# Climate Change and the Pittsburgh Urban Food System


**Department of Engineering and Public Policy**

**Department of Social and Decision Sciences**

**Carnegie Mellon University**

**Pittsburgh, PA 15213**


**January 2020**

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## **Disclaimer and Explanatory Note**

This report is the product of a Carnegie Mellon University (CMU) undergraduate research project, in which students from several academic disciplines combine their talents to explore a technology-intensive policy issue. For one semester, the students conducted research, and then presented their results to an external Review Panel under the direction of CMU faculty and graduate student managers.

A draft of this report was submitted to the Review Panel on December 5, 2019. This final version reflects additional changes made in response to comments from the Review Panel and the faculty. However, this report has not been critically reviewed by experts in the field at the level required for peer-reviewed research publications.

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# Project Participants

This is a joint study conducted by students of the Department of Engineering and Public Policy (EPP), the Department of Social and Decision Sciences (SDS) and the Heinz College (HC) at Carnegie Mellon University (CMU) for the Fall semester of 2019 under the classes 19-452: EPP Projects; 88-452: Policy Analysis Senior Projects; and 90-719: Physical-Technical Systems. Most students are pursuing a double-major degree jointly with another department or program.[1]

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[1]Other programs listed are: CEE= Civil & Environmental Engineering; EHPP = Ethics, History & Public Policy; IS (DC) = Information Systems (Dietrich College); ME = Mechanical Engineering; MSE = Materials Science & Engineering; PPM = Public Policy & Management; and STPP = Science, Technology & Public Policy program.

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The faculty, project managers, and students would like to thank the members of the Review Panel for their time, effort, and feedback on this report.

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# Executive Summary

Recent scientific studies have underscored the urgency of reducing emissions of "greenhouse gases" (GHGs) from human activities—principally carbon dioxide, methane and nitrous oxide—to avoid the most dangerous impacts of global climate change resulting from the accumulation of GHGs in the atmosphere. Studies also show that a major contributor to the GHG emissions from human activities is the production and consumption of food. Reducing GHG emissions from the urban food system is a major goal of the Climate Action Plan being developed by the City of Pittsburgh. To understand the potential for reducing emissions from this sector, this report quantifies the carbon footprint of the urban food system of Allegheny County, Pennsylvania—encompassing the City of Pittsburgh and surrounding municipalities—and recommends policy directions that could reduce that footprint.

We estimate that Allegheny County residents currently purchase approximately 1.25 million metric tons (tonnes) of food per year (including beverages), or an average of one tonne per year per resident of the county. Overall, we find that about 27% of the food entering the county is discarded as waste, mainly from the retail, residential and food services sectors. We further estimate that the county's food system currently produces approximately 3.7 million tonnes per year of $CO_2$ equivalent ($CO_2$-eq) emissions of GHGs, or about 3.1 tonnes $CO_2$- eq per year per resident of Allegheny County. Figure ES-1 depicts how these emissions are distributed among incoming food types, and across the Allegheny County food distribution system involving wholesale and retail suppliers of food to consumers in the residential sector and the food services sector (including restaurants, cafeterias, and other food providers).

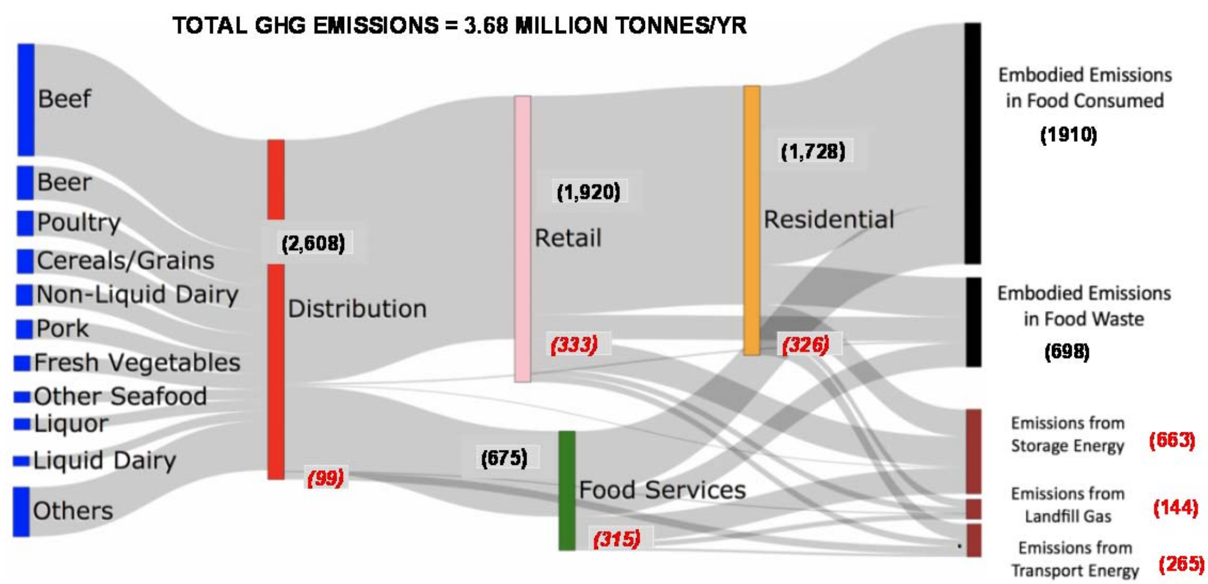


*Figure ES-1: Greenhouse Gas Emissions for the Allegheny County Food System. All values are in 1,000 tonnes $CO_2$-eq/ yr). Numbers in black are embodied emissions from food production and packaging; values in red are total additional emissions from landfills and energy used for food transport and storage.*

The majority (71%) of total emissions are GHGs embodied in the food brought into the county as a result of emissions in the production, processing, and packaging of food in agricultural regions and production facilities elsewhere. Of the food entering AC, the consumption of beef results in the largest GHG emissions, even though the quantity of beef entering the county is modest. In general, meat embodies much large GHG emissions per kilogram of product relative to non-meat items, with beef having the largest overall carbon footprint. The remaining 29% of GHGs shown in Figure ES-1 arise locally from the use of energy needed for food transportation and storage, as well as from food waste decomposing in landfills. The energy required to store and sell food in AC constitutes about 18% of total GHG emissions. Much of this energy is electricity used for refrigeration in the supply chain as well as in retail stores, food service outlets, and residences. Food-associated transportation results in about 7% of total GHG emissions, more than half of which is due to consumer trips to retail stores and food service establishments. The remaining transport emissions arise from bulk deliveries to wholesale and retail outlets (mainly by truck), as well as from the transport of food waste to landfill disposal sites. GHG emissions from landfill gases not captured for energy production account for an additional 4% of total food-related GHGs in the county.

Figure ES-1 also provides insights on methods to reduce GHG emissions. The right-hand side of the diagram shows that nearly a quarter of all emissions arise from food waste (including both embodied emissions and emissions from landfill operations). Thus, actions and policies to reduce food waste can have a large impact. Redirecting food destined for the landfill to alternative uses, preferably for feeding food-insecure individuals, has both GHG and societal benefits. AC does have innovative non-profit organizations, such as 412 Food Rescue and the Greater Pittsburgh Community Food Bank, that undertake such activities, but expanded programs of this kind are needed. Other policies, such as waste reduction incentives for households and food service establishments, and rethinking the current "best if used by" labeling system, also can reduce waste and its associated GHG emissions. Given the large amount of $CO_2$-eq emissions embodied in the production and processing of food, finding ways to avoid the production of food destined for waste can substantially reduce the overall carbon footprint of the Allegheny County food system. Ultimately, wasted food is an implicit tax on the price of food, so policies designed to eliminate waste can reduce this tax burden and provide an economic benefit to consumers and suppliers in the county.

Another 25% of total GHG emissions arise from the consumption of energy used to transport and store food. The transportation sector relies heavily on trucks. Here, wholesalers and industrial food distributors have strong economic incentives to maximize efficiency and minimize cost. While emissions from truck transport can be reduced by increased use of locally-sourced food, further study is needed to assess potential offsetting GHG impacts of food production methods. We further found that a large part of transportation-related emissions arise from consumer trips by automobile to purchase food in retail stores and food service establishments. Thus, the increased use of well-implemented delivery services could reduce these consumer-driven emissions.

We also found that the current stock of refrigeration equipment in the county in the food services, retail, and residential sectors tends to be energy inefficient due to age, maintenance, sizing, and location. Thus, policies addressing these issues could reduce these energy-associated emissions. Since most of the energy required for food storage is in the form of electricity, state and national efforts to decarbonize the electric power grid can further help GHG-reduction efforts at the city and county levels.

Finally, since the preponderance of GHG emissions are embodied in the production of foods that are consumed, shifting diets away from beef-intensive meals can substantially reduce the embodied GHG content of the Allegheny County food system. We estimate, for example, that if 10% of medium meat-eaters (the predominant diet in Allegheny County) were to become vegetarians, 78,000 tonnes of $CO_{2,}$-eq emissions would be saved each year. Additional policy options to reduce GHG emissions from the county food system are elaborated in the body of the report.

# Chapter 1: Introduction

The purpose of this report is to characterize and quantify the carbon footprint of the urban food system associated with the city of Pittsburgh, Pennsylvania, and its surrounding region captured by Allegheny County. In addition, we develop policy recommendations to reduce greenhouse gas (GHG) emissions of this urban food system. To do so, we first examine the sources, types, and quantities of food-related GHG emissions arising in the system as incoming food moves throughout the key sectors tied to the Allegheny County food system. Based on this analysis, strategies and policy recommendations for reducing GHG emissions are presented.

## 1.1 Motivation and Background

The widespread effects of climate change are intensifying and threaten the world's food supply. In 2019, the Intergovernmental Panel on Cleimate Change (IPCC) Special Report stated that climate change threatens the four pillars of food security: availability, access, utilization, and stability. Further, Co-Chair of the IPCC Working Group III, Priyadarshi Shukla, stated "Food security will be increasingly affected by future climate change through yield declines—especially in the tropics—increased prices, reduced nutrient quality, and supply chain disruptions" (IPCC, 2019).

Moreover, the food system itself is a major contributor of anthropogenic GHG emissions, producing between 19-29% of all GHG emissions (Vermuelen, et al., 2012). Agricultural production accounts for 80-86% of the GHG emissions in the food sector globally, or roughly 15-25% of the total share of anthropogenic GHG emissions. In addition, GHGs are also emitted from the packaging, transportation, storage, and waste associated with the food system.

The *2017 Pittsburgh Climate Action Plan* recognized the importance of reducing GHG emissions from the food sector. This reduction is also consistent with Pittsburgh's participation in the *100 Resilient Cities* initiative and the *Milan Urban Food Pact*. The *100 Resilient Cities* program, sponsored by the Rockefeller Foundation, began in 2013 and provides funding for cities to address various issues, including food systems, that could reduce a city's resilience. Though the formal program concluded in July 2019, the Foundation continues to fund projects that further the resilience initiatives in member cities (100 Resilient Cities, 2019). The *Milan Urban Food Pact* is an international pact signed by 206 cities at Expo 2015, with the purpose of "tackling food-related issues at the urban level" (MUFPP n.d.). The *Pittsburgh Climate Action Plan* addresses several goals related to reducing GHG emissions in the food sector, including promoting sustainable diets, reducing food waste, and supporting local and regional food sources.

## 1.2 Region of Interest

A first step to understanding the urban food system is to have a well-defined geographic region of interest. Various regions were considered, ranging from the City of Pittsburgh to larger entities such as the county that includes Pittsburgh (Allegheny County) or even the multi-county region comprising southwest Pennsylvania. For the purpose of the analyses that follow, the geographic scope of this report is Allegheny County (AC).

AC incorporates the greater Pittsburgh region, which is relevant given the interconnected nature of Pittsburgh's urban food system. The county covers 1,930 $km^2$, and as of the 2010 census had 1,223,348 residents in 537,150 households. (The City of Pittsburgh has 305,704 residents.) AC is governed by a distinct legislative body (unlike alternative definitions of a region such as statistical metropolitan areas, multi-county collections, or some fixed distance from the city center). Focusing on the county also facilitates data collection, for example, the AC Health Department inspects all food establishments in AC. Finally, AC incorporates a regional governmental body able to implement potential policy proposals focused on the food system.

## 1.3 Structure of this Report

This report is structured as follows. Chapter 2 provides an overview of urban food systems as well as the science behind determining the carbon footprint of food-related activities. The food system begins with the production and processing of various agricultural products into food (Chapters 2 and 3) that is then transported to, and within, the region (Chapter 4). Next, this food is distributed to either retail or wholesale operations (Chapter 5) that supply food to the ultimate consumers through food services such as restaurants (Chapter 6) or retail outlets selling directly to the home (Chapter 7).

GHGs are emitted at every stage of this system. Food entering the region embodies GHGs associated with the production and processing of food. Anytime food is transported, additional GHGs are generated by the energy required by the vehicles moving the food. Much of the food within the system must be stored under refrigeration, requiring electric energy that also results in GHG production. Finally, throughout the various sectors, food may be wasted, resulting in the production of additional GHGs tied to transporting this food and confining it in the waste stream. Moreover, all of the GHG emissions embodied in the production, processing, transportation, and storage of food destined to be wasted could have been eliminated if such food was never produced.

Each of the above chapters quantifies the relevant amounts of food and energy required in each sector, along with the resulting GHG emissions. Policy options to reduce the GHG emissions arising in each sector also are presented and analyzed. The final Chapter 8 then summarizes the overall conclusions and recommendations of this study.

## 1.4 Chapter 1 References


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# Chapter 2: Urban Food Systems and Their Carbon Footprints

This chapter provides an overview of Allegheny County's urban food system. It also derives a framework for calculating greenhouse gas emissions arising from the food system.

The food system is defined as the "aggregate of all food-related activities and the environments (political, socioeconomic, and natural) within which these activities occur" (Pinstrup-Andersen and Watson, 2011). In this study, these activities include the production, processing, and packaging of food-related items, transportation of these items, the distribution of these items to the retail and wholesale sectors, and final consumption of food by consumers in either the food services or residential sector. Throughout this system food may be wasted and enter various waste streams.

## 2.1 Categories of Food

A key step in understanding the food system is to segregate the various food items into a useful set of categories. Chapter 3 describes the full methodology used for performing such a categorization. Figure 2.1 provides a graphical representation of the food categories used in this report. Food is divided into two main categories: animal and non-animal products, each of which is further subdivided by more specific categories. Finally, the fruit, vegetable, and non-dairy beverage subcategories are further divided to capture key elements tied to greenhouse gas impacts.

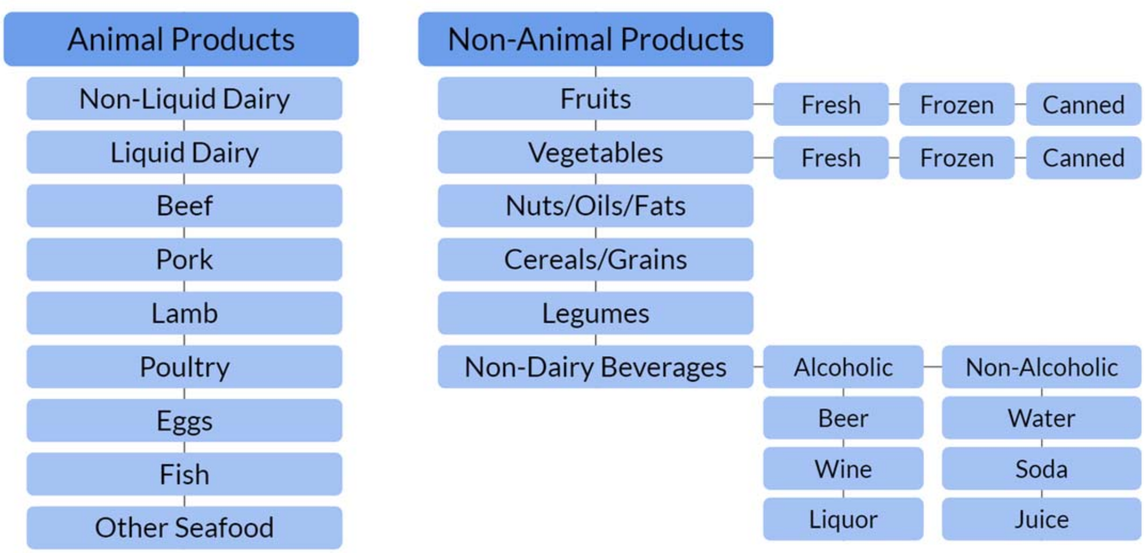


*Figure 2.1: Food Categories Used in this Study*

## 2.2 Greenhouse Gas Emission Factors across the Food System Life Cycle

GHGs contribute to what is commonly referred to as the "greenhouse effect," a global phenomenon that alters the Earth's climatic system. Increases in GHGs trap additional heat in the atmosphere, raising global temperatures with the potential to induce severe biological and economic consequences. The Environmental Protection Agency (EPA) cites four specific gases that have a large

GHG effects: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and fluorinated gases (CFC, HCFC, etc.), all of which have varying degrees of "global warming potential" (EPA, 2019a).

Global warming potential (GWP) is a measure of the quantity of heat a unit mass of a given gas can trap over its lifetime relative to a unit mass of $CO_2$, commonly calculated in periods of 20, 100, and 500 years. A GWP for a given gas changes as the timescale increases, except for $CO_2$, whose GWP is 1.0 for all time periods, by definition. The IPCC has refined its methods for calculating the GWP for various gases in its five Assessment Reports from 1992 to 2014. The UN Framework Convention on Climate Change (UNFCCC, 2019) uses the methodology from the Second Assessment Report (SAR), published in 1996, for calculating the GWP. The most commonly used value of GWP is the 100-year value ($GWP_{100}$). When several GHGs are emitted, the mass of each GHG multiplied by its GWP gives the equivalent mass of $CO_2$ that would produce the same instantaneous radiative forcing from injection of those gases into the atmosphere.

Figure 2.2 identifies the major flows of GHG attributable to the AC food system. GHG-emitting activities include the embodied GHG from food produced inside and outside the region, GHGs arising from the energy needed to transport and store food, and GHGs from the disposal of food in landfills and incinerators.

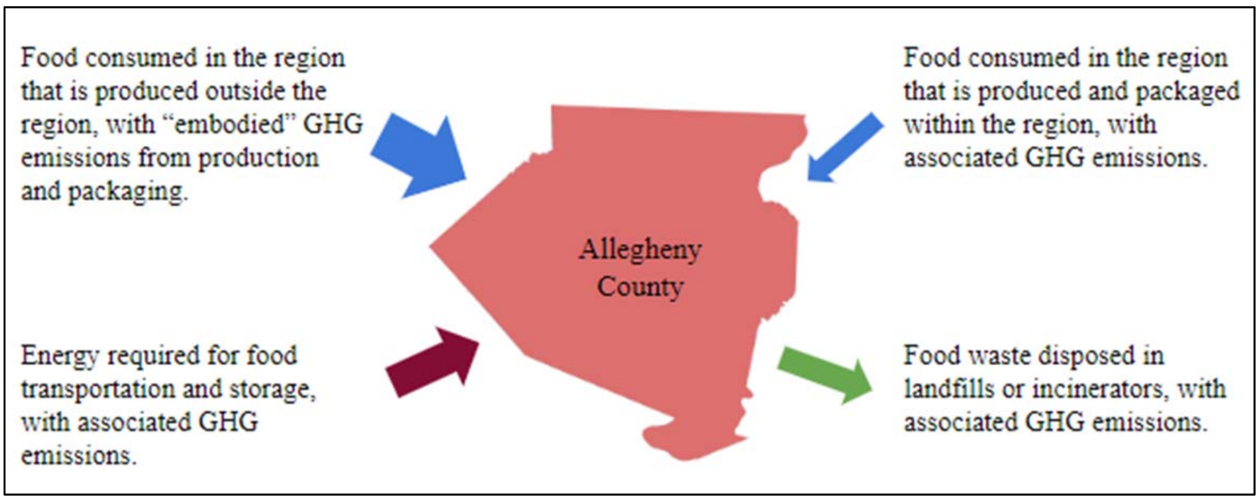


*Figure 2.2: Framework for Analysis of the Pittsburgh-Area Urban Food System*

The four arrows that outline the framework for carbon footprint analysis in Figure 2.2 can be broken down further into more specific processes that each contribute to the larger carbon footprint. These individual processes are interconnected in complex ways as shown in the food system life cycle in Figure 2.3.

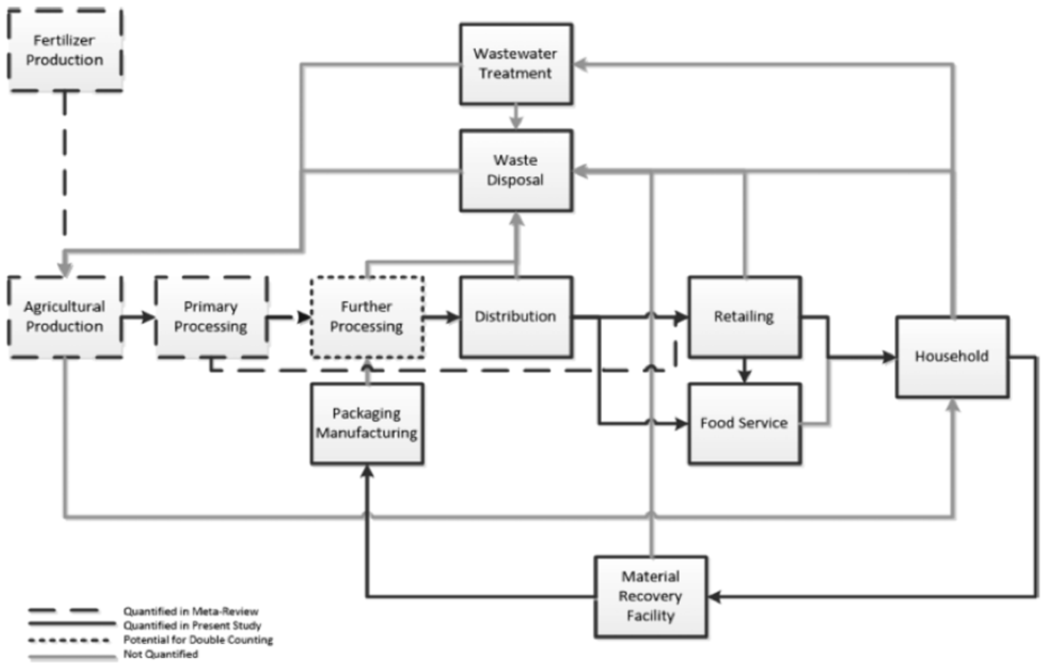


*Figure 2.3: Life Cycle of Food (Mohareb, et al., 2018).*

### 2.2.1 Food Production

GHG emissions generated during the production, processing, and packaging of various food types depends on the various practices of food producers and processors. Extensive data on the GHG emissions from food production and processing can be found in the literature (see, for example, Clune et al., 2017). A summary of emissions factors gathered using data from the appendix of Clune et al. (2017) is shown in Table 2.1. The process of determining these food production emissions factors is discussed in detail in Section 3.2.

*Table 2.1: GHG Emissions Factors from Food Production (Clune et al., 2017)*

| Food Type | Food Category | Emissions Factor (kg $CO_2$-eq/kg product) |
|---|---|---|
| Animal Products | Non-Liquid Dairy | 7.8 |
| | Liquid Dairy | 1.4 |
| | Beef | 28.7 |
| | Pork | 5.8 |
| | Lamb | 27.9 |
| | Poultry | 4.2 |
| | Fish | 4.5 |
| | Other Seafood | 13.1 |
| | Eggs | 3.4 |
| Non-Animal Products | Fresh Fruits (Produce) | 0.7 |
| | Fresh Vegetables (Produce) | 0.8 |
| | Oils/Fats/Nuts | 1.1 |
| | Cereals/Grains | 1.0 |
| | Legumes | 0.8 |
| | Water | 0.1 |
| | Soda | 0.3 |
| | Juice | 0.0 |
| | Beer | 0.7 |
| | Wine | 2.0 |
| | Liquor | 0.1 |
| | Canned Produce | 1.5 |
| | Frozen Produce | 2.3 |

The emissions factors shown in Table 2.1 are in units of kg $CO_2$-eq of GHGs emitted in the production of one kg of each product category. It should be noted that, on average, animal products have emissions factor about ten times higher than those of non-animal products. These emission factors do not consider the GHG emissions tied to the transportation, storage, or waste of these foods after they leave the production and processing facilities.

### 2.2.2 Food Transportation

Food is transported to, and within, AC by various modes of transportation. The GHG emissions from food transportation arise due to the energy required by the vehicles transporting the food. This energy depends on the vehicle type, the distance that must be traveled, and the weight of the food being transported.The emissions factor captures the average fuel efficiency and emissions associated with burning that fuel in different methods of transportation. In some cases where weight was not available, emissions factors in terms of kg $CO_2$-eq/ km traveled were used instead. The emissions factors as seen in Table 2.2 are sourced from the U.S. Environmental Protection Agency (EPA), the Environmental and Energy Study Institute (EESI), and the Environmental Defense Fund (EDF). In Chapter 4, weighted averages of these emissions factors are obtained and used to estimate emissions associated with each segment of transportation.

*Table 2.2: Emissions Factor for Different Vehicle Types*

| Transportation Method | Emission Factor |
|---|---|
| Air (include truck-air) | 1.404 kg/tonne-km[a] |
| Rail | 0.016 kg/tonne-km[a] |
| Truck | 0.111 kg/tonne-km[a] |
| Refrigerated Long Truck | 0.058 kg/tonne-km[b] |
| Dry Long Truck | 0.057 kg/tonne-km[b] |
| Refrigerated Short Truck | 1.70 kg/km[c] |
| Dry Short Truck | 1.41 kg/km[c] |
| Passenger Vehicle | 0.251 kg/km[c] |
| Garbage Truck | 0.154 kg/tonne-km[a] |

[a](Mathers et al., 2014) [b](EESI, 2015) [c](EPA,2018)

### 2.2.3 Food Storage

GHG emissions generated by food storage are caused by the energy used to store food, the scope of which varies between sectors. In the distribution, food services, and residential sectors, this scope included the electricity used to keep food refrigerated or frozen. Additionally, in the distribution sector we expand the scope to include energy for other operational needs, such as electricity for lighting and electricity or gas for heating, since these end-uses were deemed relevant to a distribution center's primary role as a food storage facility. Storage emissions within the transportation and food sources sectors are accounted for in the use of higher emission factors for the refrigerated trucks used to transport produce and other perishable food items.

For all electric end-uses, we used an emissions factor of 0.57 kg of $CO_2$-eq/kWh, which reflects the average carbon intensity of electricity generation in the Pittsburgh region (Carnegie Mellon University, 2018). Multiplying an electric consumption value by this emissions factor results in the GHG emissions of that electricity usage.

For all-natural gas end-uses, we used an emissions factor of 53.12 tonnes of $CO_2$-eq per million cubic feet of natural gas, which reflects the GHG emitted by the on-site combustion of that natural gas (Carnegie Mellon University, 2018), primarily for space heating required for retail food storage facilities.

### 2.2.4 Food Waste

The GHG emissions generated by the disposal of food depend on the disposal method. The EPA is currently studying the GHG generation rates of different food types at disposal sites, but the results are not currently available (Wittstruck, 2019). The EPA's Waste Reduction Model (WARM) (2019a) predicts emission factors from various disposal practices using a common food type. Table 2.1 provides food disposal emission factors, with the first four practices derived using WARM and the last one, animal feed, using Hall's (2016) life-cycle analysis. For each of the emission factors, the avoided emissions from power generation are adjusted to reflect the carbon intensity of the electricity used in the City of Pittsburgh, which is below the national average. Additionally, the landfill emissions factor is composed of a weighted average of waste that is burned for generation and waste that is flared. The respective weights for these processes were adjusted to reflect the Imperial Landfill near Pittsburgh (Carnegie Mellon University, 2018). It is assumed that the practices of this landfill reflect those used by all of the landfills used by AC, which leads to a landfill emission factor of 0.45 tonnes of $CO_2$-eq per tonne of food waste. Details regarding these adjustments are in Appendix A.

*Table 2.1: Post-disposal Greenhouse Gas Emission Factors for Different Disposal Practices*

| Disposal Practice | Emission Factor (tonne $CO_2$-eq / tonne food waste) |
|---|---|
| Landfilling | 0.45 |
| Combustion (waste to energy) | -0.15 |
| Composting | -0.20 |
| Anaerobic Digestion | -0.05 |
| Animal Feed | -0.37 |

Note that four of the disposal practices have negative emission factors, implying a net reduction in GHG emissions. Combustion involves burning waste in a waste-to-energy facility and the GHG emissions associated with this process come from the production of $CO_2$ during combustion. However, these emissions are offset by the avoided emissions of other power generation processes, resulting in a net negative emission factor (U.S. EPA, 2019b). Composting takes food waste and converts it to compost that can supplement nutrient-poor soil. The emissions associated with composting come from running the compost machinery and leaked gas during composting. These emissions are offset by the emissions avoided in the production of traditional fertilizer, and by avoided carbon emissions since the carbon content of the waste is added back into the soil rather than released into the atmosphere (U.S. EPA, 2019b). Anaerobic digestion grinds up the waste and feeds it into a reactor, where the waste is broken down into both compost and biogas. The compost is applied to soil and the biogas is combusted to generate electricity. The sources of emissions in this process are from running the reactor, leaked biogas during digestion, and $NO_x$ emissions after digestates are applied to soil. These emissions are offset by re-capturing some of the carbon, avoiding the use of traditional fertilizer, and avoiding emissions from other power generation processes (U.S. EPA, 2019b).

Finally, the animal feed emissions factor involves food that is diverted to be used as food for livestock, particularly pigs. This pathway has the highest net reduction in emissions. The main source of emissions reduction here is the "feed avoidance credit," which is the offset of emissions avoided from growing and processing traditional animal feed (Hall, 2016).

While all of these practices are available to AC, currently between 94% and 98% of the food waste stream is diverted to landfills with the remainder going to composting (See Appendix A for calculations related to the AC's food-waste disposal profile).

## 2.3 Conclusions

The GHG emissions associated with the urban food system of AC arise in various ways. The creation of food for consumption involves GHG emissions that arise with the production, processing, and packaging of food. Such emissions constitute a large part of the carbon footprint of urban food systems. Food must be transported from its origin to, and within, AC, and the energy used in such transport creates additional GHG emissions. These emissions depend on the mode of transportation, distance that must be traveled, and weight of the food being moved. To avoid premature spoilage, food must often be kept under refrigeration, resulting in additional GHG emissions from the energy (typically electricity) required to cool the food. Finally, wasted food must be disposed of, and the different means of disposal have implications for GHG emissions.

## 2.4 Chapter 2 References


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# Chapter 3: Food Types, Sources and Emissions

This chapter discusses the greenhouse gas emissions associated with the production of food brought into Allegheny County. Food, as defined in this report, includes edible items brought into the AC region for the purpose of human consumption. Prior to consumption, regardless of sector (commercial, residential, wholesale distribution), food must be grown, raised, processed, and packaged. This chapter focuses on the pre-consumption GHG emissions associated with the aforementioned activities.

Different types of food carry different environmental impacts. For example, red meat production is more resource dependent and environmentally harmful than fruit and vegetable production (Tucker, 2018). The analyses in this section intend to provide insight into the total amount of GHG emissions associated with the production of each food type entering AC. This is done in a three step process: for each food category (meat, vegetables etc.) we quantify how much food enters the County, determine the amount of GHG emissions associated with one unit of production (that is, the emissions factor), and multiply the incoming quantity of food by its emissions factor. By summing all of the GHG emissions associated with each food category we can estimate the total GHG emissions embodied by the food entering AC.

## 3.1 Categorizing Food Types

As stated above, "food" in this report is characterized as traditional edible and drinkable items destined for human consumption. This definition encompasses meats, produce, cereals, and alcoholic and non-alcoholic beverages. To appropriately classify food coming into AC, we considered existing food categorizations as well as developed new ones given our goal of quantifying GHG emissions.

Various entities have categorized food in a variety of ways. The United States Department of Agriculture's "MyPlate" initiative categorizes food into five groups: fruits, vegetables, grains, protein, and dairy (USDA, 2019). The National Institute of Health uses seven categories: vegetables, fruits, grains, protein, dairy, oils, and calories for other uses (NIH, 2019). The American Academy of Pediatrics' Healthy Children website uses five food groups: grains; vegetables; fruit; meat, poultry, fish, dry beans, eggs, and nuts; and dairy (AAP, 2018). Although there is some uniformity among these three approaches (specifically in their common categorization of grains, vegetables, fruits, and dairy into their own groups), they differ in how they categorize meat, beans, nuts, oils, and other forms of food.

Given the above, we further disaggregated the above food categories to provide a better way to quantify the different food types entering AC and account for similarities in GHG emissions. Figure 2.1 showed a visualization of our food categories, which were divided into two main groups: animal and non-animals products, as defined earlier. Similarly, fruits and vegetables were further sub-divided by their packaging types (fresh, frozen, and canned), given different GHG emission factors depending on the packaging. Non-dairy beverages include both alcoholic and non-alcoholic beverages. Alcoholic beverages are split into beer, wine, and liquor and non-alcoholic beverages are split into water, juice, and soda.

## 3.2 Quantification of Greenhouse Gas Emissions Factors

Quantifying the total amount of GHG emissions associated with the production of food for AC involves defining emissions factors for each type of food. Clune et al. (2017) compiled extensive data on the GHG emissions associated with the production and processing of different food types using a meta-analysis that drew from hundreds of other studies.

### 3.2.1 Aggregation of Food Types into Categories

Appendix B contains data on each food's name, group and subgroup, GHG emissions factor, and relevant studies. The emissions factor for each food type is given in units of kilograms of $CO_2$ equivalent GHG emitted per kilogram of food produced (kg $CO_2$-eq/kg product). The data in the appendix relies on 1,731 studies across the four main food groups and 223 individual foods. Using this data, we separated the food into categories based on consumer preferences in the United States (thus, items with negligible consumption, such as kangaroo and buffalo meat, were removed).

### 3.2.2 Emission Factor Calculations

After aggregating the 1,731 studies into separate categories based on United States' consumer preferences, the various emission factors for each food type were aggregated using standard statistical measures. From these data, we can identify important factors driving the embodied GHG emissions of various foods.

### 3.2.3 Organic versus Non-Organic Foods

To estimate the impact of organically sourced foods versus inorganic foods, the emissions factors for these two types of food categories were examined. As seen in Appendix B, the number of studies of GHG emissions from organic food is limited, increasing the range of our confidence intervals for these types of food. Table 3.1 presents the data for key organic food groups. Table 3.2 gives the data for non-organic foods.

*Table 3.1: GHG Emissions from Organic Production*

| Food Type | kg $CO_2$-eq/kg product | | | | | Number of Studies |
|---|---|---|---|---|---|---|
| | Median | Mean | Std. Dev. | Minimum | Maximum | |
| Dairy | 9.3 | 12.0 | 7.4 | 7.0 | 21.0 | 3 |
| Milk & Cream | 1.2 | 1.4 | 0.4 | 1.0 | 2.1 | 18 |
| Fruit | 0.3 | 0.3 | 0.1 | 0.2 | 0.5 | 10 |
| Vegetables | 0.4 | 0.5 | 0.3 | 0.1 | 1.5 | 32 |
| Beef | 22.0 | 25.0 | 6.8 | 21.0 | 33.0 | 3 |
| Pork | 5.1 | 5.1 | 0.7 | 4.4 | 5.7 | 4 |
| Lamb | 11.0 | 11.0 | * | 11.0 | 11.0 | 1 |
| Poultry | 6.2 | 5.7 | 1.1 | 3.9 | 6.4 | 5 |
| Eggs | 3.8 | 4.0 | 1.4 | 1.8 | 5.8 | 6 |
| Oils/Fats/Nuts | 2.2 | 2.3 | 1.2 | 1.2 | 3.8 | 4 |
| Cereals/Grains | 1.6 | 1.7 | 1.3 | 0.3 | 3.8 | 5 |
| Legumes | 0.4 | 0.4 | 0.0 | 0.4 | 0.4 | 2 |
| Fish | 3.2 | 3.2 | 1.2 | 2.0 | 4.4 | 3 |
| Shellfish | 13.0 | 13.0 | - | 13.0 | 13.0 | 1 |

* Standard deviation cannot be calculated for only one source.

*Table 3.2: GHG Emissions from Non-Organic Production*

| Food Type | kg $CO_2$-eq/ kg product | | | | | Number of studies |
|---|---|---|---|---|---|---|
| | Median | Mean | Std. Dev. | Minimum | Maximum | |
| Dairy | 8.3 | 7.6 | 4.3 | 1.2 | 25.0 | 54 |
| Milk & Cream | 1.3 | 1.4 | 0.6 | 0.5 | 7.5 | 246 |
| Fruit | 0.4 | 0.7 | 1.1 | 0.2 | 7.7 | 168 |
| Vegetables | 0.5 | 0.9 | 1.0 | 0.1 | 6.1 | 284 |
| Beef | 26.0 | 28.7 | 13.0 | 11.0 | 109.0 | 166 |
| Pork | 5.7 | 5.8 | 1.7 | 2.1 | 12.0 | 124 |
| Lamb | 26.0 | 27.9 | 12.0 | 10.0 | 57.0 | 56 |
| Poultry | 3.7 | 4.1 | 1.8 | 1.1 | 10.0 | 106 |
| Eggs | 3.2 | 3.3 | 1.2 | 1.3 | 6.0 | 34 |
| Oils/Fats/Nuts | 0.8 | 1.0 | 0.6 | 0.3 | 2.5 | 43 |
| Cereals/Grains | 0.6 | 1.0 | 1.1 | 0.1 | 5.7 | 111 |
| Legumes | 0.6 | 0.8 | 0.5 | 0.2 | 2.6 | 39 |
| Fish | 3.5 | 4.5 | 3.7 | 0.8 | 21.0 | 157 |
| Shellfish | 7.8 | 13.1 | 11.0 | 1.9 | 38.0 | 22 |

The above tables compare the $CO_2$-eq per kg of edible food for organic and non-organic production methods. Organic production tends to have lower emissions for the first seven food types listed in the table, while non-organic production has lower emissions for the remaining food types. For example, organically produced fruits have less of a carbon footprint than non-organically produced fruits (0.3 kg $CO_2$kg product versus 0.4 kg $CO_2$-eq/kg product), while non-organic poultry production dominates organic poultry production (3.7 kg $CO_2$-eq/kg product versus 6.2 kg $CO_2$-eq/kg product) in terms of mean GHG emissions.

## 3.3 Estimating Food Quantities

Given the above emission factors, the next step in determining the embodied GHG footprint of the food incoming to AC is to determine the quantity of each food type. One way to quantify incoming food is to obtain data on cargo entering the region from all modes of transportation (truck, rail, airplane, etc.).

### 3.3.1 Transportation Quantities and Freight Analysis Framework Data

As part of a joint effort between the United States' Department of Transportation (DOT) and Department of Commerce (DOC), the Freight Analysis Framework (FAF) provides a registry of the quantities of cargo entering the region of southwest Pennsylvania and neighboring parts of Ohio and West Virginia (DOC, 2012). The FAF breaks down cargo into 43 categories, only eight of which include food as defined above. These eight categories are: 01-Animals and Fish (live); 02-Cereal Grains (includes seed); 03-Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products); 04-Animal Feed, Eggs, Honey, and Other Products of Animal Origin; 05-Meat, Poultry, Fish, Seafood, and Their Preparations; 06-Milled Grain Products and Preparations, and Bakery Products; 07-Other Prepared Foodstuffs, Fats, and Oils; and 08-Alcoholic Beverages and Denatured Alcohol (DOC, 2012). Although much of the food in the previously defined food groups are represented in the FAF categories, not all of the categories can be easily matched. Moreover, the FAF does not give disaggregated quantities, for example, one cannot separate the quantity of eggs and honey from the amount of animal feed in category 04—the only data available to the project is tonnes of cargo per category.

Using the FAF categories that include food we can estimate the amount of food entering AC by prorating the population of AC to that of the other regions included in the FAF data. More information on this procedure can be found in Chapter 4. Doing so yields an estimate of approximately 3.9 million metric tonnes of food *entering* the county per year. This value must be adjusted by removing food exports captured by the FAF. For the category Cereal Grains, the net amount of food was negative, suggesting that much of the food produced within that category is sourced within the multi-county FAF region that includes AC. Since the surrounding counties are more rural and more agricultural than AC, the use of a population-weighted allocation likely overestimates exports from AC. Thus, instead of using this negative value, we found the average percent of net food imports over imports (46%) and multiplied that value by the imported quantity of category 02. Doing so resulted in an estimate of 1,180,000 metric tonnes of food being consumed in AC each year. Further calculations can be found in Appendix B.

### 3.3.2 Estimating Packaging Weight

The FAF data reports the total shipment weight, and thus it includes the weight of packaging. The food estimates derived in the previous discussion do not include the weight of packaging. To estimate the weight of packaging, we used a life-cycle assessment of food-packaging systems conducted in the UK that estimated that around half of total packaging is food-related (Vignali, 2016). We combined this with an estimate (EPA, 2019) of the total weight of plastic packaging generated in the United States during 2017 and total weight of all food consumed in the United States (FAO, 2013; Non-Alcoholic Drinks, 2019) to estimate that 7.4% of the total transported weight of food is due to packaging. Appendix B discusses these calculations.

### 3.3.3 Estimating Total Food Quantities

An estimate of the quantities of specific food types coming into AC can also be made using FAF data and annual consumption data for the average American. Data from the U.S. Department of Agriculture (USDA) and the Food and Agriculture Organization of the United Nations (FAO) provide the weight of each food item eaten annually by the average American. We assumed that the percent consumption of one food over total diet was equal to the percent imported of one food over total food imports.

To estimate the incoming quantities of food, we took each FAF category and found the total annual consumption weight for all items in that category plus the weight of packaging. For example, for category 05-Meat, Poultry, Seafood, and Their Preparations, we added together the consumption estimates for beef, pork, lamb, poultry, fish, and other seafood along with packaging weight. Then, we found the percent of consumption one food category accounts for within the FAF category. Lastly, we multiplied that percentage by the total weight of the imports for that FAF category to get the imported weight of that food item. A detailed breakdown of this process is provided in Appendix B. Table 3.3 summarizes the calculated quantities of food incoming to Allegheny County, according to FAF data for 2017.

*Table 3.3: Net Food Quantities into Allegheny County in 2017 using FAF Data*

| Food Category | Quantity (tonnes/yr)* | Share of Total (%) |
|---|---|---|
| Non-Liquid Dairy | 20,000 | 1.70 |
| Liquid Dairy | 51,000 | 4.33 |
| Beef | 29,000 | 2.46 |
| Pork | 24,000 | 2.04 |
| Lamb | 300 | 0.03 |
| Poultry | 44,000 | 3.73 |
| Fish | 10,000 | 0.85 |
| Other Seafood | 6,000 | 0.51 |
| Eggs | 18,000 | 1.53 |
| Fresh Fruits | 97,000 | 8.23 |
| Fresh Vegetables | 138,000 | 11.71 |
| Oils/Fats/Nuts | 32,000 | 2.72 |
| Cereals/Grains | 172,000 | 14.60 |
| Legumes | 4,000 | 0.34 |
| Water | 33,000 | 2.80 |
| Soda | 70,000 | 5.94 |
| Juice | 6,000 | 0.51 |
| Beer | 338,000 | 28.69 |
| Wine | 36,000 | 3.06 |
| Liquor | 28,000 | 2.38 |
| Canned Produce | 12,000 | 1.02 |
| Frozen Produce | 10,000 | 0.85 |
| **Total** | **1,180,000** | **100.00** |

*All values rounded to nearest 100 tonnes.

The data in Table 3.3 provides an interesting view of food consumption in AC. Beer represents the largest food item by weight, followed by cereals/grains and fresh vegetables, and fresh fruits, while lamb and legumes represent the lowest weights. Within animal products, most consumption by weight involves liquid dairy, followed by poultry, beef, and pork.

We note that this estimate of 1.18 million tonnes/yr of food consumed in AC differs from the estimate of 1.25 million tonnes derived later in this study using the per capita food quantities consumed in the residential and food services sectors. That latter estimate, based on several sources of national average data, is believed to represent a "best estimate" for purposes of this study. However, to quantify the amounts of different food items we retain the percentage contributions indicated in the last column of Table 3.3 above.

## 3.4 Carbon Footprint of Allegheny County Food Sources

AC's food sourcing carbon footprint was calculated using the emission factors for each food category and the associated incoming food quantities. Using these factors and quantities, we can derive the embodied carbon footprint of the food arriving in AC. Along with being a key element of the overall carbon footprint of the AC urban food system, this data can be used to quantify, say, the impact of changing the overall AC diet on GHG emissions.

Methodologically, each unique food category was first mapped to a FAF category. To find the quantity of food for each category, the ratio of a given category was calculated using the procedure outlined in Subsection 3.3.3. Once these quantities were identified (column 2 of Table 3.4), the emissions factor for each category was identified from the relevant literature. Details of these calculations can be found in Appendix B.

To get the final carbon footprint of AC's food sourcing sector based on the FAF data, we multiplied the quantities of incoming food by each food's emission factor. The carbon footprint of each food item as well as the total carbon footprint of food sourcing is shown in Table 3.4. As shown in the last line of the table, each tonne of food in the county embodies about two tonnes of $CO_2$-eq in its production and processing.

As noted above, the estimate of total food consumed in Allegheny County based on the FAF data is roughly 6% lower than the "best estimate" derived later in this study. Thus, the final estimate of total embodied GHG emissions is proportionally higher than the total shown in Table 3.4, at 2.608 million tonnes $CO_2$-eq per year. Further details are summarized in Chapter 8.

*Table 3.4: Carbon Footprint of Food Brought into Allegheny County based on FAF data*

| Food Category | Food Quantity (tonnes/year) | Emissions Factor (kg $CO_2$-eq/ kg food product) | Carbon Footprint (tonnes $CO_2$ eq) |
|---|---|---|---|
| Non-Liquid Dairy | 20,000 | 7.8 | 156,000 |
| Liquid Dairy | 51,000 | 1.4 | 72,000 |
| Beef | 29,000 | 28.7 | 837,000 |
| Pork | 24,000 | 5.8 | 141,000 |
| Lamb | 300 | 27.9 | 10,000 |
| Poultry | 44,000 | 4.2 | 186,000 |
| Fish | 10,000 | 4.5 | 45,000 |
| Other Seafood | 6,000 | 13.1 | 79,000 |
| Eggs | 18,000 | 3.4 | 61,000 |
| Fresh Fruits | 97,000 | 0.7 | 66,000 |
| Fresh Vegetables | 138,000 | 0.8 | 113,000 |
| Oils/Fats/Nuts | 32,000 | 1.1 | 36,000 |
| Cereals/Grains | 172,000 | 1.0 | 179,000 |
| Legumes | 4,000 | 0.8 | 3,000 |
| Water | 33,000 | 0.1 | 3,000 |
| Soda | 70,000 | 0.4 | 30,000 |
| Juice | 6,000 | 0.7 | 4,000 |
| Beer | 338,000 | 0.7 | 251,000 |
| Wine | 36,000 | 2.0 | 71,000 |
| Liquor | 28,000 | 3.0 | 84,000 |
| Canned Produce | 12,000 | 1.5 | 19,000 |
| Frozen Produce | 10,000 | 2.3 | 22,000 |
| **Total** | **1,180,000** | - | **2,467,000** |

## 3.5 Impact of Food Sources on Other Food System Sectors

Food sourcing is the first stage of the urban food system. Changes in food sources can have critical impacts on the system's overall carbon footprint.

As discussed in Chapter 4, the FAF data suggests that most of the food entering AC comes from outside of the county, often from considerable distances. Naturally, the further the food is travelling to get to the county, the larger the carbon footprint, everything else held equal. Thus, shifting to more local agricultural sources may lessen the carbon footprint, although a more detailed analysis would be required to assess potential tradeoffs associated with other variables such as production methods and transportation efficiency.

The production practices of food, such as organic versus non-organic farming, may also influence the carbon footprint. However, our analysis indicates that there may not be a dominant practice in terms of GHG emissions. For example, depending on the food type, organic farming is sometimes superior to, and sometimes inferior to, non-organic farming in terms of GHG emissions, as shown earlier in Tables 3.1 and 3.2.

"Farm-to-table" has been a popular trend in restaurants, and now this concept has been taken even further as restaurants establish their own farms or form long-term partnerships with existing farms (Dunn, 2018). This trend impacts both the sourcing and transportation sectors, though at the moment, it represents only a small portion of the overall food supply.

## 3.6 Policy Options to Reduce GHG Emissions

The USDA's 2012 Census of Agriculture indicates that the production and processing of food takes place largely outside of AC—the county itself has about 400 farms working 34,000 acres (USDA, 2012). These values are dwarfed by the estimated two million U.S. farms working 900 million acres. Additionally, our research shows that a majority of the food consumed in AC is transported into the county rather than produced within it (DOC, 2012). Thus, local government actions may be limited in its ability to alter GHG-intensive practices from outside agricultural production and food sourcing. Nonetheless, policy options to reduce GHG emissions from food sources do exist that could be implemented at higher levels of government, specifically the state and national levels.

### 3.6.1 Modification of Agricultural Practices

The first policy would promote the development and implementation of regenerative farming. Regenerative farming is a system of best practices that is better for the environment and tries to decrease the release of $CO_2$ into the air by controlling the amount of $CO_2$ in the soil and above ground. The lack of $CO_2$ in the soil due to conventional farming practices might allow such soil to be used as a possible $CO_2$ sink for atmospheric $CO_2$. These practices are not only better for the climate, but also help improve the health of the land and crop yield. A trial study conducted by the Rodale Institute showed that up to 21 giga-tonnes of $CO_2$ can potentially be sequestered through regenerative farming (Rodale Institute, 2019).

There are a few different practices that farms can adopt for regenerative agriculture. For example, no-till farming is the practice of eliminating tilling. This helps stabilize the soil, which decreases soil erosion and runoff, while also increasing the soil's ability to absorb water and sequester $CO_2$. Another regenerative practice is crop rotation, whereby different crops are planted on the same field in subsequent years. Crop rotation improves soil health and carbon sequestration (Rodale Institute, 2019). Organic annual cropping using compost and crop rotation has been shown to sequester 2-6 metric tonnes of carbon per hectare of farmland per year (Toensmeir as cited in Terra Genesis International. n.d.).

The second policy related to changes in agricultural practice is the implementation of biogas systems. Biogas systems use anaerobic digestion to take in animal manure and convert it into biogas and fertilizer that can be used for crops (GLW Energy, n.d.). Using a system like this not only promotes farming and crop growth, but it also can offset some of the non-renewable energy use with biogas generated by the system.

Implementation of the aforementioned policies can be conducted at a state or national level. An incentivized policy, such as short-term loans, could encourage farmers to adopt these practices.

### 3.6.2 Changes in Food Quantities

As shown in Table 3.1, different food types have dramatically different GHG emissions. In general, meat has much higher emissions than, say, fruit or vegetables. Thus, changes in the overall diet of the population to less meat-intensive diets could result in large decreases in food-related GHG emissions. While there are policies that could influence diet at the level of food sources, for example, taxing food items with higher GHG emissions, a more likely policy route is through behavioral changes induced downstream at the level of the food services, retail, and residential sectors. Such policies will be discussed in the subsequent chapters on each of these sectors.

Finally, as will be seen later in the report, food waste is quite common in urban food systems. Food waste emits additional GHGs when it is transported to a disposal site and, once there, when it decomposes. More importantly, if such waste could be avoided in the first place, then the embodied GHGs of producing, processing, transporting, and storing that food, could all be eliminated as well. Given the large amount of GHG emissions tied to these processes, finding ways to avoid the production of food destined for waste would have a significant impact on the overall GHG emissions of an urban food system. This policy will be discussed later.

## 3.7 Chapter 3 References

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# Chapter 4: Transportation Sector Emissions

The transportation of food to, and within, the urban food system causes the emission of greenhouse gases. It is estimated that 7% of the emissions associated with the U.S. food system are due to food distribution and grocery trips (Mohareb et al., 2018). Here we develop our own estimate of the GHG emissions due to food being moved from its point of origin to Allegheny County, as well as the movement of the food once it arrives in the county and is distributed to wholesalers and retailers, the food services sector, and residential customers. Finally, we consider the emissions produced as wasted food is sent for disposal.

The first step in quantifying the emissions associated with food transportation is determining the points of origin and types of food coming into AC. Food, originating from agricultural production and processing operations from around the world, is first transported into the County to local distribution centers. However, the United States Department of Agriculture (USDA) only begins to track the movement of food once it reaches the United States. Thus, transportation associated with, say, cattle raised and processed in another country, is only tracked once the animal products enter the US. Thus, the available data underestimates the actual distance traveled for non-domestic food sources (DOT, 2017).


*Figure 4.1: Transportation in the Food System*

Figure 4.1 outlines the various instances of transportation in the food system. Initially, food from world-wide producers arrives at distribution centers serving AC. The food is then transported from these distribution centers to various food service outlets (such as restaurants and cafeterias) and retail outlets (such as grocery and convenience stores). Next, consumers purchase food by moving between their work or homes and food service and retail outlets. Finally, food can leave the consumption stream at any point in its life cycle as waste to be transported to a disposal site such as a landfill. All of these activities generate transportation emissions. Policy to alter GHG emissions due to transportation can be targeted at any phase of the transportation process. We evaluate such policies according to their potential efficacy, timescale, and feasibility.

## 4.1 Transportation Emissions of Food Imported to Allegheny County

Food quantities entering AC were estimated by retrieving 2017 data from the Freight Analysis Framework (FAF), which is a database of freight movement compiled by the U.S. Department of Transportation. The FAF provides data on freight shipping of food into several different designated shipping areas, which enables a more specific estimate of food flow into the county. The FAF primarily sources its data from the Commodity Flow Survey performed by the Census Bureau, but supplements this information with data from the U.S. Department of Agriculture and NOAA. Shipments are tracked only when the ownership of the shipment changes hands at the destination. Since this provides an incomplete picture of the true origin of some foods, we later supplement and adjust the FAF data with more complete data from a major regional wholesaler.

Freight in the FAF database is categorized according to the standard classification of transported goods (USDC, 2012). The FAF categories relevant to food are:

1. Live Animals and Fish
2. Cereal Grains (including seed)
    a. Wheat, Corn, Rye, Barley, Oats, Grain sorghum, other grains (including rice)
3. Agricultural Products Except for Animal Feeds, Cereal Grains, and Forage Products
    a. Fresh, Chilled, and Dried Fruits and Vegetables; Beans and Seeds
    *b. Seeds for Sowing, Fresh cut Flowers, Raw Cotton*
4. Animal Feed, Eggs, Honey, and Other Products of Animal Origin
    *a. Cereal Straw, Raw hides and skins, Animal feed*
    b. Eggs in the shell, Natural Honey
5. Meat, Poultry, Fish, Seafood, and Their Preparations
    a. Fresh, chilled, frozen, brined Meat and Fish; Meat and Fish Preparations, extracts, and juice
6. Milled Grain Products and Preparations, and Bakery Products
    a. Pasta, Baked products
7. Other Prepared Foodstuffs, Fats, and Oils
    a. Dairy, Junk Food, Oil, Sweets, Soda
8. Alcoholic Beverages and *Denatured Alcohol*

Note that the FAF breaks shipments into various categories that are often comprised of unusual mixes of goods. For example, the italicized items in the above list are not for human consumption. Yet, the FAF categorizes eggs and honey—items important to the local human food system—with non-human food items such as animal feed.

The FAF designated shipping area that includes AC is the multi-county statistical area of Pittsburgh-New Castle-Weirton shown in Figure 4.1. To adjust the data to AC, it was assumed that the received freight was proportional to population. The 2010 census population of the combined statistical area was 2,625,053. The population of AC was 1,223,000, or 46.59% of the Pittsburgh-New Castle-Weirton region. Therefore, all FAF weight data was multiplied by 0.4659 to get an estimate of the quantity of food coming into AC (Census, 2012).

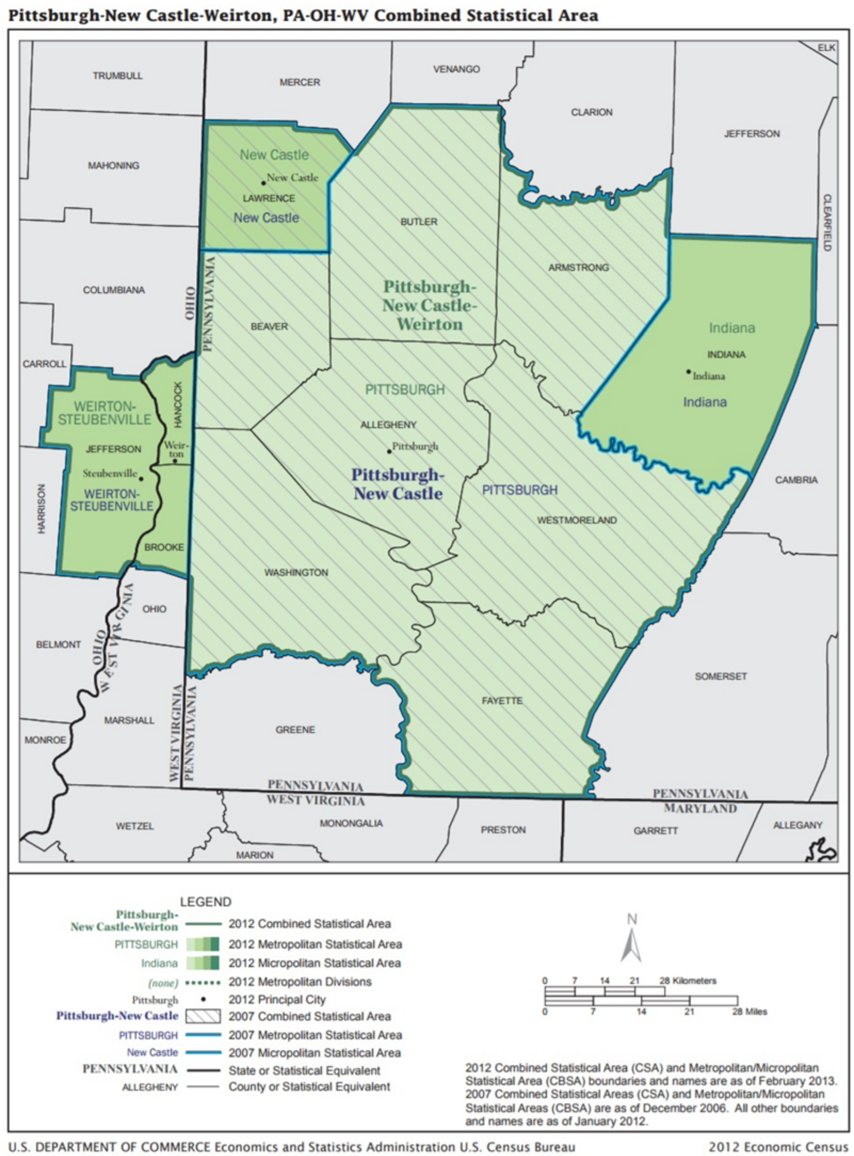


*Figure 4.2: Map of Pittsburgh-New Castle-Weirton Statistical Area (Census, 2012)*

### 4.1.1 Methodology for Estimating Emissions

The emissions of interest are those associated with the transportation of food between the various routes outlined in Figure 4.1. Emissions estimates are quantified by using the equation given in Figure 4.3.

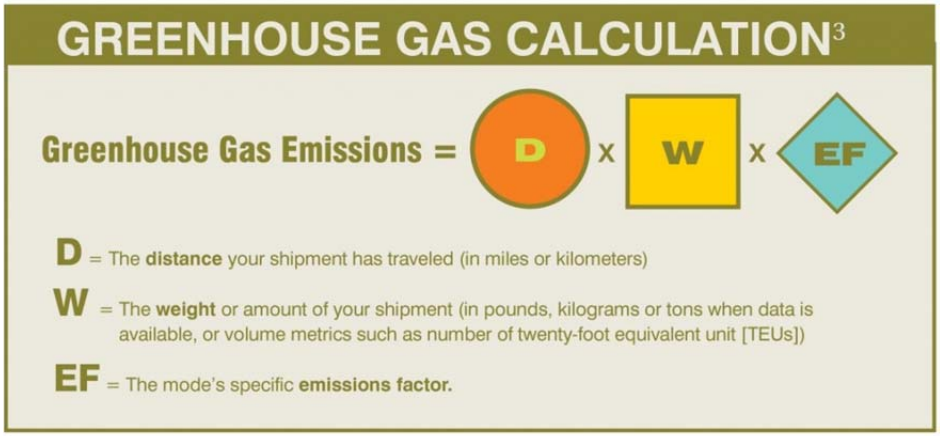


*Figure 4.3: Equation to Calculate Greenhouse Gas Emissions (EPA, 2016)*

An emission factor captures the carbon intensity of a given mode of transportation moving a fixed quantity of a good over a set distance. Here, we standardize emission factors to kg of $CO_2$-eq/tonne-km of food. Table 4.1 establishes the emissions factors used and the breakdown by transportation mode. The method of calculating proportion of packaged food transported and the resulting weighted-average emissions factor are given in Appendix G. The net weight of food and packaging entering AC, based on Chapter 3.3, is 1,274,000 tonnes. Note that unlike the food quantity weights reported in Chapter 3, which exclude the weight of packaging, the FAF weights used here include the weight of packaging since this affects the energy required for transportation.

*Table 4.1: Food into Allegheny County by Transport Method and GHG Emission Factors*

| Transport Method | | Emissions Factor (kg $CO_2$-eq/tonne-km) | Percentage of Packaged Food Weight Transported[c] |
|---|---|---|---|
| Rail | | 0.016[a] | 10.4% |
| Trucks and Multiple Modes | Refrigerated | 0.058[b] | 41.7% |
| | Dry | 0.057[b] | 47.8% |
| Air (include truck-air) | | 1.404[a] | 0.1% |
| ***Weighted Average*** | | ***0.055***[a] | ***100.0%*** |

[a](Mathers et al., 2014) [b](EESI, 2015) [c](DOT, 2017)

### 4.1.2 Adjusted Distances of Food Origins

Distances were reported in the FAF data as ranges of miles, but were converted to a singular km value using the middle of the supplied range (see Figure 4.4). FAF data implies that food travels an average of 572 km to get to AC. However, as noted above, the FAF tracks distance only when shipments change ownership, and therefore the distances may not capture the point of actual origin. Thus, our estimated emissions using the raw FAF data represent a lower-bound of the emissions associated with transporting food into AC. We also created a "FAF–Produce Adjusted" measure that modifies the distances that produce is shipped so that 60% of shipments are from 4000 km away based on estimates provided to the project by a major produce distributor (Paragon, 2019). Details of these calculations can be found in Appendix G. These modified values greatly increase our average estimate of distance from 572 km to 1,345 km. While not a perfect measure of true distances shipped (e.g., we cannot properly account for foods coming from outside the U.S. and Mexico, nor for non-produce items originating from distances beyond those reflected in the FAF data), these adjustments nonetheless provide a more accurate estimate of food transportation distances than provided by the FAF data alone.

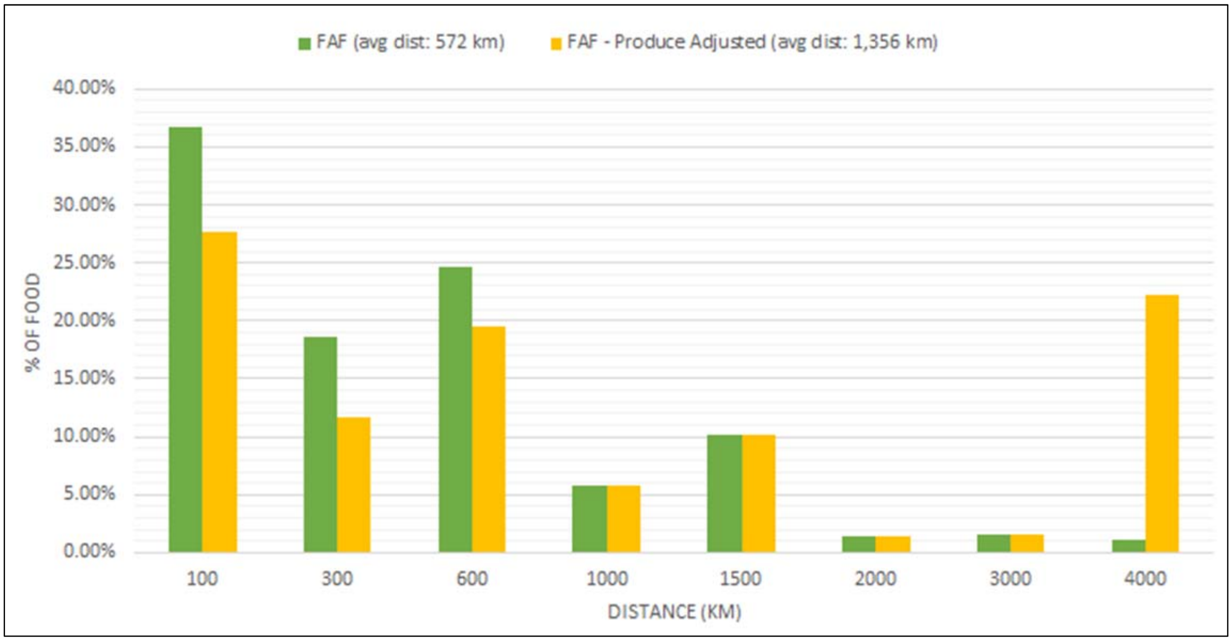


*Figure 4.4 Distance Food Travels to Enter Allegheny County (DOT, 2017)*

### 4.1.3 Estimation of Emissions

Using the above information, we estimate the GHG emissions from food transportation from the point of origin into AC. As shown in Table 4.2, our estimates range from 40,000 to 95,000 tonnes of $CO_2$-eq per year, with the larger figure arising from the produce-adjusted model. The baseline 2017 FAF emissions estimate are based on the distances given by the FAF, while the FAF–Produce Adjusted values modifies those distances as discussed above. If we average the distance between the two models, we estimate a total of 68,000 tonnes of $CO_2$-eq per year. Thus, the high estimate is 95,000 tonnes, the middle estimate is 68,000 tonnes, and the low estimate is 40,000 tonnes.

*Table 4.2: Emissions and Factors for Modeling Food Entering Allegheny County*

| Model | Emissions Factor[a] | Food and Packaging Weight (tonnes)[b] | Average Distance (km) | Annual Emissions (tonnes $CO_2$-eq/ yr) |
|---|---|---|---|---|
| 2017 FAF | 0.054 | 1,274,000 | 572 | 40,000 |
| FAF–Produce Adjusted | | | 1,356 | 95,000 |
| ***Average*** | | | ***964*** | ***68,000*** |

[a](EESI, 2015) [b](DOT, 2017)

### 4.1.4 FAF Limitations and Model Assumptions

Using FAF data to track the food entering AC has some key limitations. As discussed above, the FAF only tracks shipments that originate in the United States. Shipment records also are based on a change in ownership. Both of these factors lead to underestimates of the distance that food must travel to get to AC. Moreover, farm-based agricultural products are considered an "out-of-scope" component of the FAF data, meaning that this food freight is accounted for only from extrapolation of other data from the first location of processing or larger-scale packaging, which again underestimates the actual distance traveled (DOT, 2017). These factors help explain why, for example, the FAF data show less food than expected coming from California, an area of major national agricultural production, and why many foods appear to be sourced from fewer than 500 miles away. Additionally, distribution centers near the border of the Pittsburgh-New Castle-Weirton statistical area may service customers outside of the statistical area.

Finally, food exports from our FAF region may be more closely related to land area for agricultural production than to population. Thus, our method for allocating shipments to AC by its proportion of total regional population likely overstates AC exports.

## 4.2 Emissions from Food Distribution to Food Services Sector

To estimate the transportation emissions associated with moving the food from the distributors to food services, we rely on data provided by a major distributor. Using data on delivery truck mileage and gas purchases for AC, we estimate that trucks travel 4.5 miles per gallon (mpg) of fuel. We also estimate that trucks with onboard refrigeration use 21% more fuel. Applying the emissions factor for a gallon of diesel fuel to the observed efficiency of the trucks generates an emission factor of 1.70 kg of $CO_2$-eq/km for refrigerated trucks and 1.41 kg of $CO_2$-eq/km for dry trucks (EESI, 2015). Using the proportion of refrigerated to dry foods as given in Appendix C, the weighted average emissions factor is 1.55 $CO_2$-eq/km.

Using distributor data, we calculate that trucks travel a total distance of 13,000,000 km annually to distribute food to food service locations. Given the 1.55 $CO_2$-eq/km emission factor calculated above and the 13,000,000 km total distance, the GHG emissions from transporting food from the distributors to food services is 20,000 tonnes of $CO_2$eq.

## 4.3 Emissions from Food Distribution to Retail Sector

Similar fuel consumption rates for the food distribution to food services are applied to calculate emissions generated from transporting food from distribution to retailers. We retain the same emission factor of 1.70 kg of $CO_2$-eq/km for refrigerated trucks and 1.41 kg of $CO_2$-eq/km for dry trucks (EESI, 2015) and assume the same proportion of refrigerated and unrefrigerated foods to enter both food services and retail, again implying a 1.55 $CO_2$-eq/km adjusted emissions factor.

Using data provided by industry, we estimate that trucks travel a total of 34,000,000 km/yr to distribute food to retailers (Lazzaro, 2018). Multiplying the emissions factor (1.55 kg/km) by the total distance (34,000,000 km), the total emissions for distribution to retail outlets is 53,000 tonnes of $CO_2$ eq.

## 4.4 Emissions from Consumer Travel to the Food Service Sector

To calculate the transportation emissions associated with consumers eating outside of the home, we relied on a multicity study of travel distance to restaurants, a study of frequency of eating outside of the home, and an EPA study of average automobile mileage. Distances from home to food service locations were based on a study of 241 adults in 5 US cities: Los Angeles, California; Chapel Hill, North Carolina; Albuquerque, New Mexico; Columbus, Ohio; and Philadelphia, Pennsylvania (Liu et al, 2015). The average frequency of eating outside the home, 57.6, is calculated in Table 4.3 based on a study by Statista (2016). Using these sources, we were able to breakdown the proportion of people driving to a fast food/convenience store (requiring an average trip of 4.3 km) and sit-down restaurants (averaging 5.9 km), giving an average distance of 5.1 km. The EPA (2018) estimates an emissions factor of 251 g of $CO_2$-eq/km for the average passenger vehicle. We assume that the proportion driving to food services is the same as the 88% of households that drive to obtain groceries (USDA, 2017). Total annual distance driven is calculated by multiplying average distance/trip by the proportion of drivers (88%), total households in AC (536,429 estimated by the Census Bureau in 2017), average annual trips (57.6), and doubling the distance to account for the round trip drive, results in an estimated 278,000,000 km driven in total by consumers in AC traveling to food service outlets each year. Given the average automobile emissions factor of 0.25 $CO_2$-eq/km, we estimate 70,000 tonnes of $CO_2$-eq are produced by households traveling to eat outside of the home.

*Table 4.3: Frequency of Consumer Trips to Food Service Establishments (Statista, 2016)*

| Survey Response | **Days per Year** | **Proportion of Population** | **Weighted Average** |
|---|---|---|---|
| Once a Day | 365 | 0.05 | 18.25 |
| Couple Times a Week | 183 | 0.10 | 18.30 |
| Once a Week | 52 | 0.20 | 10.40 |
| Couple Times a Month | 36 | 0.18 | 6.48 |
| Once a Month | 12 | 0.22 | 2.64 |
| Infrequently | 6 | 0.25 | 1.50 |
| ***Average*** | | | ***57.57*** |

## 4.5 Emissions from Consumer Travel to the Retail Sector

To estimate the emissions from transportation from homes to retail establishments to buy food, we used three different models. The first assumed that all households were the same distance from grocery stores. The second used national averages of SNAP participant travel generated by the Centers for Disease Control (CDC). The third was based on a weighted average distance and proportions found by Liu et al. (2015). A Statista (2016) survey found an average frequency of 1.6 retail trips per week, or 83.2 trips annually. This frequency is applied to all 536,429 households in Allegheny County (Census, 2017).

In all three models, we assumed that consumer behavior changes depending on the distance to the grocery store. We also adjusted for residents without easy access to cars (about 12% of all households). Walking, biking, and bussing are assumed to contribute zero emissions. Buses are modeled as having zero additional emissions because we assume the addition of a single rider results in almost no increase in marginal emissions.

The Average National Distance model is based off of the national average distance traveled to a grocery store (6.1 km). The Adjusted National Distance model modifies this by a 73% increase in distance to reflect the difference between the average distance to the nearest grocery store versus the grocery store consumers prefer (USDA, 2017). We modeled distance to the nearest grocery store by taking the total land area of Allegheny County (730 sq mi) and dividing it by the number of grocery stores in Allegheny County (214) to find that each store services an average of 3.4 sq miles (Jones, 2016). Then we modeled the area as a circle to extrapolate a radius of 1.0 mi (1.6 km) as the distance to the nearest grocery store. Then we applied the ratio of the nearest grocery store versus the preferred grocery store to get an average distance of 2.9 km to the preferred grocery store. The weighted average distance is found by calculating the weighted average, as shown in Appendix H based on data provided by a CDC study (2015) that uses the midpoint of the given range as the distance traveled.

Total annual distance driven is calculated by multiplying average distance/trip by the proportion of drivers (88%), total households (536,429), average annual trips (83.2), and doubling the distance to account for the round trip. This is then multiplied by the previously derived emissions factor (0.25 $CO_2$-eq/km) to calculate the total annual emissions of $CO_2$-eq produced by household trips to retail outlets. A summary of the three models and resulting estimates of total emissions are given in Table 4.4.

*Table 4.4: Emissions due to Consumer Travel for Grocery Shopping*

| Model | Weighted Average Distance/Trip (km) | Total Annual Distance Driven (km) | Emission Factor (kg/km) | Estimated Emissions (tonnes/yr) |
|---|---|---|---|---|
| National Average Distances – High | 6.1 | 490,000,000 | 0.25 | 123,000 |
| Adjusted National Average Distances – Low | 2.9 | 233,000,000 | | 58,000 |
| Weighted CDC Average Distances – Medium | 3.5 | 281,000,000 | | 71,000 |

## 4.6 Emissions from Transport of Food Waste to Landfills

The GHG emissions associated with transporting food waste to landfills are calculated similarly to the previous sectors. Food waste, as defined in later chapters, is food that was intended for human consumption that could have been consumed safely at one point but was discarded instead. It is assumed, as mentioned in section 2.2.4, that 94% to 98% of waste generated in each sector must be transported to landfills. The weight of food that is wasted and destined for a landfill is calculated in each of the respective chapters: Wholesale and Retail waste is calculated in Section 5.3, Food Services food waste is estimated in Section 6.3, and the Residential food waste is estimated in Section 7.3.

Table 4.5 shows, for each sector, the weight of food waste and emissions associated with transporting that food to a landfill. It was assumed that food waste is generated at a constant rate throughout the year, with the amount from each sector given by the calculations discussed in subsequent chapters. The AC's garbage truck fleet consists of 50 trucks (Haulk, 2008) that each travel an average of 40,000 kilometers per year (Cannon, 2006). Assuming each truck travels 5 days a week for 52 weeks, the average distance food waste travels would be 154 km. The emission factor of a Class 7 Medium Heavy Duty truck is 0.154 $CO_2$-eq/tonne-km (EESI, 2015). Using the above, we can calculate the distance travelled and weight of food waste carried per garbage truck per trip. Using the equation in Figure 4.3, we convert these values into the GHG emissions shown in Table 4.5. Note that these are the *additional* emissions generated by garbage trucks having to carry food waste. These are not the total emissions generated by the waste-collection industry. If food waste were entirely eliminated, garbage trucks would still need to travel their routes in order to pick up other trash.

*Table 4.5 Emissions due to Transport of Food Waste to Landfills*

| Sector | Food Waste Transported to Landfill (tonnes) | Annual Emissions (tonnes $CO_2$-eq) |
|---|---|---|
| Wholesale | 1,030 | <100 |
| Retail | 92,600 | 2,200 |
| Food Services | 84,000 | 2,000 |
| Residential | 137,000 | 3,200 |
| **Total** | **314,630** | **7,500** |

## 4.7 Policy Options to Reduce GHG Emissions

Based on our estimates, the transportation of food to, and within, AC is not a major generator of GHG emissions, accounting for only about 7% of the total emissions. Nonetheless, there may be useful policies to reduce emissions in this sector. The largest transportation emissions come from consumers obtaining food from retail outlets and eating outside of the home. The two next biggest emission sources are food being transported into AC and food being distributed to retailers. As a result, the policies we considered aim to reduce GHG emissions in these sectors.

### 4.7.1 Grocery Delivery Services

Conventional food delivery has become popular within AC in the past few years. Giant Eagle, Aldi, Walmart, and Whole Foods (through Amazon Prime) are physical stores that also offer delivery services. Other grocery delivery services exist without a physical location, such as jet.com or instacart.com, where consumers order online. Typically, foods are delivered as soon as possible after the customers choose their items.

According to a study by the Environmental Protection Agency (EPA), grocery delivery has the potential to reduce the number of vehicles on the road (EPA, 2016). The study conducted assumed 115,610,216 U.S. households (U.S. Census, 2015), and compared emissions from a delivery service to that of an individual who drives eight miles round-trip to the grocery store in a 22 mpg car.

Recently, food subscription boxes that contain the needed ingredients to cook a meal, have entered the market. However, many environmentally conscious consumers frequently voice concerns about the carbon emissions from the needed transportation and packaging found in such products. However, a study at the University of Michigan has shown that these subscription boxes have a lower impact than if the typical family drives to the grocery store (Heard, et al., 2019). The average grocery-meal last-mile emissions exceed those for meal kits by 0.45 kg $CO_2$-eq/meal (Heard, et al., 2019). In addition, meal kit's direct-to-consumer model may reduce emissions by avoiding food waste, averaging 1.35 kg $CO_2$-eq/meal (Heard, et al., 2019).

It is important to note that these studies were not conducted in AC, which has a denser urban population that travels shorter distances to the grocery store. However, this density would reduce the distances that delivery trucks must travel and thus increase the potential market for such services.

With these assumptions in mind, it is estimated that if 20% of people living in AC substituted a weekly grocery trip with a weekly grocery delivery, it would reduce GHG emissions by 6,353 kg of $CO_2$-eq, or 16% of total emissions of consumers driving to grocery stores. The goal of 20% would match that of South Korea, which is currently the country with the highest percentage of groceries delivered to consumers. In the U.S., the current rate of market penetration is only a 3% (Harris, 2017).

Currently, grocery and meal kit deliveries are more expensive than going to the grocery store. In order to encourage deliveries, lower prices may be needed. For example, in Pittsburgh the average grocery bill for 31 days is $317.97 (Numbeo, 2019) whereas the average meal kit for 31 days costs $557.38 (assuming $8.99/meal, two meals a day) (Blue Apron, 2019).

### 4.7.2 Public Education

A second policy to consider is a program of public education about food choices and GHG emissions. A concept popularized in 2008 was on reducing the "food-miles" of food consumed. "Food-miles" was defined as life-cycle GHG emissions associated with food production against long-distance distribution (Weber, 2008). There is a popular misunderstanding that buying only local foods will reduce GHG emissions in the long run. This may not be true if the lower transportation emissions of locally produced food are offset by more emissions-intensive local farming practices. This is a topic that requires further study in the context of Allegheny County.

Public education could also focus on consumer grocery purchasing habits. Currently, U.S. consumers travel an average 3.79 miles to the grocery store despite living only 2.14 miles from the nearest store (USDA, 2015). Consumers also average more than one trip to the grocery store per week. Education could help consumers develop better shopping habits that reduce the number of needed trips as well as encourage the efficient grouping of errands needing an automobile. Education on "best if used by" and "sell by" dates and how long before food actually spoils would also reduce trips and eliminate waste. If every consumer drives to the grocery store only once a week as opposed to the current 1.6 times a week, there is potential to reduce AC GHG emissions by 3,504 tonnes/yr, or a 9% reduction from overall transportation emissions. However, these educational initiatives do not come without a cost as they must be carefully designed and disseminated to county residents.

### 4.7.3 Fuel Efficient Vehicles and Practices

The final policy to consider is a shift toward fuel-efficient practices within delivery truck fleets. A Canadian study estimated that many fleets could achieve a 10% fuel economy improvement through driver training and monitoring. For a typical combination truck, a 10% saving is the equivalent of nearly $2,500 a year (Larson, 2013). There are a few other factors to consider when making a fleet of trucks more environmentally sustainable. They include driving at lower speeds to maximize miles per gallon and reducing or eliminating idling when trucks are parked. The caveat with these policies is that many companies already have industrial experts working to reduce cost by minimizing fuel waste and "empty-miles," so some of these policies and practices may have been already implemented by industry.

## 4.8 Conclusions

Transportation of food occurs throughout the entirety of the food system. The largest contributions to transportation associated GHG emissions can be traced to combined emissions of residents traveling to obtain food, whether for eating out or to buy groceries for meals at home. Altogether, residential behavior contributes to 117,000 tonnes/yr of $CO_2$-eq emissions, which is 44% of all transportation-associated emissions. The breakdown of emissions for each transport segment is shown in Table 4.6.

*Table 4.6 Total Emissions from Transportation of Food and Packaging for Allegheny County*

| Sector | Tonnes of $CO_2$-eq Emissions per Year | | |
|---|---|---|---|
| | **Low Estimate** | **Middle Estimate** | **High Estimate** |
| Food Transportation into Allegheny County | 40,000 | 68,000 | 95,000 |
| Distribution to Food Services Sector | | 20,000 | |
| Distribution to Retail Sector | | 53,000 | |
| Consumer Trips to Eat Outside of Home | | 70,000 | |
| Household Trips to Retail Outlets | 39,000 | 47,000 | 83,000 |
| Food Waste Transport to Landfills | | 7,500 | |
| **TOTAL** | **229,500** | **265,500** | **328,500** |

Based on feasibility and cost, it is recommended that the delivery of groceries and meal kits be encouraged, but kept within the private sector. The attractiveness of the market and potential for growth should encourage new entrants and drive competition that will keep prices competitive. The expansion of the delivery sector has the potential to reduce total transportation emissions by about 22% or 62,175 tonne $CO_2$-eq/yr.

Distribution to the retail sector also accounts for a significant share of GHG emissions. One option to reduce these emissions would be the adoption of a more efficient delivery fleet. Improved driver training could also be effective. For example, if current vehicles operating at 3.83 km/L (9 mpg) are upgraded to hybrids at 6.38 km/l (15 mpg), total transportation emissions would be reduced by 10% or 29,350 tonnes $CO_2$-eq/yr.

Overall, transportation accounts for only 7.3% of total GHG emissions across the entire food system. The incentives for transportation companies to lower energy costs and efficiently transport goods are already large, and therefore this part of the transport sector may not have many opportunities for significant improvement. Over 40% of the sector's GHG emissions are due to consumer trips in private automobiles. Thus, improving the efficiency of these trips would be valuable, although altering household-driving behavior may be difficult. It may be the case that other sectors have better opportunities to reduce larger amounts of emissions in a more cost-effective way.

## 4.9 Chapter 4 References


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# Chapter 5: Food Distribution Sector Emissions

Food entering Allegheny County is distributed to either the commercial sector (restaurants and institutions), mostly through wholesalers, or to the retail sector, mostly through convenience stores, grocery stores (superstores, supermarkets, bulk stores, and small markets), and grocery delivery operations. During both commercial and retail distribution, food unsuitable for further distribution is lost to waste or redistributed to other outlets. The carbon footprint attributable to this sector is tied to this wasted food, as well as to the energy required for storing and selling the food. This chapter considers each type of store in the distribution sector and quantifies the associated greenhouse gas emissions to identify policy options that could decrease emissions while still maintaining profitability for the sellers and fair prices for the consumers.

For the purpose of this analysis, distribution centers are defined as wholesalers, food redistribution centers (such as food banks), convenience stores, grocery stores (including superstores, supermarkets, bulk stores, and small markets), and grocery delivery operations. Emissions during food distribution arise due to food waste and distribution center operations, along with transportation (covered in Chapter 4). This chapter quantifies the total amount of food wasted during the distribution stage, as well as the overall emissions from day-to-day operations of distribution centers such as refrigeration, lighting, and store temperature control. Additionally, policy options to reduce emissions are examined to identify opportunities to lessen the carbon footprint of the distribution sector.

## 5.1 Food Quantities Distributed in Allegheny County

The AC food distribution sector is composed of wholesalers, largely serving the food services sector, plus retailers such as grocery stores, selling directly to residential consumers. The main categories being considered here are wholesalers, grocery stores, convenience stores, delivery services, and redistribution centers such as food banks.

Wholesalers are large sale distributors who typically sell to smaller stores or restaurants. Grocery stores in AC include superstores (such as the grocery section in stores like Target and Walmart), traditional supermarkets (such as Giant Eagle and Aldi's), bulk stores (such as Sam's Club and Costco), small stores (typically local or specialty stores, such as the ones in Pittsburgh's Strip District), and farmer's markets. Of these, the first three can have additional wholesale outlets that provide supplies only for the stores within the specific chain. This analysis also includes the 986 convenience stores in AC that also sell food. The twelve food redistribution centers (food banks) in the County are also included. The final type of food distribution mechanism included in this analysis is grocery delivery services. These delivery services are offered by some existing stores as well as various local and online startups, making the exact number in the area difficult to determine. This type of service is new to the market, so data is lacking in this sector.

Table 5.1 provides a count of each type of food distributor based on data from Jones (2019) and private industry sources. Industry data indicate that the largest percentage of food sales are generated by the 115 supermarkets in AC, with the ten "superstores" having the next largest market share.

*Table 5.1: Number of Food Distributors in Allegheny County*

| Distribution Center Type | Number in AC | Source |
|---|---|---|
| Wholesalers | 7+ | Industry |
| Grocery Stores | 214+ | |
| *Superstores* | *10* | Jones (2019) |
| *Bulk Stores* | *7* | Jones (2019) |
| *Supermarkets* | *115* | Jones (2019) |
| *Local Store* | *74* | Jones (2019) |
| *Farmers Markets* | *8+* | Jones (2019) |
| Convenience Stores | 986 | Jones (2019) |
| Redistribution Centers | 12+ | foodpantries.org |
| Delivery Services | Unknown | |

### 5.1.1 Total Weight Based on Public Data Sources

Over the course of this study, three estimates were derived using different methods to estimate the total quantity of food (by weight) distributed annually in the AC food system. Two of these estimates employed publicly available data sources of different types. The third estimate was based on proprietary industry data for a segment of the total food market.

The first estimate of total food quantify distributed in AC is the one described earlier in Chapter 3, based on Freight Analysis Framework (FAF) data published by the U.S. Department of Transportation. As summarized in Table 3.3, that estimate totaled 1.18 million tonnes/yr. Chapter 3 discussed the key assumptions underlying that estimate.

The second estimate of total food quantity in AC comes from summing the separate estimates of food consumption and waste in the food services and residential sectors (Chapters 6 and 7, respectively), together with estimates of food waste in the retail and wholesale distribution chain, presented later in this chapter. These estimates are derived from a variety of public data sources, many of which report national average quantities, often on a per capita basis. The total food quantity found from this analysis is 1.25 million tonnes/yr—approximately 6% more than the FAF-based estimate (as noted earlier in Section 3.3.3).

### 5.1.2 Total Weight Based on Industry Data

The third estimate of total food quantity employed proprietary industry data on annual food sales for a segment of the AC retail sector. For some food items, the industry manifests that were obtained for this study reported the net weight of each item together with the total quantity sold. For other items, the quantity was identified in volumetric units. In these cases, the density of water was assumed to convert volume to weight. Lastly, the unit quantity of many other food items was reported in the non-specific unit of "each" (referring to a particular item or package). To estimate the weight of these latter items, the 100 most popular items were identified, and their unit weights were assigned based on background research for each item. The median of these assigned weights was then used to estimate the overall weight of the remaining unit-based items (see Appendix D for details).

This methodology further employed proprietary market share data to extrapolate the sample of industry data to the overall retail sector. The result was an estimate of 1,122,500 tonnes of food entering the AC retail distribution sector in the past year. We further estimated (see Appendix E) that retail food sales to households constitutes 75% of the overall distribution sector, with the food services sector constituting the remaining 25%, adding an additional 374,166 tonnes of food per year to the total distribution system. This brought the estimate of total food distributed in AC to 1.50 million tonnes/yr. This value is 20-27% greater than the estimates above based on public data sources.

### 5.1.3 Best Estimate of Total Food Weight

In the absence of systematic data on the types and quantities of foods consumed at the urban scale (in this case, AC), the three estimates above attempt to quantify these amounts as a basis for subsequent estimates of the carbon footprint. The result is a range of 1.2 to 1.5 million tonnes per year of food consumed in AC, with the percentages of various food types given by the values shown in Table 3.3. Given the sources and uncertainties of the three estimates derived here, our "best estimate" value for the total food weight is the middle value of 1.25 million tonnes/yr. This estimate is used to quantify the GHG emissions embodied in the food brought into and distributed throughout AC. Chapter 4 estimated the additional emissions associated with the transportation of food into and within the county. Next, we estimate the additional emissions arising from food storage and waste disposal operations.

## 5.2 Emissions from Store Operations

Storing food in distribution centers requires energy. Food must be kept refrigerated or heated. Facilities also have to maintain a temperature and lighting conducive to work and commerce. There are two primary sources of emissions for the sector. First, there is electricity use. Fossil fuels are burned at a power plant, generating electricity and releasing GHGs. This electricity is then transmitted to a distributor and used for processes such as refrigeration and lighting. The other primary emission source is natural gas, which is burned on site for heating, releasing GHGs. These two fuel sources account for the vast majority of added emissions from food storage in this sector. Several methods were employed to calculate the net energy used for food distributors in AC. Once electricity usage was determined, an emissions factor for the Pittsburgh region's electrical grid was applied to calculate the net GHG footprint. It is estimated that each kilowatt-hour of electricity generated in the Pittsburgh region produces 0.57 kilograms of $CO_2$eq. Furthermore, each million cubic feet of natural gas combusted produce 53.12 tonnes of $CO_2$-eq (Carnegie Mellon University, 2018).

### 5.2.1 Emissions Estimates for Electricity Usage

One method of estimating emissions was to apply an energy-use factor based on unit area, such as kWh/ft$^2$. For each distributor type (see Section 5.1 and Table 5.1 for the complete list) we calculated a baseline of emissions per unit area. Using estimates of net floor space of the various types of distributors, these emissions factors were applied to estimate the net emissions by each distributor category in AC. For more details on this calculation see Appendix C.

Public data was readily available on nation averages of electricity usage in the food distribution sector. A literature review was able to establish baseline values for most distributor types. Public data on natural gas was harder to come by. A literature review only provided natural gas usage data for convenience stores in Minnesota. This estimate accounted for less than 5% of net GHG emissions from AC convenience stores. As such, data on natural gas usage will be mostly absent from this section. More details on natural gas usage by food distributors (and likely a more accurate estimate of AC GHG emissions) can be found in Section 5.2.2 and Appendix C.

The EPA estimates that the average grocery store is 50,000 square feet and consumes 50 kWh per square foot per year (Energy Star, 2019), implying a per-store emission of 1,420 tonnes of $CO_2$-eq per year. Industry data obtained for AC roughly confirms these numbers—the industry value for kWh/ft$^2$ is 3.4% below the national average and the industry data average store size is 11.2% above the national average. Given the 115 supermarkets in AC, this implies a total of 163,000 tonnes of $CO_2$-eq per year from electricity usage by all supermarkets in AC. It is estimated that 30% to 60% of these emissions are from electricity used for refrigeration (Energy Star, 2019).

A similar methodology was used to estimate the total added emissions from convenience stores. While there wasn't national data publically available, energy use data was available for the state of Minnesota. Minnesota and Western Pennsylvania have relatively similar average temperatures, but it isn't a perfect approximation. There is industry data available for a more precise regional estimate (see Section 5.2.2 and Appendix C for more details). According to the Minnesota Department of Commerce (2013), an average convenience store uses 94 kWh per ft$^2$ per year and has an average size of 4,000 ft$^2$. Thus, we estimate that the 984 convenience stores in AC emit 211,400 tonnes of $CO_2$-eq per year from electricity use. The Minnesota Department of Commerce also reported natural gas usage of 50.2 cubic feet per ft$^2$ per year, or a total of 200,800 cubic ft per year. Using the AC emission factor of 53.12 tonnes of $CO_2$-eq emitted per million cubic ft of natural gas, this leads to a estimated total of 10,300 tonnes of $CO_2$-eq emitted each year from burning natural gas in all 984 convenience stores.

A Walmart electricity use report from the National Renewable Energy Laboratory suggests that superstores use around 33.1 kWh/ft$^2$ per year and occupy around 215,000 ft$^2$, with 37,000 ft$^2$ of that area devoted to food sales (NREL, 2015). This suggests that AC's ten superstores each use around 1,225,000 kWh per year associated with food storage. Given the Pittsburgh region's emission factor, this implies that these ten superstores emit a total of around 7,000 tonnes of $CO_2$-eq per year associated with food storage and sales. Assuming a similar profile for bulk stores (1,225,000 kWh per year per store associated with food storage) the seven bulk stores in AC emit a total of 4,900 tonnes of $CO_2$-eq per year.

Quantifying emissions from wholesale distributors is difficult due to limited data. To estimate these emissions, we assume that wholesale operations consume the same amount of electricity as grocery stores, namely 50 kWh per square foot. One local wholesaler has a facility of 88,000 square feet, with around 50% of the distributed food going to AC. Thus, we estimate that this operation emits 1,300 metric tonnes of $CO_2$-eq per year for the portion of food going to AC. Assuming all seven wholesalers in the region have similar sized operations in AC, we estimate that a total of 8,900 metric tonnes of $CO_2$-eq are emitted annually from the electric consumption of the wholesale distributors.

In 2018, the electricity and natural gas consumption for a 95,000 square foot AC food bank were 1.4 million kWh and 3,723 mcf, respectively. This implies an annual emission of about 820 tonnes of $CO_2$-eq from electricity and 200 tonnes of $CO_2$-eq from natural gas for this redistribution center (EIA, 2016). Because this is a large food bank that distributes food throughout a network of smaller food pantries, we assume that the emissions from this one facility capture the majority of emissions of the redistribution sector in the county.

There are limited data available on energy use for small markets. However, the scale of small markets operations in the county is such that we find it reasonable to neglect their GHG emissions.

Table 5.2 summarizes the above findings. The majority of GHG emissions from energy use in this sector are tied to supermarkets, followed by convenience stores, wholesalers, superstores, and bulk stores. If one considers market shares, superstores are a very energy-efficient provider of food in the county.

*Table 5.2: GHG Emissions due to Electricity Use in Food Distribution Sector (Jones, 2016; Energy Star, 2019)*

| Type of Building | Annual Electricity Use (kWh/ft$^2$) | Size Estimate (ft$^2$/ building) | Electricity Use per Building (MWh) | Emission Rate (kg $CO_2$-eq/ft) | No. of Stores | Total Emission Estimate (tonnes $CO_2$-eq/yr) |
|---|---|---|---|---|---|---|
| Supermarket | 50 | 50,000 | 2,500 | 28.5 | 115 | 163,000 |
| Convenience Store | 94 | 4,000 | 66 | 53.58 | 984 | 211,400 |
| Wholesale | 40.7 | 44,000 | 1,791 | 23.199 | 7 | 8,800 |
| Superstores | 33.1 | 37,000 | 1,225 | 18.867 | 10 | 7,000 |
| Bulk Stores | 33.1 | 37,000 | 1,225 | 18.867 | 7 | 4,900 |
| Small Market | Unknown | Unknown | | Unknown | 74 | Unknown, assumed to be minimal |
| Total | | | | | | 392,100+ |

### 5.2.2 Emission Estimates Based on Industry Data

We can refine some of the estimates above by using industry data on grocery and convenience stores. This data includes both electricity and natural gas, making it more complete than the estimates found in Section 5.2.1. The calculations based on this industry data can be found in Appendix C. Table 5.3 provides refined estimates using industry data for grocery and convenience stores. Using this data (in addition to values from Table 5.2 when no industry data was available), we calculate that the total annual GHG footprint from food storage in AC food distributors is 414,600 tonnes of $CO_2$eq. This estimate is likely more accurate than that given in Section 5.2.1 as it accounts for emissions from natural gas used by grocery stores. In addition, it uses specific AC county data for convenience stores, versus the convenience store data in Section 5.2.1 that is based on Minnesota convenience stores.

*Table 5.3: Refinement of Energy-Related GHG Emissions Based on Industry Data*

| Type of Distributor | Electricity Use Factor ($kWh/ft^2$) | Electricity Used per Store (kWh/yr) | Natural Gas Use Factor ($therms/ft^2$) | Natural Gas Used per Store (therms/yr) | Number of Distributors | AC Emissions (tonnes $CO_2$-eq/yr) |
|---|---|---|---|---|---|---|
| Grocery | 48.4 | 2,690,000 | 0.69 | 53,400 | 115 | 209,900 |
| Convenience | NA | 313,000 | NA | 3,269 | 984 | 187,000 |
| **Total** | | | | | | **414,600** |

## 5.3 Emissions from Food Waste

The second major source of GHG emissions during food distribution is from food waste. Food waste produces emissions when it enters the waste stream and decomposes. Moreover, eliminating the waste outright would avoid any emissions embodied in the initial production and distribution of the food (see Chapters 2-4).

To quantify the amount of waste in the wholesale sector, data was collected from a local wholesale distributor. This distributor estimated that 0.5% of its incoming food resulted in waste (an amount well below our retail estimates discussed below). It has been determined that 309,000 metric tonnes of food goes through wholesale (Appendix F). From industry data, it was found that two thirds of the total amount of wasted food goes into the waste stream. Thus, for the entire wholesale sector, 1,030 tonnes went to landfills and 515 tonnes was redistributed to food banks and others in need. With a landfill emissions factor of 0.45 tonnes of $CO_2$-eq/tonne of food waste, this produces 464 tonnes of $CO_2$-eq emissions per year from the wholesale sector of AC.

In 2008, it was estimated that 10% of food in the U.S. retail sector was wasted (Buzby, 2011). Given our estimate that 926,000 metric tonnes of food into the retail industry (Appendix F), this means that 92,600 metric tonnes become waste. We assume all of this is sent to landfills. With the landfill emissions factor of 0.45 tonnes of $CO_2$-eq/tonne of food waste, 41,670 tonnes of $CO_2$-eq are emitted by wasted food in the retail sector.

Finally, to estimate the amount of food wasted in the redistribution sector, data was obtained from the Greater Pittsburgh Community Food Bank, which distributes around 14,000 tonnes of food per year. As discussed above, this food bank is a large operation that captures much of this sector's activities. The Food Bank reports that 3.9% of their incoming food is wasted, with 57.5% of that waste ending up in landfills. This 321 tonnes of landfilled food waste produces 144 tonnes of $CO_2$-eq emissions per year. The remainder of the waste from the redistribution sector is allocated as shown in Table 5.4. Table 2.1 provides the associated emission factors for the various disposal types, with Animal Feed providing the most efficient mitigation of GHG emissions. Recycling inorganic waste from food packaging is also an important method of reducing emissions, as it has an emissions factor of -0.24 tonnes $CO_2$-eq per tonne of waste (EPA 2015). Even with a large proportion of the waste generated in this sector being directed away from landfills, the total emissions are a net positive 49.7 tonnes $CO_2$-eq from food redistribution in AC.

*Table 5.4: GHG Emissions from Food Redistribution Waste in 2018*

| Disposal Method | Waste Quantity (tonnes/yr) | GHG Emissions (tonnes $CO_2$-eq/yr) |
|---|---|---|
| Landfilling | 321 | 144 |
| Compost | 43.4 | -8.70 |
| Recycle | 86.8 | -20.9 |
| Animal Feed | 106.8 | -39.5 |

Waste from the convenience store and farmers market sectors has not been quantified given the lack of data and low market share. Also, in the case of convenience stores, much of the food is pre-packaged with long shelf lives.

## 5.4 Policy Options to Reduce GHG Emissions

Thus, we estimate that the food distribution sector is responsible for 449,300 tonnes of $CO_2$-eq per year in AC. Of this, 414,600 tonnes of $CO_2$-eq per year is due to energy use, and 42,280 tonnes is due to waste. Reducing energy emissions will likely require policies focused on encouraging the use of more energy efficient refrigeration. Waste emissions can be addressed by either reducing the waste stream or diverting food waste away from landfills. Any such policies must also take into consideration the reactions of key stakeholders in this sector.

### 5.4.1 Energy Policy Options

Because refrigeration accounts for between 30% and 60% of the food distribution sector's GHG emissions from energy consumption, an obvious place for policy is reducing the energy requirements of refrigeration. As of 2017, buying a refrigerator that is certified by Energy Star can save $597 for lifetime energy consumption for a single commercial refrigerator compared to a less efficient model (Federal

Energy Management Program, 2019), with the best available model saving upwards of $1,141 and 689 kg $CO_2$-eq annually per unit (Federal Energy Management Program, 2019).

Another option is a localized emission trading scheme, such as cap and trade. Such a program would mandate overall limits on net GHG emissions from energy use for food distributors by issuing a fixed number of permits, while also allowing market trade in those permits to best use to provide incentives for GHG producers to adopt better technology. Such a program is flexible in terms of the amount of GHG reductions desired and could even allow public interest groups wanting GHG reductions to participate in the market. The specific details and targets would have to be decided by local governments and stakeholders, though the emissions and electricity use estimates found in Sections 5.2.1 and 5.2.2 may provide a useful baseline for such a program.

### 5.4.2 Waste Management and the Food Recovery Hierarchy

The Food Recovery Hierarchy (FRH) is a tool developed by the EPA (2017) to conceptualize strategies for reducing food waste. The FRH orders different waste management practices based on their overall economic, social, and environmental impact. This hierarchy is shown in Figure 5.1

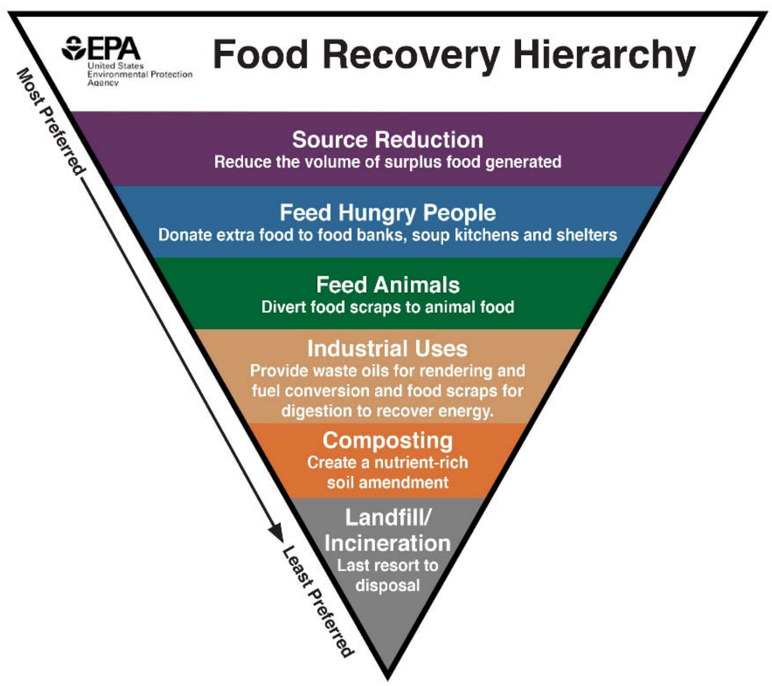


*Figure 5.1: The EPA's Food Recovery Hierarchy*

The FRH orders policy options from the most (top) to least (bottom) preferred. According to the hierarchy, the most preferred strategy is to reduce the amount of surplus food being put into the system by generating less food at the source. Next, the FRH focuses on redistributing unused food, first to feed people and then to feed animals. Next are various reuse strategies, starting with industrial uses and then composting. The least preferred option is sending food to a landfill or incineration. This section is dedicated to quantifying savings, both in waste and emissions, as well as monetary savings for businesses or customers. The section will start at the bottom of the triangle and work up.

Given the commercial nature of the food distribution sector, successful implementation of a given policy option depends not only on its environmental benefits, but also its profitability for retail and wholesale distributors. Therefore, these two elements are considered in Table 5.5. This table focuses on the potential savings to AC from the retail part of the distribution chain. We focus on the retail part for two reasons. First, this subsector makes up the largest percentage of market share. Second, this subsector has the most information available on policy impacts, making the analysis more reliable.

*Table 5.5: Impact Analysis of Grocery Store Policy Options*

| Policy Option | Total AC Landfill Emissions Saved (tonnes $CO_{2\text{-eq}}$/tonne food) | Percent of total AC Landfill Emissions Saved |
|---|---|---|
| **Composting** Implementing One Facility | 7,000[a] | 16.6% |
| **Industrial Uses** Implementing One Facility | 10,500[b] | 34.8% |
| **Feeding Hungry People** Grocery Stores Citywide | 21,000[c] | 50.0% |
| **Feeding Animals** Grocery Stores Citywide | 17,500[d] | 41.4% |
| **Improved Inventory Management** | 21,000[e] | 50.0% |
| **Improved Labeling** | 13,500[f] | 20% of consumer emissions |

[a] Assuming that 36k is around 32% of the total waste, which is 13,500 tonnes of $CO_2$-eq emissions if sent to landfills. Composting can decrease this by about 52%, which is about 7,000 tonnes of emissions saved.

[b] Assuming that 45k is around 40% of the total waste, which is 17k tonnes of $CO_2$-eq emissions if sent to landfills. Anaerobic digestion can decrease this by about 62%, which is 10,500 tonnes of emissions saved.

[c] Assuming that 50% of the total waste, which is 21k tonnes of $CO_2$-eq emissions if sent to landfills. Redistribution can decrease this by about 100%, which is 21k tonnes of emissions saved.

[d] Assuming that 60% of the total waste, which is 25k tonnes of $CO_2$-eq emissions if sent to landfills. Feeding to animals can decrease this by about 69%, which is 17,500 tonnes of emissions saved.

[e] Assuming that 50% of the total waste, which is 21k tonnes of $CO_2$-eq emissions if sent to landfills. Improved inventory management can decrease this by about 100%, which is 21k tonnes of emissions saved.

[f] Assuming that 90% of the food in the retail sector goes to consumers (around 1 M tonnes) and consumers waste 15% of that (152 k tonnes), 20% of this can be saved (30k tonnes). This saves 100% of the emissions, which is about 13.5k tonnes.

*Landfill/Incineration*

At the bottom of the food waste hierarchy is sending food to landfills or incinerations, both of which are last resorts. Landfills are currently the most common waste path for food in this sector. Given the alternative options available, this option should be avoided if possible. However, there are strong economic incentives to send waste food to landfills since Pennsylvania has relatively low tipping fees for waste disposal. As a result, other states also transport their garbage here for disposal (Bykoski, 2019). Higher fees would be needed to discourage landfilling in favor of waste reduction and more benign methods of disposal, such as composting.

*Composting*

Composting is the process of transforming organic waste, like wasted food, into humus. Pre-consumer waste is best for producing high nutrient, low contaminant compost, which is a valuable product to agriculture. Centralized composting can be profitable due to the value of the resulting compost. Composting also leads to economic development by providing new jobs (ReFED, 2016).

Compost facilities are likely to be successful in the AC region due to the value for compost, especially if there were also higher costs for waste disposal in landfills. One composting facility can cost between \$5 and \$9 million and around \$20 per ton of waste to operate. Such a facility can process about 36,000 tonnes of waste per year. If one such facility were implemented in the county, it could divert 38% of the total amount of waste in the retail sector. ReFED (2016) reports that composting reduces GHG emissions by around 52%. In AC this would amount to around 6,900 tonnes of $CO_2$-eq/yr.

Educating consumers and businesses about the benefits of food waste reduction and composting as an alternative to landfill disposal is also needed. Municipal policies and programs can encourage composting and reduce landfill waste as well. In Canada, for example, the City of Vancouver and the Metro Vancouver regional district banned food scraps from garbage disposal as of January 1, 2015 (Judd, 2014). This was accompanied by publicity and educational campaigns to discourage food waste, as illustrated in Figure 5.2. In the U.S., on Long Island, NY, it is illegal to put green waste in a landfill and a large anaerobic digestion facility is being planned (Flynn, 2019).


*Figure 5.2: Example Ad from Food Composting Initiative in Vancouver, BC*

*Industrial Uses*

Anaerobic digestion is an industrial process that is becoming more popular in the United States. Anaerobic digestion uses a series of biological process driven by microorganisms to break down organic material in the absence of oxygen, producing biogas and digestate, which can be used to create renewable energy and a nutrient rich fertilizer. The combination of producing electricity and compost, along with collecting waste disposal fees, can make anaerobic digestion economically viable. A single system can intake around 45,000 tonnes of food waste per year and has an initial cost of around $20 million dollars.

If one facility was implemented in AC, it could divert 48.6% of the total amount of waste in the retail sector. ReFED reports that anaerobic digestion can reduce around 62% of emissions, meaning that around 10,300 tonnes of $CO_2$-eq emissions can be saved.

*Feed Hungry People*

Redistributing food that would otherwise be wasted to feed food-insecure individuals is high up in the FRH. In Pittsburgh, the nonprofit 412 Food Rescue operation focuses on redirecting food to those in need, and it receives about 50% of its donations from the retail sector. Their last impact report indicated that the organization received three million pounds of food in the prior six months, which implies six million pounds (2,700 metric tonnes) of food in one year from the distribution sector. Diverting this amount of food from landfills equates to 1,000 tonnes of $CO_2$-eq emissions avoided.

The Greater Pittsburgh Community Food Bank is another major organization that works with a network of over 150 city-based partners to help feed 41,000 Pittsburgh residents. In 2016, Food Bank member agencies directly rescued 4.7 million pounds (2,100 metric tonnes) of food via donations from grocery stores, restaurants, distributors, manufacturers, farmers, gardeners and stadiums (Scales, 2017).

Another method of redirecting food to hungry people relies on individual redistribution technologies. Mostly tied to apps for smartphones, these programs work with grocery stores to send users updates on foods with near-term expiration dates that can be purchased at a discount (NYC Food Policy Center, 2019).

Tax incentives encourage stores to engage in various redistribution programs. Currently, companies can write off half of the profit they would have made had they sold the donated items, as well as any costs associated with the redistribution process (Smaros, 2019).

It is estimated that 50% of the food that is thrown out in the retail sector is perfectly edible for humans (Gunder, 2012). If this food was instead redistributed, ReFED reports that standardizing donation regulations can eliminate emissions, implying a savings of around 17,000 tonnes of $CO_2$eq.

*Feed Animals*

Food that cannot be redistributed to feed people, can often be used to feed animals. In particular, pigs eat a wide range of foods that may not be suitable for other animals. Beyond reducing the amount of food ending up in landfills, this step in the hierarchy also reduces the emissions attached to producing food for animals.

If waste is not going to other sectors, around 60% of food waste can be used to feed pigs. ReFED reports that feeding animals can reduce around 69.3% of emissions, meaning that around 14,200 tonnes of $CO_2$-eq emissions can be saved using this pathway.

*Source Reduction and Reuse*

Source reduction and reuse reduces the amount of wasted food, avoiding all of the embodied emissions that were required to produce and distribute that food. Table 5.6 analyzes the percentage of each wasted food type in the retail sector based on Buzby (2012).

*Table 5.6: Food Wasted in the Distribution Sector by Category*

| Food Type | Percentage | Food Type | Percentage |
|---|---|---|---|
| Milk | 19.6 | Produced Vegetables | 4.8 |
| Grains | 16.7 | Produced Fruit | 4.8 |
| Fresh Vegetables | 13.5 | Nuts/Fats/Oils | 4.1 |
| Fresh Fruit | 8.2 | Poultry | 3.1 |
| Sweeteners | 8.0 | Eggs | 2.9 |
| Non-Liquid Dairy | 7.8 | Fish & Seafood | 0.7 |
| Red Meat | 5.5 | Legumes | 0.4 |

Utilizing the percentages in Table 5.6, the amount of waste of each food type was calculated and the total embodied emissions for that food was quantified in Table 5.7. If the sector were able to completely eliminate food waste, this table shows the emissions that could be avoided in the food distribution sector, based on the emissions factors provided in Table 3.4. The result is that a total of 370,000 tonnes of $CO_2$-eq emissions could be avoided in the production chain if all food destined for waste were never produced. Eliminating all waste in a sector may be difficult, but the potential for reducing embodied GHG emissions in the urban food system is enormous.

There are many policy options that could help reduce waste. The first is improved inventory management. This strategy improves the ability of the retail inventory management systems to track a product's remaining shelf-life and assists the retailer in making better purchasing decisions. Such systems can divert up to 50% of the total amount of waste generated by the retail sector, saving around 17,100 tonnes of $CO_2$-eq emissions. Altering the labeling of various "sell by," "best by," and "use by" labeling could also reduce waste given consumer confusion about what these labels mean in terms of food quality and freshness. It has been estimated that more sensible labeling could save the private sector in the U.S. $1.8 billion each year (ReFED, 2016). This equates to $6.8 million annually when scaled to the population size of AC. Implementing new labeling in the AC retail sector could reduce waste by 20%, saving around 11,200 tonnes of $CO_2$-eq emissions.

*Table 5.7: Annual Food Waste and GHG Emissions in the Retail Sector*

| Food Type | Waste Amount (tonnes) | Emissions from Waste (thousand tonnes $CO_2$-eq) |
|---|---|---|
| Red Meat | 6,176 | 179.11 |
| Non-Liquid Dairy | 8,758 | 68.32 |
| Milk | 2,009 | 30.81 |
| Grains | 18,752 | 18.75 |
| Poultry | 515 | 14.76 |
| Fresh Vegetables | 15,159 | 12.13 |
| Eggs | 3,256 | 11.07 |
| Produced Vegetables | 5,390 | 8.09 |
| Produced Fruit | 5,390 | 8.09 |
| Fresh Fruit | 9,208 | 6.45 |
| Nuts/Fats/Oils | 4,603 | 5.06 |
| Fish & Seafood | 786 | 3.54 |
| Sweeteners | 8,837 | 3.53 |
| Legumes | 449 | 0.36 |
| **Total** | **1,100,000** | **370.00** |

## 5.5 Conclusions

Almost all of the food that enters AC goes through the food distribution sector. Food is then distributed from wholesalers into the food services sector (see Chapter 6) or from retailers directly into the residential sector (see Chapter 7). As food passes through the distribution sector it produces GHG emissions either in the form of energy required to store the food, resulting in the addition of 414,600 tonnes of $CO_2$-eq annually, or as waste resulting in an additional 34,700 tonnes of $CO_2$-eq from landfill decomposition. In addition, if there was a way to avoid creating waste in the overall food system, the substantial GHG emissions embodied in the production, processing, and transportation of the food to the distribution sector could be avoided altogether.

Policy options in this sector focus on reducing either energy use or food waste. Energy reduction can come from better retail and wholesale practices, such as using more efficient modern refrigerators. Waste reduction recommendations were based on the EPA's Food Recovery Hierarchy, with the goal of redistributing wasted food to where it would provide the greatest net utility and generate the lowest GHG emissions.

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# Chapter 6: Food Services Sector Emissions

This chapter discusses the carbon footprint of the food services sector in Allegheny County, which is the first of two major avenues for food consumption. For the purpose of this study, the food services sector is defined as all businesses that prepare and serve food other than grocery and convenience stores. First, definitions are provided for the food services sector and each of the major sub-sectors we have chosen for purposes of policy analysis. To provide further background into the contribution of food services to the overall food system, we calculate the total food eaten that is prepared by food service establishments. Finally, to quantify additional emissions from this sector's activities, we calculate both the quantity of food wasted and the electric power used by food service establishments for food storage.

## 6.1 Types and Number of Food Service Vendors

The food services sector in AC includes a large and diverse number of facilities. Food facility data from the AC Health Department indicates that there are approximately 9,200 establishments that align with the above definition (ACHD, 2018). Given the scale of this sector, it is important to understand its GHG contribution to the overall AC food system.

We break the sector into multiple sub-sectors since different kinds of food service establishments handle food in different ways, and policies to address GHG emissions may differ across these sub-sectors. For instance, cafeterias often use trays for food delivery whereas restaurants serve food on individual plates. Similarly, entertainment venues often serve reheated, premade food, whereas restaurants typically combine ingredients to make dishes from scratch. Therefore, we consider three broad categories: restaurants, cafeterias, and entertainment venues. We define a restaurant as any place where consumers order from a menu and food is either picked up or served at a table. Entertainment venues often operate in the same way, however there is another activity associated with eating such as seeing a movie or watching a sporting event. Cafeterias are self-service operations that exist in various forms across the County, such as in schools, hospitals, workplaces, colleges, and correctional facilities.

Note that to quantify the food waste produced from the food service sector, we rely on a more detailed set of sub-sectors suggested by the waste estimation guide used in this study (Recycling Works MA, 2018). Beyond restaurants, entertainment venues, and cafeterias, this guide distinguishes between different types of restaurants and cafeterias.

## 6.2 Food Quantity Entering the Food Services Sector

In order to determine the impact that this sector has on the overall GHG contribution to AC we first determine the quantity of food flowing through this sector. Data from individual food establishments in this sector is unavailable, so we derive various estimates of the amounts of both solid food and beverages flowing into this sector.

### 6.2.1 Food Consumption Estimates

To determine the amount of solid food consumed in food services, we use USDA Loss Adjusted Food Availability data (USDA, 2019). This data suggests a per capita annual consumption of 400 kilograms of solid food, including non-water ingredients in beverages. This estimate, however, considers food consumed in both food services and residential settings. To estimate solid food consumption within the food services sector, we use USDA (2016) estimates of food calories consumed in and away from the home. They conclude that about 25% of calories are consumed outside the home, all attributable to the food services sector. Hence, we estimate that AC residents consume an average of 100 kg of solid food per year within the food services sector (see Appendix E).

We also estimated beverage consumption in this sector. Since the solid food estimate considers non-water ingredients in beverages, here we focus only on the water content of consumed beverages. Estimating from a range of sources, an individual consumes approximately 37 gallons of bottled water (IBWA, 2017) and 58 gallons of non-water bottled beverages (Livestrong Foundation; Harvard, 2010; Tea Association of the USA) per year, giving a total of 95 gallons of beverages consumed per capita per year. Converting this to liters (1 US gallon = 3.785 liters) and assuming the density of water (1.0 kg/l) gives an equivalent of 360 kg of beverages consumed per capita per year. If we assume, as above, that 25% of this consumption is in the food services sector, we estimate that 90 kg of beverages are consumed in the food services sector per capita per year. Table 6.1 provides a summary of total consumption in the food services sector.

*Table 6.1: Food Consumption in Food Services Sector*

| Food Type | Quantity |
|---|---|
| Solid Food Consumption | 100 kg/capita/year |
| Beverage Consumption | 90 kg/capita/year |
| Total Consumption | 190 kg/capita/year |
| **Total Consumption in Allegheny County** (based on a population of 1.2 million) | **230,000 tonnes/year** |

### 6.2.2 Food Waste Estimates

The above estimates consider only the food that is directly eaten by consumers in the food services sector. The actual amount of food that flows through this sector must also consider any food that is wasted and not directly consumed. Waste in food services arises from factors such as spoilage, disposal of less-appealing foodstuffs, cooking losses, and plate waste. To identify the amount of food waste in food services we perform a series of estimates.

Food waste varies depending on where it is generated in the food services system. Central to our food waste estimates is a food waste estimation guide published by Recycling Works in Massachusetts (Recycling Works MA, 2018). This guide provides normalization factors for estimating the quantity of food waste within different sub-sectors of the food services industry. The factors come in various forms such as pounds of waste per employee or pounds of waste per visitor annually, depending on the sub-sector. In order to apply this to AC, we gather scaling factors to multiply by the normalization factors. For example, we estimate how many assisted living facility employees there are in AC. Using this number and the associated normalization factor (tonnes of waste per employee), we calculate the amount of food waste produced annually in the assisted living sub-sector. This approach is applied to each sub-sector of AC food services (see Appendix F for details).

Table 6.2 shows our food waste estimates. It is clear that restaurants contribute the highest percentage of waste within food services, about 80%. All other sub-sectors each contribute less than 5,000 tonnes per year, or less than 6% each. However, the aggregate food waste from all cafeteria-style establishments (i.e., schools, correctional facilities, and hospitals), is a substantial portion of the overall total. This suggests that waste reduction policies should focus on both restaurants and cafeterias.

*Table 6.2: Food Waste by Quantity in the Food Services Sector*

| **Sub-sector** | **Food Waste Quantity (tonnes/year)** |
|---|---|
| Full-Service Restaurants | 59,100 |
| Quick Service Restaurants | 12,800 |
| Entertainment Venues | 4,000 |
| Correctional Facilities | 1,400 |
| Elementary Schools | 1,200 |
| Middle Schools | 600 |
| High Schools | 300 |
| Hospitals | 4,000 |
| Assisted Living Facilities | 1,000 |
| Colleges | 2,500 |
| Hotels | 3,300 |
| Corporate Cafeterias | 30 |
| **TOTAL** | **90,000*** |

* Because some establishments such as hospitals have restaurants in addition to cafeterias, the sum of individual entries is larger than the actual total. See Appendix B for calculation details.

By combining the consumption and waste estimates above, we can derive an estimate of the total amount of food entering the AC food services sector. Table 6.3 presents a summary of the quantities of food for which the food service sector is responsible. Over a quarter of all food entering the food services sector is ultimately wasted. This percentage indicates that there is significant room for improvement. If waste can be reduced in food services, it can positively impact the system as a whole.

*Table 6.3: Final Food Quantity Estimates for the Food Services Sector*

| Parameter | Quantity* |
|---|---|
| Total Food Eaten in Food Services Sector | 230,000 tonnes/year |
| Total Food Wasted in Food Services Sector | 90,000 tonnes/year |
| Total Food Entering Food Services Sector | 320,000 tonnes/year |
| Percent of Food Wasted in Food Services Sector | 28% |
| Percent of AC Food Entering Food Services Sector | 28% |
| Percent of AC Food Waste Caused by Food Services | 21% |

*See Appendix A for calculation details.

## 6.3 Emissions from Food Waste Disposal

Since the embodied GHG emissions from the production and transportation of food in this sector are accounted for elsewhere in this report, the only additional GHG emissions from the food in this sector are due to food waste and food storage. We assume that wasted food is currently either landfilled or composted in AC. According to the waste profile in Appendix A, we determine the quantity of waste from food services entering each disposal stream. We then multiplied this by the emissions factors presented in Table 2.1 to determine the total emissions from food waste in food services, summarized in Table 6.4. It is evident that while there is a net reduction in emissions from the waste that is composted, these savings are overwhelmed by the emissions from landfilling.

*Table 6.4: Post-disposal GHG Emissions, Baseline Scenario*

| Process | Quantity | Value | Unit |
|---|---|---|---|
| Generation | Total Food Waste | 90,100 | Tonnes Waste |
| Landfill | Waste Quantity | 84,396 | Tonnes Waste |
| | GHG Emissions | 37,630 | Tonnes $CO_2$ eq |
| Compost | Waste Quantity | 5,704 | Tonnes Waste |
| | GHG Emissions | -1,129 | Tonnes $CO_2$ eq |
| Emissions | **Total GHGs** | **36,500** | **Tonnes $CO_2$ eq** |

## 6.4 GHG Emissions from Food Storage

The storage of food products in food services establishments adds to this sector's GHG emissions. The principal emissions source we consider here is electricty consumption for refrigeration. GHG emissions can also be produced by various refrigerants, however we did not include these in the estimates below given insufficient data to make reasonable estimates.

Table 6.5 shows the share of food service sub-sectors with at least one of each listed appliance type based on the U.S. EIA's Commercial Buildings Energy Consumption Survey's data on food service areas in buildings with non-food service primary functions (CBECS, 2012). The most prevalent refrigeration types are walk-in units and residential-type units, with an average of 80-90% of food service establishments possessing at least one of each of these equipment types. This data is particularly useful when assessing potential policy implications.

*Table 6.5: Prevalence of Refrigeration Equipment in Food Service Areas*

| **Food Service Establishment Type** | **Percent of Establishment Type with Each Equipment Type** | | | | |
|---|---|---|---|---|---|
| | **Any Refrigeration Equipment** | **Walk-in Units** | **Open Cases or Cabinets** | **Closed Cases or Cabinets** | **Residential -type or Compact Units** |
| Snack bar or concession stand | 99.8% | 81.6% | 47.5% | 68.5% | 85.8% |
| Fast food or small restaurant | 100.0% | 86.4% | 57.7% | 79.5% | 80.9% |
| Cafeteria or large restaurant | 100.0% | 89.9% | 40.8% | 66.6% | 81.7% |

We estimated that the AC food services sector requires 412,000 MWh for refrigeration each year, resulting in 235,000 tonnes of $CO_2$-eq annually, which is a sizable source of emissions. We further estimated that AC food service facilities spend on average $1400/year each on electricity for refrigeration, a total of $13.2 million per year for the sector. These estimates are detailed in Appendix F Table F9.

## 6.5 Policy Options to Reduce GHG Emissions

According to our analysis, the biggest contributor of GHG emissions in the food services sector in AC is from food storage, so this may be a key area for policy intervention. We also found that some parts of the food services sector produce large amounts of food waste, so policy interventions focused on reducing food waste might also be useful.

As seen in Table 6.2, food waste is highest in restaurants. Therefore, the majority of the options presented below are tailored to that environment. Cafeterias and entertainment venues produce less waste, but there are productive policy options applicable to these sub-sectors as well.

### 6.5.1 Waste Reduction in Restaurants

Two policies restaurants could follow to reduce their food waste are waste audits and providing patrons with portion-size options. Food waste audits allow restaurants to understand what kinds of foods they waste the most of so that they can focus their reduction efforts in these areas. Portion options, on the other hand, put the onus on patrons to select the amount of food they believe they can finish.

Waste audits have already been successfully implemented in AC. In cafeterias at the University of Pittsburgh (PittSustainability, 2018), student volunteers looked through waste bins to determine what kinds of food was being wasted. They found that omelets were being thrown away, so the chefs started using two eggs instead of three. Similarly, noodles were put in smaller bowls in smaller portions. This led to a decrease in waste by 5%, a number corroborated by LeanPath, a company that performs food audits for businesses (LeanPath, 2019). If implemented in all food-service establishments, using the scaling factor for waste to emissions, waste audits like this one could decrease GHG emissions by 2,400 tons $CO_2$-eq across the sector.

### 6.5.2 Waste Reduction in Cafeterias

Two policies that cafeterias can follow to reduce their food waste are smaller plate sizes and trayless dining. Both policies reduce both food waste and costs.

Smaller plates mean smaller portions and therefore up to 26% less food waste (Hansen et. al., 2013). This is something that can be easily implemented in any kind of establishment, and equates to a potential decrease in emissions of up to 5,200 tons $CO_2$-eq across AC food services.

Another waste policy option for this sector is trayless dining, which can be implemented in cafeteria-style establishments. Similar to plate sizes, the idea behind this policy is that trays encourage patrons to collect more food from the cafeteria line than they can eat, increasing overall waste. Without the tray, people take less and reduce waste. The act of removing trays from cafeteria-style establishments can lead to a decrease in food waste by about 30% (Sustainable America, 2013). Translated to this sector, this policy option can potentially reduce GHG emissions by 1,300 tons $CO_2$eq.

### 6.5.3 Maintenance of Existing Storage Equipment

Many commercial refrigerators and freezers are faulty, which hurts their performance and increases their electricity consumption. A UK study found that around 50% of commercial refrigeration and freezing units examined were faulty (Mudie et. al, 2016). Potential flaws include improperly sealed doors that allow cold air to escape and defective thermostats that keep appliances at colder temperatures than necessary.

Repairing defective units improves their energy efficiency, lowering both carbon emissions and the establishment's electric bills. Based on the UK study, we estimate that repairing all of the faulty commercial refrigeration appliances in AC could decrease the sector's electricity consumption by up to 120,000 MWh each year. This is equivalent to an annual emissions reduction of 68,000 tonnes of $CO_2$-eq, a savings of around 30% of the current emissions from storage, as well as a $3.8 million reduction in sector-wide electricity costs.

Developing awareness among establishment owners to regularly check their appliances could help improve the sector's energy efficiency. Additionally, the incorporation of enhanced appliance inspections into the ACHD's existing routine health inspections could help identify units in need of improvement. If the local or state government labelled carbon pollution as a public health issue, this could be grounds for adding appliance efficiency to the health inspections checklist. Further, improper or inconsistent food holding temperatures is a health violation, making the maintenance of refrigeration appliances even more relevant to such inspections.

### 6.5.4 Use of Energy Efficient Storage Units

The replacement of appliances with new, energy efficient units has the potential to further reduce this sector's GHG emissions. ENERGY STAR commercial refrigerators and freezers use, on average, 30% less electricity than their standard equivalents. Replacing all current units with energy efficient units at the end of their lifespans could decrease this sector's emissions by 67,000 tonnes of $CO_2$-eq per year and save $3.8 million in electricity costs.

Incentives like rebates, often offered through electric utilities or government programs, are popular measures to encourage the adoption of energy-efficient appliances. Duquesne Light Company—the County's primary electric utility—offers rebates for a number of energy-efficient devices and appliances, including some replacement components of commercial refrigerators and freezers (DLC, 2019). However, these rebates do not include the purchase of new commercial refrigeration equipment. The Small Business Advantage Grant program of the Pennsylvania Department of Environmental Protection provides 50% matching grants, up to a maximum of $7,000, to enable Pennsylvania small businesses to purchase energy efficient or pollution prevention equipment, or adopt waste reduction processes (PADEP, 2019). The adoption of additional and more generous rebates by Duquesne Light, the County, or state governments, could push more establishments towards efficient storage appliances.

### 6.5.5 Optimization of Cooler Space and Shipment Frequencies

We found that the frequency of food shipments to food service establishments depends on the amount of cooler space in the establishment. We analyzed whether any reduction or addition of cooler space within food service establishments would decrease emissions, taking into consideration the change in transportation emissions caused by altering shipment frequency. We assumed cooler capacity and shipment frequency were inversely related, thus cutting the amount of cooler capacity in half would double the number of shipments. We also assumed no changes in capacity would be made in distribution warehouses.

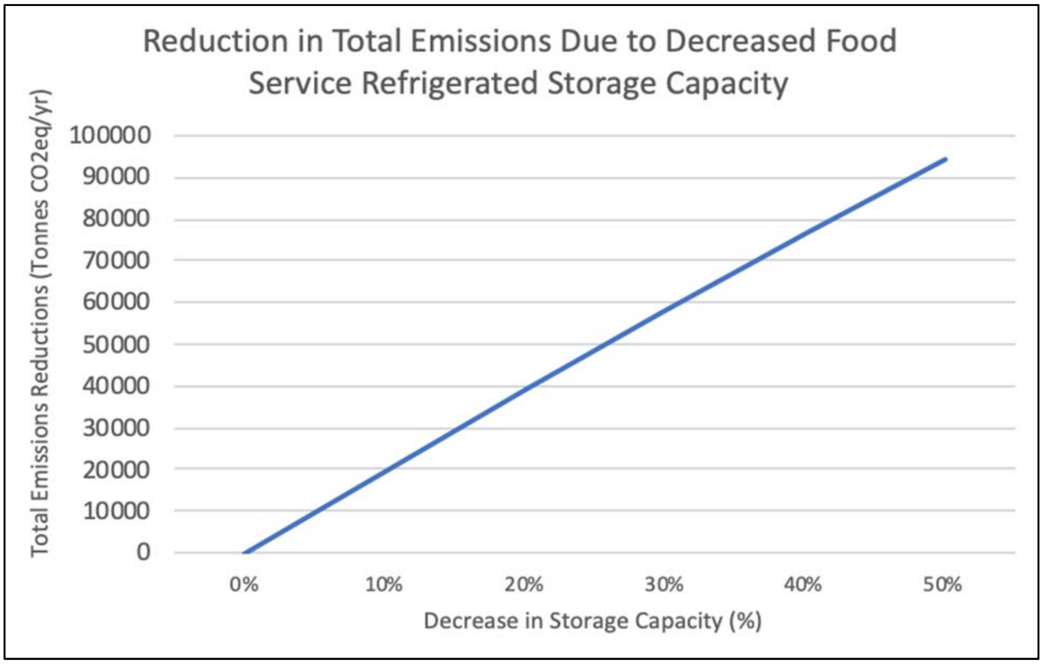


*Figure 6.1: Reduction in Total Emissions Due to Decreased Food Service Cooler Capacity*

As shown in Figure 6.1, we find that reducing food service storage capacity could significantly decrease AC GHG emissions. Thus, in terms of emissions, under certain circumstances it is more efficient to store food in wholesale distribution centers and transport it more often, then it is to store the food on site at the service establishments. For example, cutting the food services' cooler capacity in half, and subsequently doubling the frequency of food shipments, could reduce AC annual emissions by 95,000 tonnes of $CO_2$eq. This equates to about 40% of the sector's total emissions from storage.

Food service establishments could also gain significant financial advantages by reducing their cooler space. Electric bills would decrease, there would be less capital cost due to the need to acquire fewer or smaller units, and total refrigeration maintenance costs would be lowered. Additionally, the reduction in floor space dedicated to storage is advantageous to the establishment. However, those establishments may need to reorganize labor to manage the required increase in shipment frequency. This system would also increase the burden on distributors, since they must drive the same routes more often, but increased delivery fees or the redistribution of restaurants' electricity savings could offset these costs. Partnerships between food service establishments and distributors to optimize their shipment frequencies has the potential to be financially beneficial to both sectors, while also significantly reducing overall GHG emissions.

## 6.6 Conclusions

The food services sector in AC provides about 25% of the food that is eaten by residents and constitutes about 28% of the food entering the food system. Of the food entering this sector, we estimate that 28% is wasted.

We estimate that the food services sector causes 270,000 tonnes of $CO_2$-eq emissions each year in AC. The majority of these emissions, about 235,000 tonnes of $CO_2$-eq, are caused by the sector's electricity consumption for food storage. If all refrigeration appliances are either regularly maintained or replaced with energy efficient units at the end of their lifetime, the food services sector could reduce total emissions by about 25%. Furthermore, decreasing food service establishments' storage capacity in exchange for more frequent distribution shipments might also significantly lower the County's carbon footprint. These emissions-reduction policies would also lower this sector's overall costs of electricity.

Reducing food waste in this sector would also lower GHG emissions. As restaurants are the highest producers of food waste, performing food waste audits and offering patrons different portion sizes could reduce GHG emissions. As cafeterias produce the second largest amount of food waste in this sector, practices like trayless dining and smaller plates would further reduce waste and emissions.

Although refrigeration contributes the most GHG emissions in this sector, all the policies highlighted above can have a positive environmental impact, and in many cases, a positive financial impact as well. For-profit food service establishments have an inherent incentive to reduce waste and energy consumption. It is likely, however, that critical information about how to optimize operations is lacking, suggesting a potential role for policy and further research.

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# Chapter 7: Residential Sector Emissions

This section characterizes the food consumption, food waste, and diet habits of consumers in Allegheny County and their resulting greenhouse gas emissions. Policy analysis and recommendations for reducing GHG emissions are made based on the current conditions found.

The motivation behind this chapter is to quantify food consumption and food waste arising in the residential sector. Section 7.1 discusses the current food system for the residential sector in AC. Section 7.2 discusses and outlines the estimates of residential food consumption, while Section 7.3 shows estimates of residential food waste. Both estimates were done by scaling national averages and case studies of similar cities to AC. Section 7.4 next discusses consumer diet habits found in AC, such as vegetarians and vegans. In Section 7.5, the additional GHG emissions created by the residential sector are quantified, as well as the differences in embodied GHG emissions associated with dietary habits. Section 7.6 discusses and analyses different public and private policy options and concludes with several policy recommendations.

For the purpose of this study the scope of residential food consumption can be divided into two categories based on where the food was purchased. First, is the category for food purchased from retail food distributors such as supermarkets and grocery stores. Second is the category for food brought home from the food services sector. This includes items such as takeout and leftovers. These two categories encompass the total amount of food that is consumed or prepared at home for the residential sector.

## 7.1 Characterization of Residential Food System

To help understand the residential food system in AC, we also wanted to characterize food insecurity, how far people travel to get groceries, and food spending based on income. Food insecurity for the purpose of this report is defined as not being able to afford enough food to feed oneself or one's family. A food desert is defined as a census tract that meets certain USDA thresholds for low income and low access to a supermarket or large grocery store (USDA, 2011).

As with many urban areas, AC has issues with both food insecurity and food deserts. Based on a study by Feeding America, 13.1% of people in the county, including children, are food insecure (Gundersen et al., 2018). Therefore, many residents use federal nutrition programs, like the Supplemental Nutrition Assistance Program (SNAP) and Nutrition Program for Women, Infants, and Children (WIC), to feed themselves and their families. SNAP and WIC are programs that provide additional financial assistance for food purchases to those who cannot afford sufficient amounts of food themselves. Also, about 18% of AC residents have low supermarket access (Murray, 2017). Although this report does not provide an in-depth analysis of, or solution to, the food deserts and food insecurity in AC, it is important to understand the current conditions of the residential food system to properly shape policy recommendations that will fulfill the needs of consumers and have the largest impact on GHG emission reductions.

## 7.2 Food Consumption Estimates

Consumption estimates for the residential sector were obtained by first finding the total food consumed in AC and then scaling down to the residential sector. The total food consumed estimate uses the national average food and beverage consumption estimates described earlier in Section 6.2.1. That yielded a total per capita annual consumption of 400 kg of food and 360 kg of beverages, totaling 760 kg/capita per year. As discussed in Section 6.2.1, approximately 25% of that total is consumed in the food services sector, leaving 75% consumed in the residential sector. Multiplying the per capita amounts by the population of AC (1.22 million people), and taking 75% of the totals results in estimates of 364,000 tonnes/yr of solid food and 323,000 tonnes/yr of beverages consumed by AC residents. Thus, the total consumption of food, both solid and beverages, is therefore 687,000 tonnes per year in the AC residential sector.

## 7.3 Food Waste Estimates

As with the food services sector, we next need to estimate the amount of food waste to obtain an estimate of the total quantity of food purchased by the residential sector. Residential sector waste is characterized as all food that residents in AC dispose of in their households. This includes inedible food parts, such as bones and banana peels, as well as uneaten food.

### 7.3.1 Food Waste Estimates

Residential food waste was calculated in two ways to account for the uncertainty in published estimates. One estimate was computed similarly to the food consumption estimate by taking national data and scaling it to AC, as shown in equation (7.1).

$$Residential\ Food\ Waste\ =\ [National\ food\ waste\ per\ household]\ x\ [Households\ in\ AC] \quad (7.1)$$

Based on an EPA (2015) estimate, the average food waste produced per household is 276 kg/household/yr). Using equation 7.1 and multiplying by the number of households in AC (536,000 households) estimates total food waste of 148,000 tonnes food wasted/yr.

For the second estimate, we used an NRDC food waste study (NRDC, 2017). In that study, the average waste produced per person was found to be 118 kg/person/year. Multiplying this by the population of AC (1.22 million people) gives a total ood waste estimate of 144,000 tonnes/yr.

These two estimates are similar. For the purposes of this study we took the average value of these two estimates giving us a total food waste in the residential sector of 146,000 tonnes/yr. Therefore, the total food entering the residential sector is given by the equation:

$$Total\ food\ in\ sector\ =\ Food\ consumption\ +\ Beverage\ consumption\ +\ Food\ Waste \quad (7.2)$$

Using equation 7.2, the total food entering the residential sector was calculated to be 833,000 tonnes per year.

## 7.4 Consumer Diet Habits

Consumer diet habits in AC are classified as either specific types of diets, like vegetarian, or are reflected indirectly in data on obesity rates. Quantifying diet habits can help us characterize what consumers are eating and how we can then devise policies to simultaneously improve nutrition, reduce food waste, and reduce GHG emissions within the residential sector.

Based on a national survey performed by *Vegetarian Times* (Vegetarian Times, 2017), about 3.5% of U.S. adults are vegetarian, 0.5% are vegan, and 10% follow a "vegetarian inclined diet." Applying these numbers to AC, and assuming about 75% of AC is over the age of 18, these percentages equate to about 32,000 vegetarians, 4,600 vegans, and 92,000 adults following a "vegetarian inclined diet." All of these are assumed to be classified as "low meat eaters" and vegetarians. It is then assumed that about 10% of the population are high meat eaters, and the rest are medium meat eater. The GHG emissions embodied in these categories of diet habits are analyzed in Section 7.6.4.

AC reports that about 30% of adults in the County are obese (Allegheny County, 2018). Obesity rates are important to consider while looking at policy options since they may be connected to a lack of fresh produce and other healthier food options, but no direct analysis has been performed.

## 7.5 Greenhouse Gas Emission Estimates

The residential sector is responsible for GHG emissions not only along the entire food chain due to the embodied emissions in food consumption, but also within the sector itself, primarily through emissions arising from energy consumption from refrigeration for food storage, and from disposal of food waste.

### 7.5.1 Emissions from Food Waste Disposal

As in the food services sector discussed earlier, residential food waste continues to generate additional GHG emissions following its disposal, with exact emissions depending on the disposal method. Based on the same percentages used earlier in Section 6.3, we assume that 6% of residential food waste is composted while the remainder is sent to landfills. This results in 8,600 tonnes composted and 137,000 tonnes landfilled annually from the residential sector. Also, as in Section 6.3, we assume that each tonne of food waste sent to landfills results in 0.45 tonnes of $CO_2$-eq in GHG emissions, while each tonne sent to compost results in 0.20 tonnes of $CO_2$-eq saved. Consequently, the resultant post-disposal emissions generated from residential food waste in AC is 60,100 tonnes of $CO_2$-eq annually.

### 7.5.2 Emissions from Food Storage

Another method with which the residential sector adds to the greenhouse gas emissions of the AC food system is through energy consumption from refrigeration for food storage. According to the U.S. Energy Information Administration's Residential Energy Consumption Surveys (REF), the average household in the Northeast Middle Atlantic uses 701 kWh of electricity on refrigeration in a year, about 50 kWh less than the national average. Factoring in 0.57 kg $CO_2$-eq/kWh from Section 4.2 (for the Pennsylvania electric grid), these 701 kWh of electricity contribute 400 kg $CO_2$-eq per household per year. For the entire residential sector in AC this totals 375 GWh of electricity consumed and 214,000 tonnes of $CO_2$-eq produced from household refrigeration each year.

### 7.5.3 Emissions Embodied in Consumer Diet Habits

Although these are not additional emissions to the total in AC, considering the embodied emissions of diet habits is important while shaping policy recommendations. Different types of diets have been shown to have different amounts of GHG emissions attached to them, since products like meat result in higher emissions than, say, fruits and vegetables.

To quantify the impact of consumption in the residential sector, we consider how diet habits directly influence emissions. Specifically, how much meat a person consumes can have a significant impact on GHG emissions. For example, vegetarian diets produce nearly half the quantity of $CO_2$-eq per day compared to high meat eaters, and vegans account for less than half the emissions of even a medium meat eater (Scarborough et al., 2014).

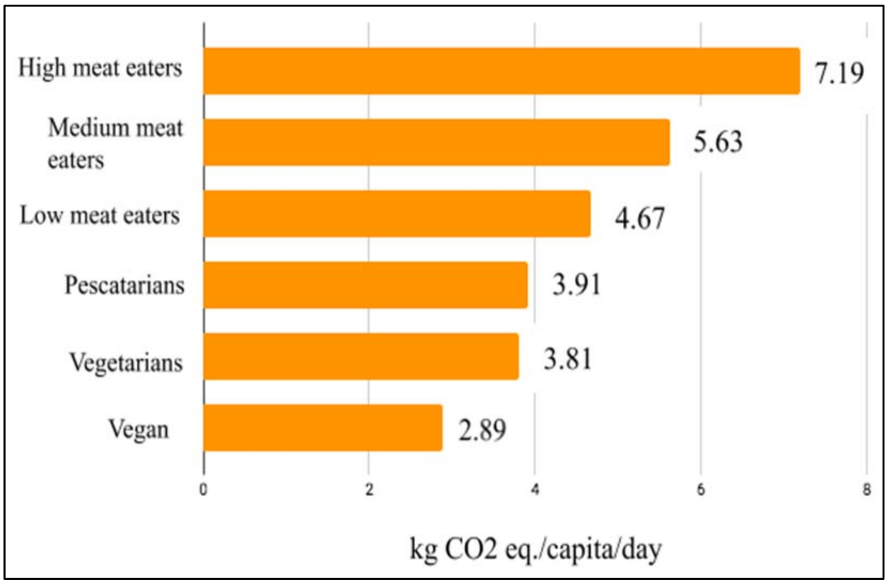


*Figure 7.1: Embodied GHG Emissions based on Consumer Diets (Scarborough et al., 2014)*

As seen in Figure 7.1, different diet habits have large effects on the embodied GHG emissions in food consumed. According to the Scarborough study, a high meat eater classifies as a person who consumes more than 100 grams of meat per day, a medium meat eater consumes between 50 and 99 grams of meat per day, and a low meat eater consumes less than 50 grams of meat per day. A vegetarian diet consumes zero grams of meat per day, though some other animal products may be present, and a vegan diet consumes zero grams of meat and other animal products per day.

Table 7.1 outlines the total embodied emissions based on consumer diets and the estimated percentage of each diet type in AC, assuming that 75% of the population are adults. Embodied GHG emissions decrease as less meat and dairy products are consumed. There are large differences in GHG emissions per year between a medium meat-eater and a vegetarian. These emissions are embodied because the food consumed results in GHG emissions as a result of its production, packaging and transportation processes.

*Table 7.1: Embodied GHG Emissions based on Consumer Diets*

| Diet | Percentage in Allegheny County[a] | Embodied GHG Emissions (1,000 tonnes $CO_2$-eq/yr) [b] |
|---|---|---|
| High meat eaters | 10% | 240,000 |
| Medium meat eaters | 76% | 1,432,000 |
| Low meat eaters | 10% | 156,000 |
| Vegetarians | 3.5% | 45,000 |
| Vegans | 0.5% | 4,800 |

[a] Percentages for vegan, vegetarian and low meat-eater diet were obtained from a national poll. Others estimates were based on a distribution of diets.

[b]GHG emissions were calculated as follows: 75% * [Population of Allegheny County] * [Percent on Diet Type] * [Diet Emissions Factor] * 365 da/yr

### 7.5.4 Embodied Emissions in Discarded Food Waste

To quantify the full impact of waste in the residential sector, we also calculated potential savings (in emissions) from un-consumed residential food. Specifically, we calculated how much GHG was being emitted as a result of producing food that ultimately would not be eaten in the residential sector. We took the estimate of food waste generated in AC (144,000 tonnes/year) and scaled it by the associated $CO_2$-eq emissions (EPA, 2019). From there, we were able to create three estimates that demonstrate potential GHG savings from changes in diet, as seen in Table 7.2.

*Table 7.2: Potential Emission Savings from Un-Consumed Foods*

| Diet Type | Emissions Factor (kg $CO_2$-eq/kg product) | Annual Savings (tonnes $CO_2$-eq/yr) |
|---|---|---|
| Low (non-meat) | 0.76 | 110,000 |
| Medium (weighted averages) | 3.66 | 530,000 |
| High (meat only) | 15.10 | 2,200,000 |

The low estimate assumes that all food waste in the residential sector stems from fruits. Similarly, the high estimate assumes that all food waste in the residential sector is beef. This has a significant impact and results in a twenty-fold increase in $CO_2$-eq emissions over the low estimate. Finally, the medium estimate was calculated using a distribution of identified foods from the NRDC (2017) study on food waste. In total, the medium estimate is 530,000 tonnes of $CO_2$-eq per year in AC. These estimates show the wide range of GHG reductions potentially achievable by policies directed toward reducing food waste in the residential sector.

## 7.6 Policy Options to Reduce GHG Emissions

The three areas we have chosen to focus on for the residential sector policy analysis are changing consumer diet, reducing food waste, and upgrading refrigerators. By targeting these three areas, we hope to find solutions to reduce overall GHG emissions within the AC food system.

### 7.6.1 Changing Consumer Diet

For changing consumer diets, we found that "Green Carts" and public education might be effective policies. Halliday et al. (2019) developed a menu of actions to shape urban environments for improved nutrition which focused on case studies throughout the world. These case studies focused on encouraging healthy eating and discouraging unhealthy retail through zoning permits and licenses, fiscal measures, and business advice and training.  For example, New York City implemented a new class of permits for "Green Cart" street vendors who sell fresh fruits and vegetables in various locations. This specifically targets local consumption of healthy foods in regions where there are not enough supermarkets (also known as food deserts), a common diet problem in urban areas. It can also reduce overall food waste and transportation-related emissions by providing people with local access to a more constant food supply. This particular intervention was implemented because of the strong correlation found between residents in food deserts and low consumption of locally sourced fruits and vegetables. Since its implementation, the overall demand for fruits and vegetables in the region of the Green Carts has increased significantly.

Another way to change diet habits is through public education. A possible platform for public education is digital marketing and college campuses. A recent Deloitte study found that although only 4% of grocery shopping is done online, more than half of consumers are influenced by digital media while shopping (Rose, 2019). By targeting online advertisements and education about diet habits, AC could reach a wide network of consumers.

### 7.6.2 Reducing Food Waste

For reducing food waste, we have chosen to focus on the role of education in shaping consumer habits. A Stanford University program on moving towards zero waste was implemented in reaction to the crisis of global climate change and with the idea that further education could make a substantial difference. Over the past few decades, Stanford has implemented major programs relating to recycling, composting, and overall education for waste minimization. They have also established programs such as the "My Cardinal Green" engagement program which rewarded students who signed up to learn more about minimizing environmental impact and maximize sustainability efforts across campus. The overall implementation of these programs across the campus decreased the amount of waste sent to landfills by about 41%, from 14,000 tons in 1998 to 8,190 tons in 2017 (Kekauoha, 2018).

Even though the populations of Stanford and AC are very different, the ways in which Stanford encouraged people to learn more about recycling and composting could be applicable to the county. A lot of zero-waste implementation has been aimed towards the way that the dorms are structured and how students are taught to establish sustainable habits that they can further expand to their own lives after they graduate. Therefore, since Pittsburgh's concentration of students is so high, targeting students living in dorms and incentivizing them to reduce waste could have a long-term impact on emissions in the area (Sustainable Stanford, 2019).

In conjunction with public education, consumer spending can be targeted. In 2015, the average household spent $4,015 on food at home (Bureau of Labor Statistics, 2016). Savings can be framed to the individual so they will be motivated to spend less on groceries while also reducing their food waste.

### 7.6.3 Upgrading Refrigerators

In terms of refrigeration, there do not seem to be current city-wide incentives for a consumer to upgrade their refrigerator. However, the impact of refrigeration on emissions is significant. The company Energy Star has focused their promotional efforts on getting people to upgrade their refrigerators to achieve both energy and monetary savings. The “Flip your Fridge” messaging uses a combination of statistics and behavioral science to persuade people into buying new refrigerators. An example is: “Replacing a 15-year old refrigerator with one that has earned the ENERGY STAR could save you $260 over the next five years and reduce your carbon footprint by 8,200 lbs of $CO_2$ over the lifetime of the product.” They also have a calculation tool that estimates total energy consumption and savings.

Energy consumption from refrigerators depends on the age of the refrigerator—newer refrigerators are much more energy efficient than older refrigerators, especially for refrigerators older than 20 years. Table 7.3 shows the total energy and GHG emissions savings tied to replacing older refrigerators with new ones, based on the distribution of refrigerator ages in the Northeast Middle Atlantic and 536,000 households as in AC.

*Table 7.3: Potential Emissions Savings from Replacing Old Refrigerators (U.S. EIA, 2019)*

| Primary Refrigerator Age | Percentage of Total Refrigerators in AC | Energy Savings (GWh/yr) | GHG Emissions Savings (1,000 tonnes $CO_2$ eq) |
|---|---|---|---|
| <5 years | 32% | -- | -- |
| 5-9 years | 35% | 9.3 | 5.3 |
| 10-20 years | 28% | 36.2 | 20.6 |
| 20+ years | 5% | 14.2 | 8.1 |

As seen in Table 7.3, upgrading refrigerators would reduce GHG emissions. Replacing10-20 year-old refrigerators would result in the largest savings of energy and GHG emissions, given their larger proportion and low efficiency. Table 7.4 shows the money that could be saved over a five-year period from upgrading a single refrigerator based on its age. The average savings over five years is substantial for refrigerators older than 20 years. These savings can be marketed to the consumer as an incentive to upgrade their refrigerator to an ENERGY STAR model.

*Table 7.4: Energy Cost Savings for Refrigerator Upgrade (ENERGY STAR, 2019)*

| Primary Refrigerator Age | Average Energy Cost Savings over 5 Years if Upgraded |
|---|---|
| <5 years | -- |
| 5-10 years | $28 |
| 10-20 years | $136 |
| 20+ years | $715 |

### 7.6.4 Comparison of Policy Options

To determine which policy would have the highest impact, we calculated how GHG emissions would be reduced by a 10% change in each of the previous three policy areas. These amounts are given in Table 7.5.

*Table 7.5: Potential Emissions Savings from Policy Options*

| Policy Type | Policy Action | GHG Emissions Saved Per Year (1,000 tonnes $CO_2$eq) |
|---|---|---|
| Changing diet | 10% medium meat eaters become vegetarian | 78.0 |
| Reducing food waste | 10% of food saved from landfill | 5.0 |
| Upgrading refrigerator | 10% of old refrigerators upgraded | 3.4 |
| **Total GHG Savings** | | **95.4** |

Table 7.6 summarizes a consumer's savings per year if they changed their diet, reduced their food waste, or upgraded their refrigerator.

*Table 7.6: Individual Savings as a Result of Investing in the Policy.*

| Policy Action | Direct consumer action | Average individual savings per year | Source |
|---|---|---|---|
| Changing diet | Become vegetarian | $750 | Journal of Hunger & Environmental Nutrition |
| Reducing food waste | Buy 10% less food | $400 | Bureau of Labor Statistics |
| Upgrading refrigerator | Upgrade a 15-year-old refrigerator to an ENERGY STAR model | $30 | ENERGY STAR |

Based on Tables 7.5 and 7.6, we find that changes in diet habits would have the highest impact on reducing GHG emissions as well as the largest payoff to a consumer. With feasibility in mind, we believe that working with higher education in AC would be an effective way to reach a large number of people, since there are currently 80,852 college students in the county (College Tuition Compare, 2019). Schools could be encouraged to adopt part of Stanford's zero waste policies as well as advertising better diet habits.

Another effective way to educate the public about food waste and diet habits is through a communications campaign, including the use of digital media. By directly discussing the monetary savings of a vegetarian diets or reducing food wastes, consumers might modify their habits. Also, by investing in Green Carts, existing issues of food deserts and food insecurity could be addressed while also improving the diet of vulnearable populations. Tax incentives and rebates to upgrade to newer refrigerators is a reasonable policy option as well. Combining incentives from the government with the framing of savings to individuals might encourage households to upgrade their refrigerators.

## 7.7 Conclusions

This chapter focused on quantifying the total food consumption of the residential sector of AC, along with the total amounts of food waste and the additional GHGs arising from waste disposal and electrical energy used for food storage. We estimated that county households take in approximately 833,000 tonnes of food per year, of which 146,000 tonnes (17.5%) is discarded as waste that ends up in a landfill. The decomposition of this food waste produces emissions of methane, a powerful greenhouse gas. Food waste also represents a direct financial loss for consumers. In terms of policy options to reduce GHG emissions in the residential sector, we find that measures focused on changing consumer diets to reduce meat consumption, reducing food waste, and upgrading refrigerators to more energy-efficient models can have a large impact on reducing food-related GHG emissions in AC.

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# Chapter 8: Conclusions and Recommendations

The preceding chapters have defined the major elements of the urban food system supplying Allegheny County, Pennsylvania. This region of 1.2 million people includes 128 municipalities, the largest being the City of Pittsburgh. This study represents the first attempt to characterize the types and quantities of foods consumed in this region, and the "carbon footprint" associated with the production, packaging, transport, storage, and wastes produced by this system.

Our first overall conclusion is that quantifying the amounts and types of food coming into this (or any) urban region is a difficult task, beset by uncertainties due to the lack of any systematic, publicly available data. Thus, while there are many published studies and reports related to food consumption and food waste, as well as national databases on relevant parameters such as food freight shipments between points of ownership, there is nonetheless a lack of reliable, systematic data on food quantities delivered to, or shipped from, major metropolitan areas. Nor is there a standardized nomenclature for what constitutes "food"—while some terms are in common use, there are also significant differences in the terms and categories used by different organizations.

This problem is further compounded when the objective is to quantify the greenhouse gas emissions associated with the urban food system. Again, while peer-reviewed studies are available to quantify the life cycle GHG emissions associated with certain food types, the lack of standardized food categories, coupled with differences in nomenclature and measures of quantification (e.g., mass vs. volume), hampers efforts to conduct such an analysis. Even the question of whether "food" includes both solid foods as well as liquid beverages is often ambiguous or defined differently by different studies.

Thus, our study draws upon a variety of sources and approaches to achieve its objectives, and attempts to carefully define and delineate the terms and measures used to quantify food types, amounts, and GHG consequences. This chapter briefly summarizes the key conclusions and recommendations of this study.

## 8.1 Summary of Food Quantities in Allegheny County

Table 8.1 shows our best estimate of the total quantity of food consumed annually in AC, along with the amounts of food waste sent to regional landfills. The total of 1.25 million metric tons (tonnes) per year excludes the weight of all food packaging (which adds about 8% to the total food weight). Figure 8.1 shows how this total quantity is divided among the major consuming sectors analyzed in this study. As depicted in the diagram, approximately 26% of AC's food goes into the food services sector. The remaining 74% goes into the retail food sector which, in turn, supplies the residential sector. The percentage of food waste varies by sector, as shown in Table 8.1. Overall, we find that approximately 27% of all food is wasted.

Because of the lack of standard measuring and reporting of food quantities there is uncertainty in the "best estimate" quantities shown above. Other estimates of the total AC food consumption derived using different methods ranged from 1.2 to 1.5 million tonnes/yr (see Section 5.1).

*Table 8.1: Quantity of Food Used in Allegheny County in 2017, Excluding Packaging*

| Sector | Food Mass into Sector (tonnes/yr) | % Total Mass In | Food Waste out of Sector* (tonnes/yr) | % Waste in Sector |
|---|---|---|---|---|
| **Distribution** | 1,251,800 | 100 | 6,300 | 0.5 |
| **Food Services** | 320,000 | 26 | 92,600 | 28.1 |
| **Retail** | 925,600 | 74 | 146,000 | 10.0 |
| **Residential** | 833,000 | 67 | 90,000 | 17.5 |

* Total waste in all sectors is 334,500 tonnes. Values shown may not sum to total due to rounding.

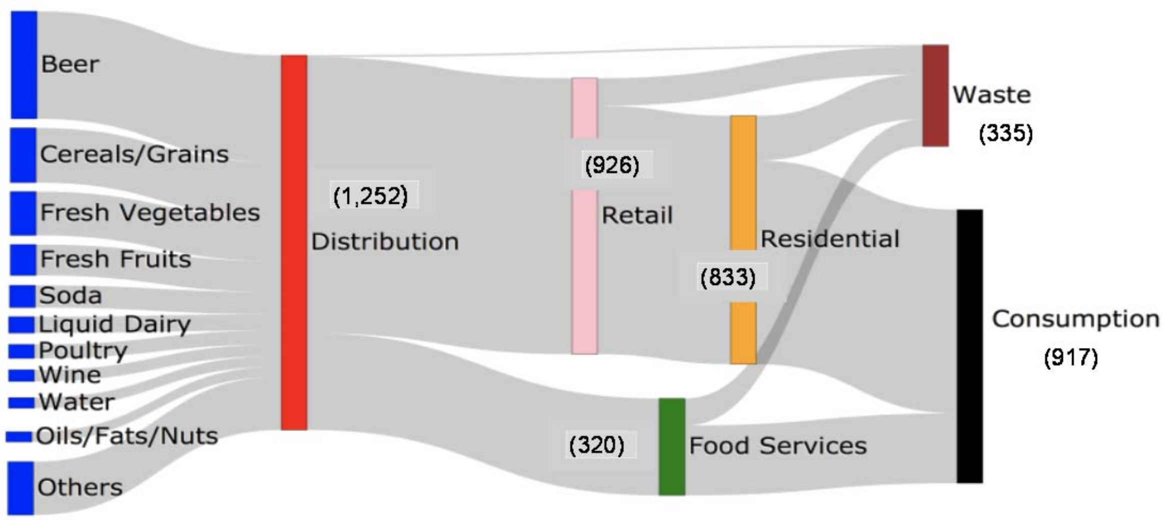


*Figure 8.1: Quantities of Food Flow in Allegheny County, 2017 (all values in 1,000 tonnes/yr)*

The types of foods consumed in AC were categorized for consistency with available data on food system GHG emissions. To estimate the quantities of different food categories, we mapped the GHG-based food categories with the groupings used to track food shipments in the U.S. Table 8.2 shows the top ten products based on their total weight (including packaging). On this basis, the top three categories are beer, cereals/grains, and fresh vegetables.

*Table 8.2: Top 10 Foods by Weight Consumed in Allegheny County*

| Food Type | % by Weight |
|---|---|
| Beer | 29% |
| Cereals/Grains | 15% |
| Fresh Vegetables | 12% |
| Fresh Fruits | 8% |
| Soda | 6% |
| Liquid Dairy | 4% |
| Poultry | 4% |
| Wine | 3% |
| Water | 3% |
| All Others | 17% |

## 8.2 Summary of Greenhouse Gas Emissions

The total "carbon footprint" of the AC food system was estimated to be 3.7 million tonnes of carbon dioxide equivalent gases emitted per year. Of this, 71% (2.6 million tonnes) represents the "embodied emissions" associated with the production and packaging of food that is delivered to warehouses serving AC. Most of this food comes from regions far outside the county, although accurate data on the true origin of all food shipments are not available. However, adjustments to the Department of Transportation's Freight Analysis Framework (FAF) data based on actual distances for AC produce shipments indicated an average distance of 1,356 km (approximately 850 miles).

The remaining 29% of GHGs arise from three additional sources: (1) transportation of food into the county, as well as transportation of food and food waste within the county; (2) the use of energy (mostly electricity) for refrigeration and other food storage needs, and (3) landfill gases arising from the decomposition of food waste in landfills. The breakdown as a percentage of total GHGs is 18% from energy for storage, 7% from energy for transportation, and 4% from landfill emissions.  Figure 8.2 depicts the quantities of GHGs in different parts of the AC food system.

Table 8.3 gives the top ten food items as a percentage of the total embodied emissions of all food types.  This ranking is quite different from the one based on mass. Here, the biggest contributor to GHG emissions is the consumption of beef, followed by beer and poultry.

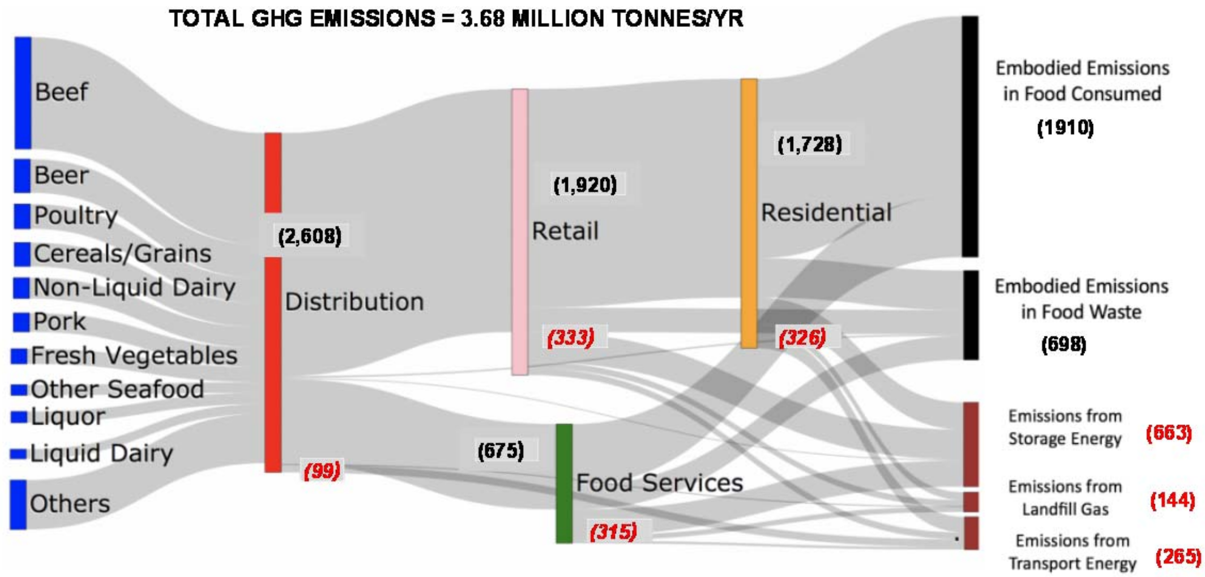


*Figure 8.2: Greenhouse Gas Emissions for the Allegheny County Food System, 2017*
*All values are in 1,000 tonnes $CO_2$-eq/yr). Numbers in black are embodied emissions from food production and packaging; values in red are total additional emissions from landfills and energy used for food transport and storage.*

*Table 8.3: Top 10 Food Items in Allegheny County by Embodied GHG Emissions*

| **Food Type** | **% of Embodied GHGs** |
|---|---|
| Beef | 34% |
| Beer | 10% |
| Poultry | 8% |
| Cereals/Grains | 7% |
| Non-Liquid Dairy | 6% |
| Pork | 6% |
| Fresh Vegetables | 5% |
| Liquor | 3% |
| Other Seafood | 3% |
| All Others | 18% |

## 8.3 Summary of Policy Recommendations

Policy measures to reduce GHG emissions can be found across all sectors of the AC food system. Chapter 3–7 of this report presented details of policy options recommended for each of the major sectors studied, including food production, transportation, wholesale and retail distribution, food services, and residential consumption. Here we summarize some of the major recommendations, several of which cut across multiple sectors of the overall food system.

Our analysis has shown that the most impactful policies to reduce GHG emissions are those that either focus on reducing food waste or alter consumer diets. Both measures can significantly reduce the embodied emissions stemming from food production, which contribute most to the total GHG emissions of the food system. Waste reduction additionally reduces emissions arising from waste transport and landfill operations. Thus, we recommend exploring the public education options discussed in earlier chapters.

For example, a Stanford University study discussed in Section 7.6 reduced food waste by educating students on college campuses. We believe that using college campuses as a way to educate the public about diet habits and food waste can be a powerful platform because the college population in AC is large, and because young adults have been proven to adjust their diets more often to follow trends they see and learn about. Student-focused education also could extend to high schools and middle schools.

Another platform for public education is online "advertising." More than half of grocery shoppers use the internet to guide their shopping. By investing in online advertising, more shoppers could become better educated in the implications of their diet habits and be encouraged to change what they choose to buy at grocery stores. Along with educating consumers on the benefits of changing their diets and reducing their food waste, it is important to emphasize the financial savings an individual will recieve by making such changes. For instance, it is estimated that a vegetarian diet costs $750 less per year than the medium meat-eater diet commonly followed in AC. Also, buying less food, and ultimately reducing food waste, can save around $400 per person, per year.

Another measure to improve diets is to implement a program of "Green Carts" (or some variation) to supply fresh fruit and produce to communities in need. A program targeted at serving low-income populations and ameliorating "food deserts" would not only help reduce emissions related to diet, but also decrease the distance that people in affected communities must travel to obtain locally-sourced food (see Section 7.6.1).

GHGs can also be reduced by policies aimed at reducing the energy used for food storage. For example, based on the age of their primary refrigerator, an individual can save from $30 to $1,000 over a five year period by upgrading their refrigerator to an Energy Star model. Food service providers can similarly see substantial energy savings by upgrading, repairing, or downsizing their refrigeration equipment. Because consumers and business owners tend to be financially driven, these are good reasons for them to change their current inefficient equipment. We recommend that the county explore the possibility and cost of providing a rebate or tax credit to households and establishments who trade in their old refrigerator for a new Energy Star model to provide additional financial incentives to these stakeholders. Such a program would supplement the state and utility company rebates that are currently available to small businesses and households for certain types of energy-efficiency improvements.

Other measures expanding beyond those above can also contribute significantly to reducing GHG emissions. In the food production sector, AC could invest in alternative agricultural practices, such as regenerative farming, that can be implemented at a regional or statewide level (see Section 3.6). Various options exist to reduce GHG emissions from the food transport sector. Given the high contribution of consumer trips to purchase food, we recommend policy incentives for grocery stores or others to invest in optimizing grocery delivery services so that consumer trips are reduced (see Section 4.7). To reduce emissions stemming from the wholesale, retail, food services and residential sectors, both public and private organizations should be incentivized to incorporate more green energy practices, and expand programs that redirect excess food and potential food waste to those in need, such as 412 Food Rescue and the Greater Pittsburgh Community Food Bank (see Sections 5.4, 6.5, and 7.6). Expanding and promoting public education programs in each sector is also recommended so that people in AC live healthier lives with a lower carbon footprint.

Government agencies at the county, state, and federal levels should review current practices regarding "sell by" and "best if used by" food labeling to determine whether, or to what extent, such labels are inadvertently causing unnecessary food waste. If so, current practices should be changed or modified.

To facilitate future studies of the environmental and other impacts of the urban food system, agencies should also undertake efforts, including public-private partnerships, to collect standardized data of the type sought in this study on the quantities and types of food consumed in major regions of interest, including at the county and state levels. Such data collection efforts could be modeled on those for the energy sector, where publicly available information on the quantities and types of fuels is critical to an understanding of their environmental impacts and ways to reduce them. Our food system needs an analogous effort.

# Appendices

## Appendix A: Food Waste Disposal Profile

The percentage of food waste in Allegheny County that is going to various waste streams is estimated based on national data released by the U.S. EPA (2018a).

*Table A1: National Food Waste Disposal Profile*

| Disposal Method | Food Waste in 2014 (tonnes) | Food Waste in 2015 (tonnes) | Average Food Waste (tonnes) | % of Total |
|---|---:|---:|---:|---:|
| Landfill | 29,530 | 30,250 | 29,890 | 76% |
| Compost | 1,940 | 2,100 | 2,020 | 5% |
| Combustion | 7,200 | 7,380 | 7,290 | 19% |
| **Total** | **38,670** | **39,730** | **39,200** | **100%** |

According to the Allegheny County Health Department's Municipal Solid Waste Plan, there are no waste combustion facilities to which the county sends its waste (2018). Therefore, this practice is not considered in the baseline disposal profile of the county. If only the relative amount of national landfill and compost quantities are considered, it appears that 4% of food waste is composted and the remaining 94% is sent to a landfill.

Because Allegheny County may not be representative of the rest of the country, we verified these proportions with data specific to the county. From 2013 to 2016, Allegheny County reported the quantity of food waste that they recycled, which is assumed to mean composted. The average of these values was about 4,000 tonnes of food waste composted annually (2019). According to the aforementioned ACHD Municipal Solid Waste Plan, there are about 200,000 tonnes of total food waste annually in the county. This indicates that about 2% of the total food waste is composted, which is similar to the national proportion estimate. We ultimately chose to use 4% composting for our emissions model because the quantity of food waste composted is self-reported by the county, and we consider national data to be more reliable.

As described in Section 2.2.4, the average landfill emission factor is derived from the EPA Waste Reduction Model (WARM) (2019a) as follows.

Most landfills in America burn some of their landfill gas to produce energy and the rest is simply burned without energy recovery, which is known as flaring. Each of these processes have different emission factors reported by the EPA (2019b). The process of recovering energy has an emission factor of 0.42 tonnes $CO_2$ equivalent per tonne of food waste and the process of flaring has an emission factor of 0.54 tonnes $CO_2$ equivalent per tonne of food waste. The EPA then determined its average landfill emission factor by created a weighted average of these two factors based on the national average percentages of gas burned for energy and gas flared, which are 63% and 37%, respectively. The Imperial Landfill in Allegheny County has the same proportion of energy recovery and flaring as the national average, so this report assumes that these proportions represent all of the landfills in the county (Carnegie Mellon University, 2018).

For each of these factors, transportation accounts for 0.02 tonnes $CO_2$ equivalent per tonne of food waste (EPA, 2019b). Because the emissions from transportation are calculated independently in this report, the contribution of transportation is subtracted from the landfill emissions factor to get of 0.40 tonnes $CO_2$ equivalent per tonne of food waste for energy recovery and 0.52 tonnes $CO_2$ equivalent per tonne of food waste for flaring.

Further, the national average avoided emissions from energy recovery is -0.10 tonnes $CO_2$ equivalent per tonne of food waste. However, the carbon intensity of electricity in Pittsburgh is lower than the national average. These emissions factors for Pittsburgh and the national average are 0.71 tonnes $CO_2$-eq/MWh and 0.57 tonnes $CO_2$-eq/MWh, respectively (EPA, 2018b; Carnegie Mellon University, 2018). Scaling the avoided emissions by the ratio of local to national emission factors leads to avoided emissions of -0.08 tonnes $CO_2$ equivalent per tonne of food waste. After making these adjustments, the process of recovering energy has an emission factor of 0.42 tonnes $CO_2$ equivalent per tonne of food waste and the emission factor of flaring is unaffected. The weighted average is then recalculated as follows.

$$\left(0.42\,\frac{tonnes\ CO_2eq}{tonne\ food\ waste}\right) * 63\% + \left(0.52\,\frac{tonnes\ CO_2eq}{tonne\ food\ waste}\right) * 37\% = 0.45\,\frac{tonnes\ CO_2eq}{tonne\ food\ waste}$$

Hence, the average landfill emissions factor for Allegheny County is 0.45 tonnes $CO_2$ equivalent per tonne of food waste. Note that the electricity emission factor adjustment is also applied to the other disposal practices to arrive at the rest of the values found in Table 2.1.

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## Appendix B: Food Source Sector Quantities

*Table B1. Sources for Food Consumption Values and Emission Factors*

| Unique Food Category | Food Quantification Source | Emission Factor Source |
|---|---|---|
| Non-Liquid Dairy | Food and Agricultural Organization of the United States (FAO), 2013 | Clune, Crossin, & Verghese (2017) |
| Liquid Dairy | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Beef | Nijdam, Rood, & Westhoek, 2012 [Carcass Weight], FAO, 2013 [Quantity] | Clune, Crossin, & Verghese (2017) |
| Pork | Nijdam, Rood, & Westhoek, 2012 [Carcass Weight], FAO, 2013 [Quantity] | Clune, Crossin, & Verghese (2017) |
| Lamb | Nijdam, Rood, & Westhoek, 2012 [Carcass Weight], FAO, 2013 [Quantity] | Clune, Crossin, & Verghese (2017) |
| Poultry | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Fish | Nijdam, Rood, & Westhoek, 2012 [Carcass Weight] | Clune, Crossin, & Verghese (2017) |
| Other Seafood | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Eggs | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Fresh Fruits | United States Department of Agriculture: Economic Research Service (USDA ERS), 2017 | Clune, Crossin, & Verghese (2017) |
| Fresh Vegetables | USDA ERS, 2017 | Clune, Crossin, & Verghese (2017) |
| Oils/Fats/Nuts | FAO, 2013 | Clune, Crossin, & Verghese (2017), Brodt, Kendall, Kramer, & Yuan, n.d. [Honey and Other Sweeteners] |
| Cereals/Grains | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Legumes | FAO, 2013 | Clune, Crossin, & Verghese (2017) |
| Water | Non-Alcoholic Drinks - worldwide, 2019 | Beverage Industry Environmental Roundtable (BIER), 2012b |
| Soda | Non-Alcoholic Drinks - worldwide, 2019 | BIER, 2012c |
| Juice | Non-Alcoholic Drinks - worldwide, 2019 | Heller, 2017 [Orange Juice]; Werner & Tholstrup, 2014 [Apple Juice] |
| Beer | FAO, 2013 | BIER, 2012a |
| Wine | FAO, 2013 | BIER, 2012e |
| Liquor | FAO, 2013 | BIER, 2012d |
| Canned Fruits and Vegetables | USDAERS, 2017 | Farnett, Smith, Nicholson, & Finch, 2016 |

**Quantification of Packaging**

The United States produces a total of 80.08 million short tons of municipal solid waste annually (EPA, 2017). Around half of total waste can be attributed to food containers and packaging (Vignali, 2016). Using 1,400 kg of food consumed per year (non-loss adjusted) (FAO, 2013) and a United States population of 326 million, we can estimate the percentage of packaging in each FAF category as follows. Note again that all of these figures are annual.

$$80.08\ million\ short\ tons\ MSW\ * (50\%) * (907.185\ kg/short\ ton) = 36.3 * 10^9\ kg\ packaging$$

$$36.3 * 10^9\ kg\ packaging/363\ million\ people = 112\ kg\ packaging/capita$$

$$\frac{112\ kg\ packaing/capita}{112\ kg\ packaing/capita\ +\ 1400\ kg\ food/capita} = 7.42\%\ packaging$$

**Disaggregation of FAF Food Categories and Calculation of Carbon Footprint**

Our general process to disaggregate the FAF categories was to determine the percentage of consumption that each food makes up and multiply it by the net category weight, subtracting non-edible products like packaging out of the total weight. Note that all Annual Consumption data is from the Food and Agriculture Organization of the United Nations (2013) unless otherwise noted.

*Table B2: Food Quantity and Carbon Footprint of Category 01-Animals and Fish*

| | | | | | FAF Net Category Weight (tonnes) = | | 55,315 |
|---|---|---|---|---|---|---|
| **FAF Subcategory** | **Annual Consumption (kg/yr)** | **Percent of Category by Weight** | **Edible Product Yield*** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **輟arbon Footprint (tonnes $CO_2$-eq/yr)** |
| Live bovine animals | 36.24 | 25.6% | 37.10% | 28.7 | 5,255 | 150,987 |
| Live swine | 27.64 | 19.5% | 56.25% | 5.8 | 6,077 | 35,369 |
| Live poultry | 50.01 | 35.3% | 0.56 | 4.2 | 10,947 | 46,305 |
| Live fish | 12.39 | 8.8% | 40.00% | 4.5 | 1,937 | 8,717 |
| Other live animals (sheep) | 0.43 | 0.3% | 34.50% | 27.9 | 58 | 1,618 |
| Other live animals (not sheep) | 4.30 | 3.0% | | | | |
| Packaging | 10.50 | 7.4% | | | | |
| Total | 141.51 | 100.0% | | | | **243,000** |

*(Nijdam et al, 2012)

The edible product yield of an animal is the percent by weight of meat that can be consumed over the total live weight of the animal.

*Table B3: Food Quantity and Carbon Footprint of Category 02-Cereal Grains*

| | | | | FAF Net Category Weight (tonnes) = | 28,274 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/year)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Grains | 93.39 | 92.6% | 1.0 | 26,175 | 26,175 |
| Packaging | 7.49 | 7.4% | | | |
| **Total** | **100.88** | **100.0%** | | | **26,000** |

*Table B4: Food Quantity and Carbon Footprint of Category 03-Agricultural Products*

| | | | | FAF Net Category Weight (tonnes) = | 270,466 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/yr)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Fresh vegetables | 91.90* | 47.9% | 0.8 | 129,426 | 106,129 |
| Dried vegetables | 5.94* | 3.1% | 0.8 | 8,369 | 6,862 |
| Fresh fruit | 64.71* | 33.7% | 0.7 | 91,141 | 61,976 |
| Dried fruit | 4.30* | 2.2% | 0.7 | 6,062 | 4,122 |
| Nuts | 7.86 | 4.1% | 1.1 | 11,070 | 12,398 |
| Legumes | 3.07 | 1.6% | 0.76 | 4,324 | 3,286 |
| Non-edible products | assume negligible | | | | |
| Packaging | 14.25 | 7.4% | | | |
| **Total** | **192.04** | **100.0%** | | | **191,000** |

*(USDA, 2017)

Category 04-Animal Feed, Eggs, Honey was calculated different than the other categories because this category had too many non-edible products in it to quantify. The only edible products in this category were eggs and honey. Other products include animal feed, raw hides and skin, wool, raw silk, etc. There were too many items to disaggregate for this category so we instead took our non-loss adjusted consumption data and multiplied it by the population of AC to get a rough estimate of the quantity and carbon footprint of eggs and honey.

*Table B5: Food Quantity and Carbon Footprint of Eggs and Honey*

| Food Category | Annual Consumption (kg/yr) | Allegheny Population (million) | Emissions Factor (kg $CO_2$-eq/kg) | Food Quantity (tonnes) | Carbon Footprint (tonnes $CO_2$-eq/yr) |
|---|---|---|---|---|---|
| Eggs | 14.58 | 1.223 | 3.4 | 17,831 | 60,627 |
| Honey | 0.67 | 1.223 | 1.1 | 819 | 901 |
| **Total** | | | | | **62,000** |

*Table B6: Food Quantity and Carbon Footprint of Category 05-Meat, Poultry, Fish, Seafood*

| | | | | **FAF Net Category Weight (tonnes) =** | 96,643 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/yr)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Beef | 36.24 | 24.7% | 28.7 | 23,862 | 685,560 |
| Pork | 27.64 | 18.8% | 5.8 | 18,200 | 105,921 |
| Lamb | 0.43 | 0.3% | 27.9 | 283 | 7,902 |
| Poultry | 50.01 | 34.1% | 4.2 | 32,929 | 139,290 |
| Fish | 12.39 | 8.4% | 4.5 | 8,158 | 36,712 |
| Seafood | 9.17 | 6.2% | 13.1 | 6,038 | 79,399 |
| Packaging | 10.89 | 7.4% | | | |
| **Total** | **146.77** | **100.0%** | | | **1,055,000** |

*Table B7: Food Quantity and Carbon Footprint of Category 06-Milled Grain Products*

| | | | | **FAF Net Category Weight (tonnes) =** | 157,637 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/yr)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Grains | 93.39 | 92.6% | 1.0 | 145,937 | 145,937 |
| Packaging | 7.49 | 7.4% | | | |
| **Total** | **100.88** | **100.0%** | | | **146,000** |

*Table B8: Food Quantity and Carbon Footprint of Category 07-Other Foodstuffs*

| | | | | FAF Net Category Weight (tonnes) = | 255,209 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/yr)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Milk and cream | 185.10* | 20.1% | 1.4 | 51,405 | 71,968 |
| Non-liquid dairy | 71.79* | 7.8% | 7.8 | 19,937 | 155,511 |
| Canned fruit | 6.11* | 0.7% | 1.5 | 1,696 | 2,543 |
| Frozen fruit | 2.17* | 0.2% | 2.3 | 602 | 1,355 |
| Canned vegetables | 38.46* | 4.2% | 1.5 | 10,682 | 16,023 |
| Frozen vegetables | 33.02* | 3.6% | 2.3 | 9,171 | 20,634 |
| Chips | 8.07* | 0.9% | 1.1 | 2,242 | 2,511 |
| Oils/fats/nuts | 106.37 | 11.6% | 1.1 | 29,541 | 33,086 |
| Coffee, tea, and spices | 8.04 | 0.9% | | | |
| Soda | 251.50** | 27.4% | 0.43 | 69,845 | 30,211 |
| Juice | 20.44** | 2.2% | 0.72 | 5,677 | 4,099 |
| Water | 119.67** | 13.0% | 0.09 | 33,234 | 2,973 |
| Packaging | 68.21 | 7.4% | | | |
| **Total** | **918.95** | **100.0%** | | | **334,000** |

*(USDA, 2017) **(Non-Alcoholic Drinks, 2019)

*Table B9: Food Quantity and Carbon Footprint of Category 08-Alcoholic Beverages*

| | | | | FAF Net Category Weight (tonnes) = | 434,863 |
|---|---|---|---|---|---|
| **Food Category** | **Annual Consumption (kg/year)** | **Percent of Category by Weight** | **Emissions Factor (kg $CO_2$-eq/kg)** | **Food Quantity (tonnes)** | **Carbon Footprint (tonnes $CO_2$-eq/yr)** |
| Beer | 78.93 | 77.8% | 0.74 | 338,403 | 250,992 |
| Wine | 8.47 | 8.4% | 1.95 | 36,314 | 70,887 |
| Liquor | 6.50 | 6.4% | 3.03 | 27,868 | 84,368 |
| Non-edible alcohol | assume negligible | | | | |
| Packaging | 7.53 | 7.4% | | | |
| **Total** | **101.43** | **100.0%** | | | **406,000** |

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# Appendix C: Distribution Sector Energy Quantities

**Sample Emissions Calculations**

The following general equation was used to calculate net emissions from food distributors in Section 5.2.1:

$$Emissions = \text{Electric Factor} * \text{Size} * \text{Emissions Factor} * \text{Stores}$$

Where Electric Factor is the distributor's average annual electricity use in $kWh/ft^2$, Size is the average size of a distributor in $ft^2$, Emissions Factor is the $CO_2$ emission rate for AC in kg of $CO_2$-eq emitted per kWh, and Stores is the number of stores of a specific distributor type in AC. This equation will produce a final value of Emissions in kg $CO_2$ eq.[2] See Table 5.2 for the primary applications of this calculation.

As an example of this calculation, take the grocery stores. They have an electric factor of 50 $kWh/ft^2$ (Energy Star, 2019). They have an average size of 50,000 $ft^2$, The standard emission factor for Pittsburgh used by this report is 0.57 kg $CO_2$/kWh (Sustainability at CMU, 2018). And there are 115 grocery stores in AC (Jones, 2016). Putting that all into the equation above yields the following:

$$AC\ Grocery\ Emissions = 50\ kWh/ft^2 * 50{,}000\ ft^2 * .57\ kg\ CO_2eq/kWh * 115\ stores = 163{,}000{,}000\ kg\ CO_2\ eq$$

The same equation can be used for any of the food distributor categories analyzed in section 5.1.

**Industry Data Calculations**

Industry data was provided for both grocery stores and convenience stores in AC. This data consisted of both electricity and natural gas use, making it more complete than the estimates found in Section 5.2.1. The industry data provided for industry grocery stores in AC was that their annual electricity usage is 48.4 $kWh/ft^2$ and their annual natural gas usage is 0.96 $therms/ft^2$. The industry data also gave average store sizes of 55,600 $ft^2$. That gives the following energy use per store:

$$\textit{Electricity Use/Store} = 48.4\ kWh/ft^2 * 55{,}600\ ft^2 = 2{,}690{,}000\ kWh/store$$

$$\textit{Natural Gas Use/Store} = 0\ .96\ therms/ft^2 * 55{,}600\ ft^2 = 53{,}400\ therms/store$$

Given that there are 115 grocery stores in AC (Jones, 2016) and the electricity emission factor is 0.57 kg $CO_2$-eq/kWh (Sustainability at CMU, 2018), we can perform the following calculation for AC grocery stores:

$$\textit{Annual GHG Emissions from Electricity} = 2{,}690{,}000\ kWh/store * 115\ stores * 0.57\ kg\ CO_2\text{-}eq/kWh = 176{,}300\ tonnes\ of\ CO_2eq$$

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[2] Out of convenience, for most of the report, this final value is then immediately converted into Metric Tonnes of $CO_2$ eq.

A similar calculation can be performed for natural gas, given the emission factor of 5.31 kg $CO_2$-eq/therm (Sustainability at CMU, 2018). As such, we can perform the following calculation for AC: grocery stores:

*Annual GHG Emissions from Natural Gas = 53,400 therms/store * 115 stores * 5.31 kg $CO_2$-eq/therm = 32,600 tonnes of $CO_2$eq*

There was less industry data available for convenience stores. The numbers available are annual energy/store, not annual energy/$ft^2$. In AC, an average convenience store annually uses 313,000 kWh and 3,269 therms of natural gas. As such, we can use the following calculations to find convenience store emissions in AC:

*Annual GHG Emissions from Electricity = 313,000 kWh/store * 984 stores * 0.57 kg $CO_2$-eq/kWh = 169,900 tonnes of $CO_2$eq*

*Annual GHG Emissions from Natural Gas = 3,269 therms/store * 984 stores * 5.31 kg $CO_2$-eq/therm = 17,100 tonnes of $CO_2$eq*

**References**:


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## Appendix D: Distribution Sector Food Quantities

Industry data was used to assist in quantifying the total amount of food purchased in Allegheny County. We obtained confidential data on the past 12 months of retail sales history for a selected set of stores in Allegheny County. After eliminating all non-food items, there were 53,358 food items listed and identified by: category description, group description, subgroup description, Universal Product Code, item description, item size, unit of measurement, unit of measurement quantity, and package quantity. A total of 10,034 food items sold at auxiliary operations such as in-store cafes and small convenience stores were removed, leaving 43,324 items purchased at retail stores.

Reported units of measurement were used as the first identifiers to quantify the total weight of food items sold. Separate lists were created based on the unit of measurement descriptions. Items reported in ounces or pounds were split into two separate spreadsheets and summed to find their total weight. Items measured in gallons, liters, milliliters, pints, and quarts were split into five separate spreadsheets, summed by their volumetric unit, then multiplied by the density of water (1 liter=1 kg) to estimate total weight. For these seven categories, if the reported unit of measurement was set at '0', the package quantity

The remaining 4,301 items had a non-specific unit of "each" to describe the size of each unit purchased. To estimate their weight, the most common clumping phrases were identified in the item description column: "bag," "bags," "independent," "item," "lb," "oz," and "pack." Items that had "lb," and "oz," in their descriptions were first identified. The number of lbs or ounces was pulled from the item description, multiplied by the item size and the package quantity to obtain the total weight of that item.

Items in the "bag," and "bags," category were primarily tea bags. Here, the net weight of the tea bag was found from an internet search and multiplied by the item size and package quantity. The unit weight of items that were not tea were individually found online, then multiplied by item size and package quantity to get the total weight of the item. The remaining items in "independent," "item," and "pack," were also individually investigated to find their unit weight, which was multiplied by item size and package quantity to get the total weight of the item.

This procedure was used for 554 items, which left 3,747 items that had no obvious weight measure. For this, the most popular words within the item description were identified and the top 15 that were easily identifiable were used to search online for the item weight (words like "organic," or "sdls" were skipped, as these were not identifiable). These items were individually found online, and again their weight was multiplied by the item size and package quantity to find total weight. Through this, 1,296 additional items were uniquely identified.

Then, the list all 4,301 items in the "each" category was sorted by the top 100 items in terms of total package quantity sold. These 100 items were then investigated individually (if not already found in previous online searches), and their per unit weights were multiplied by item size and then by package quantity. The median value of these top 100 items was applied to the remaining additional items, that were unweighted. This median was used and multiplied by the item size and then package quantity for the remainder of the items.

In addition, 773 items (total weighted at 3.7 thousand tonnes) were identified to be canned goods by their item description had their final net weight decreased by 43%, based on findings by Consumer Reports that on average only 57% of the contents of canned foods is solid food, with the rest being non-consumed water or other liquids used for packaging (Consumer Reports, 2019). On this basis, the total weight of all 43,324 food items (including beverages) was found to be 253,000 tonnes sold at the selected Allegheny County stores.

To extrapolate to all retail food sales in the county, this value was then divided by the estimated market share percentage of these stores, obtained from other confidential data. The result was an estimated 1.1 million tonnes of food purchased annually in the retail sector (which we assume represents residential or household purchases of food).

Based on USDA data (Appendix F), we further estimated that 75% of food is consumed at home and 25% in food service establishments like restaurants and cafeterias. Based on this 3:1 ratio, we estimated that an additional 374,000 tonnes of food is bought annually in the food service sector. This brings the total to around 1.5 million tonnes/year of food purchased in Allegheny County.

Not this entire amount is consumed (ingested). To account for various forms of loss, we assumed waste percentages based on our sector-specific studies of 0.5% for wholesale distributors, 10% for retail stores, 15% for households, and 18% for the food service sector. This leaves approximately 1.1 million tonnes of food being consumed per year, or an average of 939 kg of food consumed by each person in Allegheny County each year.

**References:**

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# Appendix E: Food Service Sector Consumption Estimate

## Consumption in Food Service Sector

The USDA presented multiple estimates for the percentage of calories consumed in the food services sector. In order to account for this variation, we averaged the percentage estimates (NHANES, 2016) (USDA, 2019).

$$(26\% + 31\% + 19\%) / 3 = 25\%$$

Using this percentage, we calculated the number of kilograms of solid food consumed per capita, per year, as follows (USDA, 2019):

$$25\% * 2105 \text{ calories / day} * 1 \text{ gram} / 1.87 \text{ calories} * 365 \text{ days / year}$$

$$= 103 \text{ kilograms / capita / year}$$

To get an estimate of the total solid food consumed within the food services sector in Allegheny County, we simply multiplied the estimate above by the population of the county (Census, 2018):

$$103 \text{ kilograms / capita / year} * 1{,}200{,}000 \text{ persons}$$

$$= 124{,}000 \text{ metric tonnes/yr}$$

To estimate the additional mass of beverages consumed in this sector we applied the same percentage (25%) to the national average per capital estimate of 360 kg/yr of beverages to estimate and additional 90 kg/capita-yr of food consumed. Thus, the total food consumption in this sector is:

$$193 \text{ kilograms / capita / year} * 1{,}200{,}000 \text{ persons}$$

$$= 231{,}000 \text{ metric tonnes/yr.}$$

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# Appendix F: Food Services Sector Waste and Energy Use

### Values for Waste Estimates

*Table F1: Entertainment Venue Establishments and Visitor Count*

| Venue Name | Venue Type | Locations in AC | Annual Visitors per Location | Total Annual Visitors (all locations) | Reference |
|---|---|---|---|---|---|
| AMC theater | Movie Theater | 6 | 344,000 | 2,064,000 | (AMC Theatres, 2018) |
| Cinemark theater | Movie Theater | 3 | 540,000 | 1,620,000 | (Nato, 2013) |
| Small movie theater | Movie Theater | 41 | 200,000 | 8,200,000 | See derivation below. |
| David Lawrence Convention Center | Convention Center | 1 | 558,336 | 558,336 | (Pittsburgh SEA, 2018) |
| Kennywood | Amusement Park | 1 | 2,100,000 | 2,100,000 | (Pitt News, 2010) |
| Carnegie Science Center | Large Museum | 1 | 700,000 | 700,000 | (Carnegie Science Center, 2019) |
| PPG Paints Arena | Professional Sports Venue | 1 | 1,537,071 | 1,537,071 | (Pittsburgh SEA, 2018) |
| Heinz Field | Professional Sports Venue | 1 | 1,128,499 | 1,128,499 | Ibid. |
| PNC Park | Professional Sports Venue | 1 | 1,577,570 | 1,577,570 | Ibid. |
| **Total** | | **56** | **--** | **19,485,476** | |

Annual attendance of small movie theaters was calculated as follows:

According to the MPAA, theaters in the US and Canada totaled 1.32 billion visitors in 2016. It is assumed that this is representative of the current number of annual visitors (MPAA, 2016). According to the National Association of Theater Owners, there are 5,900 movie theaters in the US (NATO, 2013).

According to the US Census, there are about 330 million people in the US (Census, 2018). According to the Canadian Census, there are about 35 million people in Canada (Statistics

Canada, 2018). Assuming attendance is proportional to population size, we determine the number of people per theater in either country.

$$(1.32\ billion\ annual\ visits, US\ \&\ Canada) * \frac{330\ million\ people, US}{(330+35)\ million\ people, US\ \&\ Canada}$$

Dividing by the number of theaters in the US yields the average yearly visits per theater.

$$\frac{1.20\ billion\ annual\ visits, US}{5900\ theaters, US} = 200{,}000\ annual\ visits\ per\ theater$$

*Table F2: School and College/University Student Count*

| Colleges/Universities | | References |
|---|---|---|
| Non-Residential Students | | 78,431 |
| 1,412 | Carlow | (US News) |
| 6,142 | CMU | (US News) |
| 653 | Chatham | (Chatham, 2019) |
| 3,710 | Duquesne | (US News) |
| 866 | LaRoche | (US News) |
| 3,062 | Point Park | (Point Park) |
| 2,545 | Robert Morris | (US News) |
| 16,344 | Pitt | (US News) |
| 43,697 | CCAC | CCAC |
| Residential Students | | 31,657 |
| 664 | Carlow | (US News) |
| 8,483 | Carnegie Mellon | (US News) |
| 653 | Chatham | (Chatham, 2019) |
| 5,564 | Duquesne | (US News) |
| 577 | LaRoche | (US News) |
| 1,037 | Point Park | (Point Park) |
| 2,350 | Robert Morris | (US News) |
| 12,329 | U. of Pittsburgh | (US News) |
| **Schools** | | **References** |
| 64,299 | Elementary students in AC | (Statistical Atlas) |
| 51,472 | Middle school students in AC | (Statistical Atlas) |
| 54,887 | High school students in AC | (Statistical Atlas) |

*Table F3: Allegheny County Inmate Population*

| Quantity | | **References** |
|---|---|---|
| 2,300,000 | inmates nationally | (Prison Policy Initiative, 2019) |
| 8,400 | AC inmates | Scaled by US Census |

*Table F4: Allegheny County Restaurant Employees*

| **Quantity** | | **References** |
|---|---|---|
| 15,100,000 | restaurant employees nationally | (National Restaurant Association) |
| 55,000 | restaurant employees in AC | Scaled by US Census |
| 15 | employees/quick service restaurant | (Statista, 2013) |
| 850 | quick service restaurants in AC | (ACHD, 2018) |
| 12,750 | quick service restaurant employees in AC | -- |
| 42,250 | full service employees in AC | -- |

*Table F5: Allegheny County Hotels and Lodging Employees*

| **Quantity** | | **References** |
|---|---|---|
| 60,600 | employees in food service and accommodation in AC | (US Bureau of Labor Statistics, 2019) |
| 5,600 | employees in accommodation | (US Bureau of Labor Statistics, 2019) |

**Waste in Food Service Sector**

We used a number of different methods to calculate food waste in each of the sub-sectors described in the food waste table.

*Table F6: Food Waste Calculations*

| Establishment Type | Normalization Factor | | | Multiplication Factor | | | Subtotal | Unit |
|---|---|---|---|---|---|---|---|---|
| Full Service Restaurants | 1,400 | kg/employee/year | x | 42,250 | employees | = | 59,200 | tonnes/year |
| Quick Service Restaurants | 1,000 | kg/employee/year | x | 12,750 | employees | = | 12,800 | tonnes/year |
| Entertainment Venues | 0 | kg/visitor/year | x | 20,000,000 | visitors | = | 4,000 | tonnes/year |
| Correctional Facilities | 164 | kg/inmate/year | x | 8,400 | inmates | = | 1,400 | tonnes/year |
| Middle Schools | 12 | kg/student/year | x | 51,472 | students | = | 600 | tonnes/year |
| High Schools | 6 | kg/student/year | x | 54,887 | students | = | 300 | tonnes/year |
| Hospitals | 570 | kg/bed/year | x | 7,000 | beds | = | 4,000 | tonnes/year |
| Assisted Living Facilities | 215 | kg/employee/year | x | 5,726 | employees | = | 1,200 | tonnes/year |
| Colleges/Universities | 64 | kg/residential student/year | x | 31,657 | students | = | 2,000 | tonnes/year |
| | 17 | kg/non-residential student/year | x | 78,431 | students | = | 1,300 | tonnes/year |
| Hotels and Lodging | 592 | kg/employee/year | x | 5,600 | employees | = | 3,300 | tonnes/year |
| Corporate Cafeterias | 0.3 | kg/meal/year | x | | | = | 0 | tonnes/year |
| **Total** | | | | | | | **90,000** | **tonnes/year** |

*Table F7: Final Food Quantity Estimates for Food Services Sector*

| Parameter | Method of Quantifying |
|---|---|
| Total Food Eaten in Sector | Consumption in Food Services Estimate |
| Total Food Wasted in Sector | Sum of All Waste Estimates |
| Total Food Entering Sector | Total Food Wasted + Total Food Eaten |
| Percent of Food Wasted in Sector | Total Food Wasted / (Total Food Wasted + Total Food Eaten) |
| Percent of AC Food Entering Sector | Total Food Entering Food Services / Total Food Entering AC |

**Storage Electricity and Emissions Estimates**

**Method 1:**

- According to the EIA, there were 380,000 food service buildings in the U.S in 2012 (EIA CBECS, 2016)
- The Consortium for Energy Efficiency reported that the U.S. food services industry consumed 447 trillion BTU in 1999 (CEE, 2016)
- National Grid reports that 13% of restaurant energy consumption in Allegheny County's climate zone is caused by refrigeration (National Grid, 2002)
- Assuming 8029 food service establishments in Allegheny County, using data from the ACHD

$$447\ trillion\ BTU/yr\ * \frac{1\ kWh}{3412\ BTU} *\ 13\% * \frac{8029\ establishments\ in\ AC}{380{,}000\ establishments\ in\ US}$$

$$= 360{,}000\ MWh/yr$$

$$360{,}000\ MWH/yr\ *\ 0.57\ tonnes\ CO2eq/MWh\ = 205{,}000\ tonnes\ CO2eq/yr$$

**Method 2:**

- Using a study of 14 UK full-service restaurants by the International Journal of Low-Carbon Technologies, the average establishment uses 123.11 kWh/day on refrigeration (IJLCT, 2013)
- Refrigeration consumption in full-service restaurants were assumed to be the average across all food service establishments
- Assuming 8029 food service establishments in Allegheny County, using data from the ACHD

$$\mathbf{123.11\ kWh/day\ *\ 365\ days/yr\ =\ 44,935\ kWh/yr/establishment}$$

$$\mathbf{44,935\ kWh/yr/establishment\ *\ 8029\ establishments\ =\ 360,800\ MWh/yr}$$

$$\mathbf{360,800\ MWh/yr\ *0.57\ tonnes\ CO2eq/MWh\ =\ 205,600\ tonnes\ CO2eq/yr}$$

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## Appendix G: Transport of Packaged Foods to Allegheny County

The proportion of food traveling by each category was obtained by filtering out food destined for Pittsburgh that was also categorized by method of transportation in the 2017 FAF database (DOT, 2017). The proportion of imported food was assumed to be equivalent to the proportion of food intended for Pittsburgh-area consumption.

*Table G1: Methods of Food Transport to Allegheny County (DOT,2017)*

| Transport Method | ktons of Food Imported by this Method | Percentage of Food Imported by this Method |
|---|---|---|
| Truck | 7952.6 | 89.5% |
| Rail | 926.3 | 10.4% |
| Air | 4.5 | 0.1% |
| Total | 8883.4 | 100% |

Trucks were further broken down into dry and refrigerated by using the breakdown of food intended for Pittsburgh consumption in Appendix B.

*Table G2: Foods Transported by Refrigerated and Dry Truck Delivery (DOT,2017)*

| Type of Truck | Food Categories | Quantity Transported (tonnes/yr) | Percentage of Total |
|---|---|---|---|
| Refrigerated | Fresh vegetables, fresh fruits, eggs, meat, poultry, fish, seafood, frozen other foodstuffs, dairy | 555,000 | 46.6% |
| Dry | Live animals, cereal grains, dried vegetables, dried fruits, nuts, legumes, honey, milled grains, canned goods, snacks, non-dairy liquids, alcoholic beverages | 637,000 | 53.4% |

The "FAF–Produce Adjusted" model modifies the distances that produce is shipped so that 60% of produce shipments originate from 4000 km away based on estimates provided to the project by a major distributor (Paragon, 2017). Because the distance from "origin" to Pittsburgh changes whenever ownership of the food changes, all unprocessed food were adjusted for 60% to originate from 4000 km or more.

*Table G3: Food Transport by Distance in FAF and Produce-Adjusted Models*

| Distance, "origin" to AC (km) | FAF Import Weights (tonnes) | FAF Produce (tonnes) | FAF % of Total Produce | FAF % from each distance | Produce Adjusted Model (tonnes) | Produce-Adjusted Produce (tonnes) | Produce-Adjusted % Total produce | Produce-Adjusted % by distance |
|---|---|---|---|---|---|---|---|---|
| 100 | 1,425,000 | 350,000 | 24.4% | 36.7% | 1,075,000 | 0 | 0% | 27.7% |
| 300 | 724,000 | 270,000 | 18.8% | 18.6% | 454,000 | 0 | 0% | 11.7% |
| 600 | 958,000 | 523,000 | 36.5% | 24.7% | 757,000 | 322,000 | 22.4% | 19.5% |
| 1000 | 223,000 | 131,000 | 9.1% | 5.7% | 223,000 | 131,000 | 9.1% | 5.7% |
| 1500 | 398,000 | 36,000 | 2.5% | 10.2% | 398,000 | 36,000 | 2.5% | 10.2% |
| 2000 | 54,000 | 39,000 | 2.7% | 1.4% | 54,000 | 39,000 | 2.7% | 1.4% |
| 3000 | 59,000 | 47,000 | 3.3% | 1.5% | 59,000 | 47,000 | 3.3% | 1.5% |
| 4000 | 46,000 | 39,000 | 2.7% | 1.2% | 867,000 | 860,000 | 60.0% | 22.3% |

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## Appendix H: Weighted Average Distance to Retailers and Food Service Locations

One model of average distance traveled for consumers to retailers and food service locations is based on the weighted average of distance traveled to each location based on national data supplied by a 2015 CDC study (Liu et al, 2015). Distance from a restaurant or a fast food establishment was taken as the average of the weighted averaged distance to a restaurant or a fast food establishment.

*Table H1: Consumer Travel to Food Retail Outlets (Liu et al, 2015)*

| Distance From Home (miles) | Average Distance (mi) | Fraction of trips in this range | Weighted Average Distance (mi) |
|---|---|---|---|
| 0–1 | 0.5 | 0.64 | 0.51 |
| 1–2 | 1.5 | 0.09 | 0.22 |
| 2–3 | 2.5 | 0.05 | 0.20 |
| 3–4 | 3.5 | 0.04 | 0.23 |
| 4–5 | 4.5 | 0.03 | 0.22 |
| 5–6 | 5.5 | 0.04 | 0.35 |
| 6–7 | 6.5 | 0.03 | 0.31 |
| 7–8 | 7.5 | 0.04 | 0.48 |
| 8–9 | 8.5 | 0.01 | 0.14 |
| 9–10 | 9.5 | 0.04 | 0.61 |
| 10–11 | 10.5 | 0 | 0 |
| 11–12 | 11.5 | 0 | 0 |
| 12–13 | 12.5 | 0.01 | 0.20 |
| 13–14 | 13.5 | 0 | 0 |
| 14–15 | 14.5 | 0 | 0 |
| 15–16 | 15.5 | 0 | 0 |
| 16–17 | 16.5 | 0 | 0 |
| 17–18 | 17.5 | 0 | 0 |
| 18–19 | 18.5 | 0 | 0 |
| 19–20 | 19.5 | 0 | 0 |
| | | | **3.48 mi** |

*Table H2: Consumer Travel to Food Service Locations (Liu et al, 2015)*

<table>
<tr><th>Distance from Home (mi)</th><th>Average Distance (miles)</th><th>Fraction of Trips to a Sit-Down Restaurant</th><th>Fraction of Trips to Fast-Food or Convenience Store</th><th>Weighted Average Distance to Sit-Down Restaurant (km)</th><th>Weighted Avg. Distance to a Fast Food or Convenience Store (km)</th></tr>
<tr><td>0–1</td><td>0.5</td><td>0.45</td><td>0.57</td><td>0.36</td><td>0.46</td></tr>
<tr><td>1–2</td><td>1.5</td><td>0.1</td><td>0.12</td><td>0.24</td><td>0.29</td></tr>
<tr><td>2–3</td><td>2.5</td><td>0.09</td><td>0.03</td><td>0.36</td><td>0.12</td></tr>
<tr><td>3–4</td><td>3.5</td><td>0.04</td><td>0.07</td><td>0.23</td><td>0.39</td></tr>
<tr><td>4–5</td><td>4.5</td><td>0.08</td><td>0.03</td><td>0.58</td><td>0.22</td></tr>
<tr><td>5–6</td><td>5.5</td><td>0.03</td><td>0.03</td><td>0.27</td><td>0.27</td></tr>
<tr><td>6–7</td><td>6.5</td><td>0.05</td><td>0.04</td><td>0.52</td><td>0.42</td></tr>
<tr><td>7–8</td><td>7.5</td><td>0.04</td><td>0.02</td><td>0.48</td><td>0.24</td></tr>
<tr><td>8–9</td><td>8.5</td><td>0.01</td><td>0.02</td><td>0.14</td><td>0.27</td></tr>
<tr><td>9–10</td><td>9.5</td><td>0.04</td><td>0.01</td><td>0.61</td><td>0.15</td></tr>
<tr><td>10–11</td><td>10.5</td><td>0.01</td><td>0.01</td><td>0.17</td><td>0.17</td></tr>
<tr><td>11–12</td><td>11.5</td><td>0</td><td>0.02</td><td>0</td><td>0.37</td></tr>
<tr><td>12–13</td><td>12.5</td><td>0.02</td><td>0.01</td><td>0.40</td><td>0.20</td></tr>
<tr><td>13–14</td><td>13.5</td><td>0.01</td><td>0.02</td><td>0.22</td><td>0.43</td></tr>
<tr><td>14–15</td><td>14.5</td><td>0.01</td><td>0</td><td>0.23</td><td>0</td></tr>
<tr><td>15–16</td><td>15.5</td><td>0.01</td><td>0</td><td>0.25</td><td>0</td></tr>
<tr><td>16–17</td><td>16.5</td><td>0.01</td><td>0</td><td>0.27</td><td>0</td></tr>
<tr><td>17–18</td><td>17.5</td><td>0.01</td><td>0</td><td>0.28</td><td>0</td></tr>
<tr><td>18–19</td><td>18.5</td><td>0.01</td><td>0</td><td>0.30</td><td>0</td></tr>
<tr><td>19–20</td><td>19.5</td><td>0</td><td>0.01</td><td>0</td><td>0.31</td></tr>
<tr><td rowspan="2">Average</td><td rowspan="2"></td><td>3.67</td><td>2.685</td><td>5.91</td><td>4.33</td></tr>
<tr><td colspan="2"></td><td colspan="2">5.12</td></tr>
</table>