, and there's really no places around to do it.*
>
> - O'Rourke, 2018

UMass Amherst is located near an industrial composting facility, which, according to Britt Florio the Senior Sustainability Coordinator at UMass Amherst, is essential to the success of the university's food waste diversion endeavors; *"the other critical piece of this [UMass Amherst's food waste diversion practices] is that we have a industrial composting facility in Massachusetts, relatively close by. If we didn't have that, we wouldn't have the option sending it anywhere"* (Florio, 2018). Martin's Farm, the industrial composting operation based in Greenfield,

MA, is the largest industrial composting operation in Western Massachusetts and as a result collects food from an expansive geographic area - from Springfield, MA to Brattleboro, VT and from Charlemont, MA to Athol, MA – from grocery stores, such as Big Y and Whole Foods, hospitals, and other schools (Martin, 2018). The food waste from UMass Amherst accounts for about 33 percent of total food waste that the farm composts (Martin, 2018).

Unlike UMass Amherst, which contracted with an existing composting operation for diverting its food waste, Smith College created its own food waste diversion infrastructure by proposing a partnership with Bridgmont Farm, a grass-fed beef operation that at the time did not compost off-site material. Through this partnership both Smith and Bridgmont Farm have benefitted – Smith through reduced tipping fees and Bridgmont Farm as another source of income and through producing compost that can be applied to fields, reducing the need to purchase fertilizer (Montague, 2018; Kerr, 2018).

MassArt has approached the need for food waste diversion infrastructure a little differently than the other case study institutions. Since the college is located in an urban area and does not have the capacity to deliver food waste to a diversion facility on its own, it relies on haulers to provide organic waste diversion. Each time that the college goes out to bid for waste hauling services, it includes requirements for food waste diversion in its contract stipulations, ensuring that the college is able to maintain its food waste diversion goals within its waste hauling services (Ellyn, LaRosee, Laznick, 2018).

Local Food Purchasing and Increased Food Waste Generation

In conjunction with many colleges and universities engaging in food waste diversion as an effort to increase their environmental sustainability, many institutional dining programs are taking steps to address other facets of sustainability, including increasing local food purchasing. Each of the four universities included in the case studies have programs in place to support and increase local food purchasing. This issue is also at the forefront of student interests; Andy Cox explained that students at Smith College are *"concerned about supply chain and where the food is coming from"* (Cox, 2018). While purchasing local food can have many different benefits, one challenge of increased local food purchasing, especially regarding produce, is that it shifts food waste down the supply chain. As a result of its local food purchasing, UMass Amherst has noticed

> *When you switch your procurement from conventional farming to more local and sustainable farming you tend to get more waste, especially on the trim side; farm fresh veggies come in usually whole as opposed to already processed, and chopped, and bagged.*
>
> - Florio, 2018

Emma Kerr, from Smith College, echoed similar sentiments,

> *We have done a major increase in our local food purchasing […] in some cases that has actually contributed to compost a little bit because instead of buying peeled, diced squash we're buying whole product so we have more ends and peels.*
>
> - Kerr, 2018

Andy Cox, the Director of Dining Services at Smith did clarify that while local food may lead to an increase in back of the house food waste, food waste is not a problem of local food, especially if *"[the increase in food waste] was*

marginal, then the economic impact and transparency in the supply chain might offset a significant portion of [the newly created food waste]"(Cox, 2018).

Differences across Case Study Institutions

Motivations for Food Waste Diversion

The largest discrepancy amongst the colleges and universities included in the case studies is their motivations for food waste diversion, which include student-driven interests, institutional priorities, cost savings, and environmental benefits. UMass Amherst was the first of the case study institutions to adopt food waste diversion practices. At the time that the university began composting food waste the local landfills were closing and as there was pressure on the university's waste stream to divert recyclable materials and compostable materials from the landfills to both take pressure off of the landfills and to reduce waste-related expenses. The main motivation to implement a food waste diversion operation was economic. The tipping fees for compost are significantly lower than those for the landfill; the university currently pays approximately $41 per ton to compost food waste compared to $69 per ton at the landfill (Pepi, 2018). While economic incentives first motivated UMass Amherst's composting initiatives, environmental benefits including reduced greenhouse gas emissions have supported the growth of the initiatives (Pepi, 2018).

Wheaton College's food waste diversion, namely the college's diverting food waste to a local pig farm, is motivated by both Aramark's and Wheaton's interests in the environment and sustainability. Since Wheaton's dining program

is run by Aramark the initiatives and priorities are a combination of company-wide interests that Aramark has in waste reduction and diversion, such as the use of LeanPath software and the use of the EPA's Food Recovery Hierarchy, and Wheaton's specific environmental interests, such as the construction of a LEED certified dining hall (O'Rourke, 2018; Thompson, 2018).

Unlike UMass Amherst and Wheaton College where food waste diversion practices were driven by the institution, student interest was the original motivation behind Smith College's composting program. *"We [Smith College] started composting in a small-scale effort in 2005, […] [which] was really prompted by students […] [over time] students were a driving factor [in food waste diversion], but I think Smith also recognized it was the right thing to do"* (Kerr, 2018). The current institutional interest in and support for food waste diversion is largely based in economic and environmental motivations, though the college is also concerned about food insecurity and the social benefits of food waste diversion (Cox, 2018).

MassArt was the most recent of the institutions to adopt food waste diversion practices, beginning its composting program in 2012. The student body at MassArt is very interested in environmental issues, which is evident through student-run programs on campus as well as programs of study related to environmental sustainability. In the case of food waste diversion, the administration initiated environmental practices and programs prior to the students demanding action, which has helped to foster community amongst the students and administration (Ellyn, LaRosee, Laznick, 2018). While there were

differences across the case studies in motivations for reducing and diverting food waste, one similarity was that at each institution the motivations evolve over time as programs are implemented and continue to develop.

Chapter 6: Discussion and Recommendations

Discussion

The four case studies on the waste stream for colleges and universities highlighted the individual practices and experiences of institutions and food waste diversion facilities with respect to the Commercial Food Waste Disposal Ban, but also suggest overall implications of the ban for colleges and universities subject to the ban throughout Massachusetts. Although there may be some instances where colleges and universities began implementing food waste diversion practices as a result of the ban becoming effective in October of 2014, the implementation of the ban did not necessarily trigger widespread changes in behavior at the case study institutions. These institutions largely established food waste diversion practices without being required because of economic, environmental, and social interests in food waste diversion and the existence of requisite supporting infrastructure throughout the state – which can be directly tied to the development phase of the ban. There is anecdotal support for this idea beyond the case study institutions. John Fischer at MassDEP and Christine Beling at EPA noted the widespread adoption of food waste diversion practices across this sector and their progressive actions across food waste diversion streams (Fischer, 2018; Beling, 2018). This is partly because of the support for food waste diversion practices and infrastructure from MassDEP, the EPA, and many nonprofit groups both in Massachusetts and at the national level. MassDEP began conversations about implementing a food waste disposal ban in 2000 and worked to establish

voluntary food diversion programs for large food waste generating businesses, including colleges and universities. Formal stakeholder meetings regarding the ban began in 2011 (Fischer, 2017). During the same time period, the EPA established the Food Recovery Challenge, which first focused on reducing and diverting food waste generated by colleges and universities, based on the EPA's Food Recovery Hierarchy (Beling, 2018). In 2016, 21 colleges and universities in Massachusetts, including UMass Amherst, participated in the Food Recovery Challenge, diverting over 5,200 tons of food waste from the landfill or combustion facility (Bowen, 2018). Because of the growing interest and involvement with food waste diversion, not only at the college and university level, but across the waste stream, there were no concerns expressed during the formal public comment period while the ban was being developed (Fischer, 2017; Beling, 2017). The multi-year process of developing the ban, establishing voluntary diversion programs, and supporting infrastructure for food waste diversion likely had a significant influence on colleges and universities – namely those that began implementing food waste diversion practices in the decade or so before the ban was enacted. Rather than suddenly establish a requirement that food waste generators must comply with, MassDEP worked with food waste generators, haulers, diversion facilities, and other stakeholders to develop and expand the necessary infrastructure, including expanding the number of haulers collecting food waste, and supporting the development of more diversion facilities. In addition, establishing voluntary programs prior to enacting a ban allowed MassDEP to collect data on the feasibility of implementation to support

the non-negative economic impact of the ban on generators subject to the ban. As a result of this process, *"you're almost hard pressed to find a college or university not doing something [to divert food waste]."*(Beling, 2018). Support for food waste reduction and compliance with the ban has continued to grow. RecyclingWorks, the EPA's Food Recovery Challenge, and MDAR provide technical assistance to institutions and businesses in the food waste stream to assist food waste generators, haulers, and diversion facilities with compliance (Macaluso, 2018; Beling, 2018; Bowen, 2018).

The widespread adoption of food waste diversion practices at colleges and universities can also be seen as a result of the unique structure of colleges and universities compared with other food businesses. The primary customers at colleges and universities are students in early adulthood, who are often times very interested in social, environmental, and political issues that are directly related to a campus' dining operation – the carbon footprint of food waste and food insecurity are a couple of examples (Beling, 2018; Ellyn, LaRosee, Laznick, 2018; Thompson, 2018). Not only are students often interested in issues concerning food waste, but also as consumers they may have more power and leverage over their campus dining operations than the typical consumer at a grocery store or restaurant. Because of student interest in food waste, colleges and universities often participate in a range of food waste reduction and diversion practices, some of them student run or initiated. In addition to particular examples from the case studies, Smith College beginning composting or UMass Amherst eliminating dining trays, the Food Recovery Network illustrates how students can

influence dining operations (Kerr, 2018; Florio, 2018). As a result of student-run chapters of the Food Recovery Network colleges and universities, including Smith College and UMass Amherst, have implemented food donation programs, often in addition to other food waste diversion initiatives.

The case studies, and lack of stakeholder opposition to the ban, also indicate that while a ban on food waste disposal may be perceived as burdensome, in practice adopting food waste diversion and reduction strategies is not only easy to do, but also results in economic benefits. According to Matthew Thompson, Aramark's Culinary Director for Higher Education,

> *We [Aramark] anticipated some challenges whether that be […] financially, […] partnering with a new location, or whether that was an on-site logistic in terms of getting new […] equipment or […] communication materials, or if it was just simply a behavioral change for some of our guests. We honestly, in higher education, found very little barrier to being able to accomplish the goals of the ban*
>
> - Thompson, 2018

The ease of implementing food waste diversion practices was echoed by Kory Laznick, the Director of Dining Services at MassArt;

> *Once your infrastructure is there and you have your vessels in place […] now it's second nature […] in the back of the house, in the kitchen, or on the line you're either throwing your stuff in this color or that color, so it's pretty simple*
>
> - Laznick, 2018

The economic benefits that diverting food waste provides to colleges and universities signifies both the success of the ban in targeting food waste generators of a certain scale, without an economic burden, and the opportunities for colleges and universities subject to the ban (Fischer, 2018). Each of the colleges and universities included in the case studies have lower waste disposal costs by participating in diversion than they would if food waste was treated as trash. The case studies provide varying examples of food waste diversion including contracting organics diversion through a waste hauler, donating food waste for animal feed, or paying for waste to be composted on a farm (Ellyn, LaRosee, Laznick, 2018; O'Rourke, 2018; Pepi, 2018; Florio, 2018; Kerr, 2018; Cox, 2018). The range of diversion practices shows that regardless of geography or size of a college or university, it is possible to divert food waste and save money on tipping fees. In addition to reduced waste disposal costs, waste reduction practices such as LeanPath software, have the potential to result in significant cost savings; UMass Amherst saved $750,000 in a three-year period because of source reduction (Florio, 2018).

Another opportunity of the Commercial Food Waste Disposal Ban is that it does not specify a specific means or food waste diversion or follow a hierarchy for recovery. The unrestricted nature of the ban allows food waste generators to pursue whatever means of diversion are easiest to implement, located in their region, most cost-effective, or that they are generally most interested in (Fischer, 2018). This not only makes it easy to comply with the ban, but allows food waste generators to begin with one means of diversion and develop their practices over

time to include different routes of diversion, especially shifting towards higher, more preferable tiers of the EPA's Food Recovery Hierarchy. From her experience interacting with the ban in Massachusetts and the similar bans in other New England states, Christine Beling noted that, *"everybody starts with compost, and then as you start to chug along more and more the donation angle comes up, the source reduction angle; you know people start thinking more about it"* (Beling, 2018).

Regardless of when colleges and universities began diverting food waste, whether it was before the ban was implemented or as a result of the ban, the successes and challenges of implementing programs that comply with the ban can be applied to all scenarios. Stakeholders across the case study institutions emphasized the importance of programming that is engaging that creates interest and enthusiasm across both students and the people who work in the dining operations. By engaging staff and consumers, food waste diversion practices are more successful because people feel a sense of purpose and understanding behind their behavior change. The shadow boxes in the dining hall at MassArt serves as an example of a way to visually engage people eating in the dining hall with the college's food waste diversion efforts (Ellyn, LaRosee, Laznick, 2018). The LeanPath software used by both UMass Amherst and Wheaton College provides an opportunity for staff in the kitchen to understand the importance of food waste diversion by presenting metrics on the environmental and economic impacts of food waste (Florio, 2018; O'Rourke, 2018). However, the use of software alone cannot create enthusiasm and interest in food waste diversion practices. Smith

College's attempt to implement software to track pre-consumer waste was met with staffing and adoption challenges, partly because of the shared management structure across the campus' many dining facilities (Cox, 2018). Both UMass Amherst and Wheaton, which have seen success from the use of LeanPath software, stressed the importance of manager support for food waste diversion practices to engage staff with the initiatives (Florio, 2018; O'Rourke, 2018). UMass Amherst also offers internal incentives for staff to increase participation in these practices (Florio, 2018).

Colleges and universities in Massachusetts, as well as other institutions and businesses subject to the ban, have the unique benefit of being located in a region where four of the region's six states have food waste bans. Although currently the bans in Connecticut, Massachusetts, Rhode Island, and Vermont are in different phases and vary in the types of waste generators subject to the ban, the overall regional interest in food waste diversion has benefits both for compliance with and enforcement of the ban. For example, the increased demand from food waste generators, especially colleges and universities, for biodegradable and compostable packaging, serviceware, and containers can influence the market to make products more readily available and more affordable (Pepi, 2018). From the enforcement perspective, once the bans throughout New England reach similar thresholds, there is the potential for better enforcement of waste that does not travel to a transfer facility in Massachusetts before it crosses state lines. Waste generated in border communities may not travel to a transfer station in Massachusetts before being shipped to another state for disposal, posing the

possibility for generators in these communities to be out of compliance with the ban without MassDEP knowing so since the Department does not visit out of state waste facilities. While waste that does not travel to a transfer station or waste disposal facility in Massachusetts only accounts small percentage of the overall waste generated in Massachusetts, improving enforcement will only strengthen the effectiveness of the ban (Fischer, 2018).

Looking ahead, in order to continue to grow food waste diversion efforts in Massachusetts and strengthen the power of the Commercial Food Waste Disposal Ban it is important for the MassDEP to increase funding for inspections. While the assumed level of compliance for the Commercial Food Waste Disposal Ban is quite high, the reported compliance rate is likely an overestimate because of the challenging nature of enforcing a ban on food waste at a particular threshold. In order to improve the enforcement process without completely changing how inspections are conducted it is necessary to increase the funding allocated to inspections to allow for more inspections per year. Increasing the number of inspections increases the number of loads that can be inspected and decreases the probability of missing loads that are out of compliance with the ban.

The advertised success of the ban is largely dependent on the quality of data available. MassDEP's most recent data on food waste generators in Massachusetts was collected in 2011, which was before the Commercial Food Waste Disposal Ban went into effect. While there is some assumed consistency in the data over time because of the nature of food businesses, it would be valuable for MassDEP to update its data on food waste generators, to determine how many

generators are subject to the ban and the role that source reduction has had in reducing waste. In addition to updating the data on food waste generators, it would also be valuable for MassDEP to include the original food waste data it collected in 2002 in its assessment, to help reflect the direct and indirect influence of the planning and development phases of the ban on diversion practices. Additionally, updating the data on food waste generators should consider generators as they are in the ban, for instance multiple businesses sharing a dumpster. This would identify generators that might unknowingly be out of compliance with the ban.

Recommendations

The following recommendations come out of the literature review on food waste, including diversion and regulation, stakeholder interviews and case study analysis, and data assessment. These recommendations seek to improve the overall effectiveness of the Commercial Food Waste Disposal Ban in Massachusetts, better coordinate the actions and interests of stakeholders across the waste stream, provide recommendations for other states considering implementing a similar ban, and illuminate areas for further research. The Commercial Food Waste Disposal Ban has shown to be effective and impactful in increasing the amount of food waste that is diverted each year, supporting related infrastructure development, and providing economic benefits, but there is room for improvement.

For Colleges and Universities

- **Do Not Overlook Source Reduction:** While the Commercial Food Waste Disposal Ban is focused on diverting food waste from the landfill or combustion facility and to another source, reducing the amount of waste generated can have substantial benefits for institutions. Software such as LeanPath or Phood Solutions allows universities to easily track the amount of pre-consumer food waste that they generate and calculate the cost and environmental impacts associated with this waste. UMass Amherst's success with this software – saving more than $750,000 and reducing food waste by more than 500,000 pounds – shows the impact of source reduction.

- **Consider Food Waste Diversion Pathways Not Currently in Existence:** As a result of the Commercial Food Waste Disposal Ban, infrastructure to support food waste diversion is much more prolific, but because of economic, geographic, or scale constraints the appropriate infrastructure may not be available. Especially in agricultural communities there may be potential to establish composting or animal feed donation programs with local farmers to aid in compliance with waste bans. These partnerships can be beneficial for all parties involved; colleges and universities can reduce the amount of food waste that they send to a landfill or combustion facility and save money on tipping fees while farmers can potentially establish a new source of income and can save money on purchasing necessary inputs like fertilizer or animal feed.

For MassDEP

- **Establish Reporting Requirements for Generators:** Though MassDEP is confident that most large scale food waste generators are in compliance with the ban, there is still a significant amount of uncertainty within the enforcement process since it is extremely challenging to identify food waste on the tipping floor and trace it back to its generator. It would be advantageous to require all food waste generators subject to the ban to report the amount of food waste that they generate and identify where it is diverted. Since the generators subject to the ban are larger businesses and institutions and have the capacity to adopt food waste diversion practices without it being an economic burden they would also likely have the capacity to generate these reports. For generators that pay for food waste diversion – which is most businesses – this information would generally be included in a service invoice, so it would not be a significant reporting burden for generators.

System-wide Coordination

- **Coordination Across Stakeholders Involved in the Ban:** Massachusetts, or any state with a food waste ban, should improve coordination between policy, industry, and other stakeholders involved in the ban. As a result of the ban and increased interest in composting, the use of compostable bags, serviceware, and containers has grown as a means to ease food waste separation and reduce waste in the traditional waste stream. Though compostable, these products contain synthetic materials that are not Certified Organic. Currently there are no Certified Organic compostable alternatives on the market. As a result, facilities that compost food waste currently face the challenge of either composting only waste that can be qualified as certified organic, reducing the amount of food waste diversion that they can participate in, or accepting all forms of compostable material and producing a product that is not organic. Improving coordination between organic certification organizations, industry, waste generators, and composting facilities would better support the food waste stream as a whole and the individual entities within it, particularly composting facilities that experience the brunt of this issue.

In Other States

- **Support Food Waste Diversion Infrastructure:** The colleges and universities included in the case studies stressed the importance of having food waste diversion facilities, with the capacity to receive their food waste, nearby. In order for a food waste ban to be effective, food diversion facilities need to be located throughout the state. Massachusetts currently experiences a shortage of food waste diversion facilities on Cape Cod, which poses challenges for businesses in the area that are subject to the ban. States interested in implementing a food waste ban should encourage the growth and development of food waste diversion facilities through grants, policy changes, and other means of support. Businesses interested in establishing food waste diversion facilities should consider the likely amount of food waste for diversion based on the ban and the state's goals and the necessary capacity to meet these goals. The number of food waste diversion facilities that have been built or are permitted exceeds the necessary capacity for food waste diversion in the state. Because of this, it is likely that some facilities will not receive enough food waste to stay in business.

- **Engage Stakeholders in the Development Process:** Much of the success of the Commercial Food Waste Disposal Ban can be attributed to the lengthy stakeholder process that MassDEP led to receive feedback from waste generators, haulers, diversion facilities, and other stakeholders on

the structure of the ban. By engaging stakeholders a state can reduce potential opposition and increase a ban's effectiveness.

- **Establish Voluntary Programs during Development:** In addition to this formal stakeholder process, MassDEP also engaged different stakeholders in voluntary programs to divert food waste. These voluntary programs provided an opportunity for the state to assess the impacts of food waste diversion on businesses and help to support necessary infrastructure for diversion.

- **Provide Technical Assistance:** Massachusetts businesses have the opportunity to receive technical assistance on issues of food waste diversion from government agencies, MDAR and the EPA's Regional Office, and RecyclingWorks Massachusetts, which is funded by MassDEP. Technical assistance in the form of on-site visits, conferences, workshops, best management practices, and general coordination helps businesses across the waste stream comply with the ban. These resources not only support compliance, but can improve the quality of food waste diversion and the overall effectiveness of the ban.

- **Measure the Success of the Ban Beginning with Development:** Analysis of the effectiveness of an action, such as implementing a ban, often compares the time before or at the ban being implemented and the time after implementation. In instances with long development processes, such as that with Massachusetts' Commercial Food Waste Disposal Ban, the development process can have significant impacts on behavior and outcomes that may occur prior to a ban formally being enacted. In order to best assess the full scope of impacts of the ban it is important to collect data before any part of the process beings, during the development process and prior to formal implementation, and after formal implementation.

Chapter 7: Conclusion

The Commercial Food Waste Disposal Ban was the result of a long process between MassDEP, food waste generators, waste haulers, and food waste diversion facilities. More than three years since the ban was enacted, the state has seen significant growth in the infrastructure for food waste diversion, as well as the amount of waste diverted to composting, anaerobic digestion, animal feed, and food recovery. The influence of the ban on different categories of waste generators does however vary as a result of the history of waste diversion in different sectors. Voluntary programs, institutional interests, and other factors spurred many colleges and universities to participate in food waste diversion prior to the ban taking effect. That being said, the presence of the ban has helped to increase the overall demand for food waste diversion and has provided valuable resources that businesses in the food waste stream can benefit from. Beyond MassDEP's support for food waste diversion, market demand and a greater social awareness of food waste since 2014 have provided benefits to colleges and universities subject to the ban.

The Commercial Food Waste Disposal Ban has largely been effective in increasing food diversion, though there are still some uncertainties about the level of compliance. In addition to increasing the amount of food waste diverted from landfills and combustion facilities, the ban has led to economic growth in the state, especially through job creation. For colleges and universities specifically,

the ban does not seem to have had an influence on the behavior of institutions that generate waste, as many diversion initiatives were implemented before 2014.

MassDEP is able to assess the overall impacts of the ban with data on diversion rates, but it is important to not just look at the waste stream in its entirety, but the individual categories of waste generation within it. To do this it is important to consider how other sectors of the waste stream, aside from Colleges and Universities, engage with the ban and have changed their practices. There is currently a great deal of uncertainty around food processors, distributors, and wholesalers and corporate cafeterias with regard to their experience with the ban. These two industries, as well as all other categories of food waste generators present valuable areas for future research.

In order to appropriately assess how Massachusetts is doing with respect to the goal of reducing food waste by 350,000 tons per year by 2020 it is important to have an accurate view of the current level of diversion. Compost, anaerobic digestion, and food donation are rather well documented types of food waste diversion in Massachusetts. Diversion to animal feed is however a category of diversion that is assumed to be underestimated by MassDEP data. Much of this diversion is arranged directly between a food waste generator and a farm, so it can be difficult to track, especially since unlike other food waste diversion facilities, such as composting, which is regulated by either MassDEP or MDAR, diversion to animal feed is not regulated.

A final area for further research is to consider other ways in which food waste generators may comply with the ban besides diversion. The Commercial

Food Waste Disposal Ban focuses on food diversion, but many institutions, especially colleges and universities are also engaging in source reduction. Since assessments of the ban look at the amount of food waste being diverted to composting, anaerobic digestion, food donation, and animal feed, there is no way to measure how much food waste is not going to the landfill or combustion facility because of source reduction. This type of food recovery is associated with many environmental, economic, and social benefits, but the scale at which it is happening and the impact that it has may currently be overlooked at the regulatory level.

This assessment has illustrated the impacts that the Commercial Food Waste Ban likely had on colleges and universities while it was still being developed. This suggests that it is insufficient to measure the impact of the ban, or a similar ban, from the date that the ban was enacted as this does not capture the prior impacts connected to the interests and work of MassDEP and other stakeholders in the waste stream. As food waste bans are implemented in other states it is of value to collect data before and during the planning of a ban, as well as after the ban is enacted to fully see the impact.

Appendices

Appendix A – Interview Questions

For Government Agencies and RecyclingWorks Massachusetts

- What have been the results of the Commercial Food Waste Ban since it was implemented in 2014?
    - How much wasted food has been diverted from the waste stream [either in terms of a single business or across an entire sector depending on the interviewee]?
    - How many facilities are there to receive diverted wasted food?
    - What are the economic impacts of the ban [either in terms of a single business or across an entire sector depending on the interviewee]?
- What is the intended enforcement of the Commercial Food Waste Ban and how is it enforced?
    - What is the process of monitoring and enforcing the ban?
        - Who is responsible for enforcement?
        - What policies and resources support enforcement?
    - How many businesses have received notices of noncompliance?
    - What is the assumed compliance for the other banned materials in Massachusetts?
- Where have been successes and challenges of the ban and what might be done to improve its effectiveness?

For Businesses in the Food Waste Stream

- How have your operations regarding food waste changed since the Commercial Food Waste Ban went into effect? [for food waste generators, haulers, and diversion facilities]
    - Were you already implementing food waste diversion practices before the ban was enacted? [for food waste generators]
    - Was your businesses established in anticipation of or because of the ban or was it preexisting? [for diversion facilities and haulers]
    - Did your business focus shift as a result of the ban? [for haulers and diversion facilities]
    - How do you decide what methods of food diversion to pursue? [for food waste generators]
    - Do you feel that the resources and support are available to effectively comply with the ban? [for food waste generators, haulers, and diversion facilities]

Appendix B - IRB Approval

Tufts UNIVERSITY | Office of the Vice Provost for Research

Title: An Assessment of the Massachusetts Commercial Food Waste Disposal Ban: Implementation and Effectiveness Three Years into the Bab

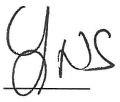
January 25, 2018 | Notice of Action

IRB Study # 1801027 | Status: EXEMPT

PI: Alexandra Raczka
Faculty Advisor: Penn Loh
Review Date: 1/25/2018

The above referenced study has been granted the status of Exempt Category 2 as defined in 45 CFR 46.101 (b). For details please visit the Office for Human Research Protections (OHRP) website at: http://www.hhs.gov /ohrp/humansubjects/guidance/45cfr46.html#46.101(b)

- The Exempt Status does not relieve the investigator of any responsibilities relating to the research participants. Research should be conducted in accordance with the ethical principles, (i) Respect for Persons, (ii) Beneficence, and (iii) Justice, as outlined in the Belmont Report.
- Any changes to the protocol or study materials that might affect the Exempt Status must be referred to the Office of the IRB for guidance. Depending on the changes, you may be required to apply for either expedited or full review.

IRB Administrative Representative Initials: 

Social, Behavioral, and Educational Research • Institutional Review Board • FWA00002063
75 Kneeland Street, 6th Floor, Boston, MA 02111 • T: 617.627.8804 • E: SBER@tufts.edu

Bibliography

110 U.S. Congress §3011 (1996)

23 R.I. Gen. Laws §18.9 (2016)

A Growing List of Food Waste Bans Across America. *Spoiler Alert Blog*, December 9, 2016, http://blog.spoileralert.com/food-waste-bans.

About Us. Boston Area Gleaners. No date. http://www.bostonareagleaners.org/about-us.html.

About Us. Rescuing Leftover Cuisine. Last modified 2018. https://www.rescuingleftovercuisine.org/.

After One Year, Mass. Commercial Food Waste Disposal Ban Gets Results. Center for EcoTechnology. Last modified October 6, 2015. https://www.cetonline.org/after-one-year-mass-commercial-food-waste-disposal-ban-gets-results/.

Air Emissions from MSW Combustion Facilities. United States Environmental; Protection Agency Web Archive. Last updated March 29, 2016. https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/airem.html.

Animal Feed. ReFED. n.d. http://www.refed.com/solutions/animal-feed.

Around Campus. UMass Dining UMass Amherst. No date. http://umassdining.com/locations-menus/around-campus.

Basic Information about Anaerobic Digestion (AD). United States Environmental Protection Agency. October 3, 2016. https://www.epa.gov/anaerobic-digestion/basic-information-about-anaerobic-digestion-ad.

Beling, Christine (Project Engineer, Assistance and Pollution Prevention Unit, Environmental Protection Agency, Region 1), interviewed by Alexandra Raczka over phone, October 19, 2017.

--- interviewed by Alexandra Raczka over phone, March 23, 2018.

Bilsens, Linda. "Rhode Island – Food Waste Recycling Requirements." *Institute for Local Self-Reliance*. April 22, 2016. https://ilsr.org/rule/food-scrap-ban/rhode-island-food-waste-recycling/.

Blazek, Kellian et al. "Tax Deduction for Food Donation." April 2016. https://www.chlpi.org//wp-content/uploads/2013/12/Food-Donation-Fed-Tax-Guide-for-Pub-2.pdf.

Boland, Claire, "Environmental and Economic Benefits of Food Waste Management," March 2, 2017.

Bowen, Janet. 'Tufts UEP Thesis: Massachusetts Commercial Food Waste Disposal Ban'. Email, 2018.

Bowen, Sean (Agricultural Composting Commissioner, Massachusetts Department of Agricultural Resources), interviewed by Alexandra Raczka over phone, February 12, 2018.

Broad Leib et al. Leftovers for Livestock: A Legal Guide for Using Food Scraps as Animal Feed. August 2016. https://www.chlpi.org/wp-content/uploads/2013/12/Leftovers-for-Livestock_A-Legal-Guide_August-2016.pdf.

BSR, "Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Restaurants." 2014. http://www.foodwastealliance.org/wp-content/uploads/2014/11/FWRA_BSR_Tier3_FINAL.pdf.

CalRecycle . *2014 Disposal-Facility Based Characterization of Solid Waste in California*. 2015. http://www.calrecycle.ca.gov/Publications/Documents/1546/20151546.pdf .

Center for EcoTechnology, "RecyclingWorks in Massachusetts Year End Report: Fiscal Year 2017 (July 2016 – June 2017)," July 2017.

--- "RecyclingWorks in Massachusetts Year End Report: Fiscal Year 2016 (July 2015 – June 2016)," August 2016.

--- "RecyclingWorks in Massachusetts Year End Report: Fiscal Year 2015 (July 2014 – June 2015)," September 2015.

--- "RecyclingWorks in Massachusetts Year End Report: Fiscal Year 2014 (July 2013 – June 2014)," September 2014.

Christenson, Scott and Isabelle Cozzarelli. "The Norman Landfill Environmental Research Site What Happens to the Waste in Landfills." *U.S. Geologic Survey*. August 2003. http://archive.chej.org/wp-content/uploads/Landfill-Failures-PUB-0091.pdf.

Commercial Food Waste Disposal Ban. Energy and Environmental Affairs. Last modified 2017, http://www.mass.gov/eea/agencies/massdep/recycle/reduce/food-waste-ban.html.

Commercial Organics Recycling Law Information & Guidance for Food Residual Generators. Connecticut Department of Energy & Environmental Protection. Last modified January 2017. http://www.ct.gov/deep/cwp/view.asp?a=2718&q=552676&deepNav_GID=1645.

Comply with the Organics Waste Ban. RecyclingWorks Massachusetts. Last modified, 2017, https://recyclingworksma.com/commercial-organics-waste-ban/.

Cox, Andrew (Director of Dining Services, Smith College), interviewed by Alexandra Raczka over phone, March 2, 2018.

Cuéllar, Amanda and Michael Webber. "Wasted Food, Wasted Energy: The Embedded Energy in Food Waste in the United States." *Environmental Science & Technology*, August 15, 2010. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2922696/.

Ellyn, Claudine. 'Follow-up'. Email, 2018.

Ellyn, Claudine (Sustainability and Environmental Health and Safety Officer, Massachusetts College of Art and Design), Howard LaRosee (Executive Director of Facilities Planning, Massachusetts College of Art and Design), Kory Laznick (Director of Dining Services, Massachusetts College of Art and Design, Wentworth Institute of Technology, Massachusetts College of Pharmacy and Health Sciences), interviewed by Alexandra Raczka at Massachusetts College of Art and Design, 621 Huntington Avenue, Boston, MA, March 1, 2018.

Fischer, John, *Massachusetts Commercial Food Scraps Disposal Ban – One-Year Milestone*. EPA Sustainable Materials Management Webinar, November 2015.

Fischer, John. 'Tufts UEP Thesis: Massachsuetts' Commercial Food Waste Disposal Ban'. Email, 2018.

--- *Massachusetts Organics Progress Report*. Massachusetts Department of Environmental Protection. December 7, 2017.

--- *Massachusetts Waste Disposal Bans*. Retail Sustainability & Environmental Compliance Conference 2016. 2016. https://www.rila.org/events/conferences/retailsustainability/2016Presentations/2016%20Presentations%20Library/Waste%20Ban%20Awareness_%20Fischer.pdf.

--- (Branch Chief of Commercial Waste Reduction and Waste Planning, Massachusetts Department of Environmental Protection), interviewed by Alexandra Raczka over phone, October 16, 2017.

--- interviewed by Alexandra Raczka at Massachusetts Department of Environmental Protection, 1 Winter Street, Boston, MA, February 1, 2018.

Florio, Brittany (Senior Sustainability Coordinator, UMass Auxiliary Enterprises, University of Massachusetts Amherst), interviewed by Alexandra Raczka over phone, February 27, 2018.

Food Recovery Challenge. United States Environmental Protection Agency. January 5, 2018. https://www.epa.gov/sustainable-management-food/food-recovery-challenge-frc#what.

Food Recovery Hierarchy. United States Environmental Protection Agency. February 19, 2017. https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy.

Food Rescue Programs. Food for Free. Last modified 2017. http://www.foodforfree.org/food-rescue-programs.

Food Waste Estimation Guide. RecyclingWorks Massachusetts. n.d. https://recyclingworksma.com/food-waste-estimation-guide/.

Food Waste. RecyclingWorks Massachusetts. n.d. https://recyclingworksma.com/how-to/materials-guidance/food-waste-2/.

Frequently Asked Questions. United States Department of Agriculture. N.D. https://www.usda.gov/oce/foodwaste/faqs.htm.

Guiney, Michelle Lee. 'MA Waste Bans – Organics – School Thesis'. Email, 2018.

Hladky, Gregory. "Connecticut's Campaign to Cut Food Waste." *Hartford Courant,* July 25, 2016. http://www.courant.com/business/hc-food-waste-efforts-20160725-story.html.

Hongoltz-Hetling, Matt. "Few in Vt. Using Food Scraps Bin." *Valley News*. August 15, 2017. http://www.vnews.com/New-Composting-Requirements-in-Vermont-11860516.

Household Income: 2016. U.S. Census Bureau. Last modified September 2017. https://www.census.gov/content/dam/Census/library/publications/2017/acs/acsbr16-02.pdf.

How to Prevent Wasted Food through Source Reduction. United States Environmental Protection Agency. Last modified August 25, 2016. https://www.epa.gov/sustainable-management-food/how-prevent-wasted-food-through-source-reduction.

ICF. "Massachusetts Commercial Food Waste Ban Economic Impact Analysis," December 2016, http://www.mass.gov/eea/docs/dep/recycle/priorities/orgecon-study.pdf.

Industrial Uses for Wasted Food. United States Environmental Protection Agency. December 12, 2017. https://www.epa.gov/sustainable-management-food/industrial-uses-wasted-food.

Jones, Carol Adaire, "Organics Disposal Bans And Processing Infrastructures," *BioCycle*, September 2017.

Kaplan, Susan, "Massachusetts Food Waste Ban Gains Broad Acceptance," *NPR*, November 4, 2014, http://www.npr.org.

Kerr, Emma (Campus Sustainability Coordinator, Smith College), interviewed by Alexandra Raczka over phone, February 27, 2018.

Leibrock, Amy, "Are Food Waste Bans Working?," *Sustainable America*, January 11, 2017, http://www.sustainableamerica.org/blog/are-food-waste-bans-working/.

Levis, James and MA Barlaz. "What is the most environmentally beneficial way to treat commercial food waste?." *Environmental Science and Technology* 45 no. 17 (2011): 7438-7444.

Macaluso, Lorenzo (Director of Client Services, Center for EcoTechnology), interviewed by Alexandra Raczka over phone, February 13, 2018.

Mandatory Commercial Organics Recycling (MORe). CalRecycle. Last modified May 9, 2017. http://www.calrecycle.ca.gov/Recycle/Commercial/Organics/.

Mapping the Largest Sources of Food Waste in Massachusetts. *Spoiler Alert Blo*g, March 7, 2015, http://blog.spoileralert.com/food-waste-massachusetts?__hstc=192189557.695e006221dc69078eeec5d055f23853.1506908809505.1506908809505.1506908809505.1&__hssc=192189557.1.1506908809505&__hsfp=4019304804.

Martin, Adam (Farm Owner, Martin's Farm), interviewed by Alexandra Raczka at Martin's Farm, 341 Plain Road, Greenfield, MA, March 8, 2018.

Massachusetts Colleges. College Simply. N.d.
http://www.collegesimply.com/colleges/massachusetts/.

Massachusetts Department of Environmental Protection. *Commercial Organic Materials Waste Ban Guidance for Businesses, Institutions, and Haulers*. Boston, MA, 2016.
https://www.mass.gov/files/documents/2016/08/mz/orgguid.pdf.

--- *2016 Solid Waste Date Update*. 2018.
https://www.mass.gov/files/documents/2018/02/13/16swdata.pdf.

--- "Fact Sheet Food Waste Composting." Boston, MA, 2015.
https://www.mass.gov/files/documents/2016/08/ni/organics.pdf.

---*Food Waste Generators in Massachusetts*. 2011.
https://www.mass.gov/files/documents/2017/12/14/foodmap.pdf.

--- *Massachusetts 2010-2020 Solid Waste Master Plan*. Boston, MA: 2013.

--- *MassDEP Organics Study and Action Plan*. Boston, MA: 2017.

--- *Overview: Solid Waste Management in Massachusetts*. Boston, MA, n.d.
http://www.mass.gov/eea/docs/dep/recycle/solid/swminma.pdf.

--- *Revised Guidance for Solid Waste handling and Disposal Facilities on Compliance with MassDEP's Waste Bans*. Boston, MA, 2014.
https://www.mass.gov/files/documents/2016/08/xh/wbguid.pdf.

--- *Site Assignment Regulations for Solid Waste Facilities*. Boston, MA, n.d.
http://www.mass.gov/eea/docs/dep/service/regulations/310cmr16.pdf.

--- *Sites Accepting Diverted Food Waste.* 2017.
https://www.mass.gov/files/documents/2017/12/13/fdcomlst.pdf.

Michael Cahill (Director, Division of Animal Health, Massachusetts Department of Agricultural Resources), interviewed by Alexandra Raczka over phone, February 13, 2018.

Montague, Peter (Farm Owner, Bridgmont Farm), interviewed by Alexandra Raczka over phone, March 5, 2018.

Mugica, Yerina. "Food to the Rescue: Vermont's Universal Recycling Law." *Natural Resources Defense Council*. October 24, 2017.
https://www.nrdc.org/resources/vermonts-universal-recycling-law.

O'Rourke, Scott (Director of Dining, Wheaton College, Aramark), interviewed by Alexandra Raczka over phone, February 27, 2018.

Our Work. Lovin' Spoonfuls. No date. https://lovinspoonfulsinc.org/what-we-do/our-work/.

Overview of Greenhouse Gases. United States Environmental Protection Agency. Last modified April 14, 2017. https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Pepi, John (General Manager, Office of Waste Management, Moving, and Surplus, University of Massachusetts Amherst), interviewed by Alexandra Raczka over phone, February 21, 2018.

Plante, Brian (Owner, Plante Brothers Farm), interviewed by Alexandra Raczka over phone, March 5, 2018.

Platt, Brenda. "Connecticut – Organics Recycling Mandate." *Institute for Local Self-Reliance*. April 15, 2015. https://ilsr.org/rule/food-scrap-ban/connecticut-organics-recovery/.

Quick Facts. Massachusetts College of Art and Design. Last modified 2017. https://massart.edu/quick-facts.

Quick Facts. United States Census Bureau. Last modified 2017. https://www.census.gov/quickfacts/fact/table/VT,RI,MA,CT,CA,US/PST045217.

RecyclingWorks Massachusetts. "Food Waste Diversion Case Study Massachusetts College of Art and Design." RecyclingWorks Massachusetts. Last modified 2016. https://recyclingworksma.com/wp-content/uploads/2016/05/MassArt-Written-Case-Study.pdf.

--- "Massachusetts Commercial Organics Waste Disposal Ban," N.D., https://recyclingworksma.com/wp-content/uploads/2013/07/Learn-More.pdf.

--- *Massachsuetts Business Recycling Efforts Increase in 2013: Many Businesses and Institutions Already Comply with 2014 Food Waste Disposal Ban*, 2013.

Reduce Wasted Food by Feeding Animals. United States Environmental Protection Agency. March 8, 2017. https://www.epa.gov/sustainable-management-food/reduce-wasted-food-feeding-animals.

Reduce Wasted Food by Feeding Hungry People. United States Environmental Protection Agency. Last modified December 12, 2017. https://www.epa.gov/sustainable-management-food/reduce-wasted-food-feeding-hungry-people.

Reducing the Impact of Wasted Food by Feeding the Soil and Composting. United States Environmental Protection Agency. Last modified March 20, 2017. https://www.epa.gov/sustainable-management-food/reducing-impact-wasted-food-feeding-soil-and-composting.

ReFED. A Roadmap to Reduce U.S. Food Waste by 20 Percent. 2016. https://www.refed.com/downloads/ReFED_Report_2016.pdf.

Resident Population Data. United States Census Bureau. Last modified n.d.https://www.census.gov/2010census/data/apportionment-dens-text.php.

Resources for Food Donation in Massachusetts. Center for Health Law & Policy Innovation; Harvard Law School. Last modified 2017. https://www.chlpi.org/food-law-and-policy/resources-for-food-donation-in-massachusetts/.

Rosengren, Cole, "Massachusetts commercial food waste ban has generated $175M in economic activity," December 22, 2016, http://www.wastedive.com.

--- "Update: New Jersey Gov. Christie passes bill to halve food waste by 2010." *Waste* Dive. July 24, 2017. https://www.wastedive.com/news/update-new-jersey-gov-christie-passes-bill-to-halve-food-waste-by-2030/438156/.

Serreze, Mary. "Massachusetts reduces waste, hauls trash out-of-state as landfills close." *MassLive*. March 20, 2017. http://www.masslive.com/news/index.ssf/2017/03/report_massachusetts_solid_was.html

Shafer, Chris. *Organic Waste Management Rhode Island*. Northeast Waste Management Officials' Association Compost Presentation. 2017. http://www.newmoa.org/events/docs/264_232/compostpresetationchris2017amended050317.pdf.

Smith at a Glance. Smith College. Last modified 2018. https://www.smith.edu/about-smith/smith-glance.

Spiegel, Jan Ellen. "Recycling food waste in Connecticut: Slow as molasses." *The CT Mirror*, April 11, 2016. https://ctmirror.org/2016/04/11/recycling-food-waste-in-connecticut-slow-as-molasses/.

Spoiler Alert. “A Beginner’s Guide to Food Waste.” 2017.

Sustainability. College of Fenway. Last modified 2018. https://new.dineoncampus.com/cof/sustainability.

Sustainable Management of Food. Environmental Protection Agency. Last modified August 23, 2017. https://www.epa.gov/sustainable-management-food.

The Basics. Wheaton College. No date. https://wheatoncollege.edu/about-wheaton-college/basics/.

Thompson, Matthew (Culinary Director, Higher Education, Aramark), interviewed by Alexandra Raczka over phone, February 20, 2018.

UMass at a Glance. University of Massachusetts Amherst. Last modified 2018. https://www.umass.edu/gateway/about/umass-glance.

United States Environmental Protection Agency Archive. *Source Reduction* WARM Version 13. 2015. https://www3.epa.gov/warm/pdfs/Source_Reduction.pdf.

United States Environmental Protection Agency, *Feeding Animals – The Business Solution to Food Scraps*. 2015. https://www.epa.gov/sites/production/files/2015-08/documents/rutgers.pdf.

--- *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012*. 2015. https://www.epa.gov/sites/production/files/2015-09/documents/2012_msw_fs.pdf.

--- *Volume to Weight Conversion Factors*. 2016. https://www.epa.gov/sites/production/files/2016-04/documents/volume_to_weight_conversion_factors_memorandum_04192016_508fnl.pdf.

Universal Recycling law Timeline. Vermont Department of Environmental Conservation. No date. http://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/Universal-Recycling/Timeline-factsheet_CURRENT.pdf.

Vermont’s Universal Recycling law Status Report. Vermont Department of Environmental Conservation. Last modified December 2016.

http://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/Universal.Recycling.Status.Report.Dec_.2016.pdf.

Vermont's Universal Recycling Law. Vermont Department of Environmental Conservation. No date. http://dec.vermont.gov/waste-management/solid/universal-recycling.

Waste Management (n.d.). *WM CORe, Converting Boston Waste to Clean Renewable Energy* [handout]. (Available from Michelle Lee Guiney, Waste Management New England).