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REPORT

FEEDING A CITY:

FOOD WASTE AND FOOD NEED ACROSS AMERICA

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NRDC is an international nonprofit environmental organization with more than 3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Montana, and Beijing. Visit us at nrdc.org.

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Executive Summary

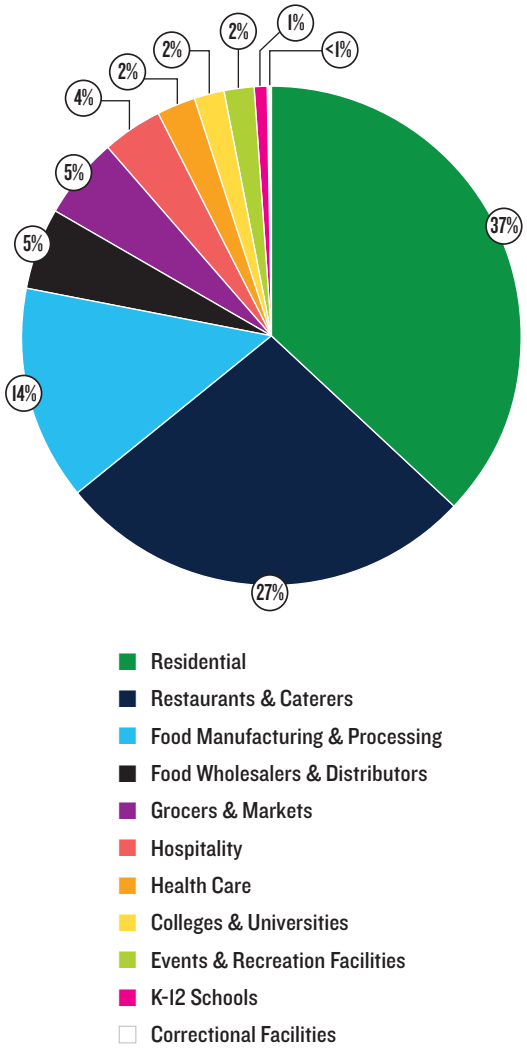
Up to 40 percent of all food in the United States is wasted, and with that food we're wasting a tremendous amount of water, energy, and money while simultaneously producing climate pollutants.[1] The goal of NRDC's Food Matters project is to help U.S. cities establish policies and programs that reduce food waste. The first step in reducing municipal food waste is data gathering: understanding the amounts and sources of wasted food at the local level, as well as the amounts and sources of surplus food that potentially could be rescued instead of wasted. This information can then be used to determine the most promising city strategies for reducing food waste and to set a benchmark for assessing progress.

Food Matters came up with innovative modeling techniques in order to estimate these initial food waste amounts and sources and presented them in a pair of 2017 reports.[2] After using these modeling techniques to estimate food waste in Denver, New York City, and Nashville, Food Matters went on to replicate this work in a number of other cities across the country. As we worked with additional cities, trends began to emerge in how city size and demographics affect food waste efforts, how various sectors—such as restaurants, grocers, and hospitality—contribute to municipal food waste, and which sectors offer the greatest opportunities for food rescue. We sorted the cities by various geographic and demographic factors into five groups and looked for food waste commonalities that might hold true for other cities meeting the same criteria. In this report we present our findings. By identifying and exploring these trends, we hope to provide guidance and recommendations for future municipal food waste work in additional cities.

Key findings:

- The breakdown of food waste generation by sector is fairly consistent across most cities.
- On average, the residential sector generates the largest proportion of cities' food waste, typically more than one-third (Figure ES-1). Restaurants tend to be the second-largest generator of food waste overall (and the largest commercial generator), responsible for more than one-quarter of cities' food waste. Food manufacturing and processing is the most variable sector of those we investigated; in half of the cities we explored, it is among the top three food waste–generating sectors (with residential and restaurants), while some cities have very little food manufacturing and processing at all. Consistently, three sectors are the smallest food waste generators across all cities investigated: correctional facilities, K–12 schools, and health care facilities.

FIGURE ES-1. AVERAGE SECTOR CONTRIBUTIONS TO MUNICIPAL FOOD WASTE



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- Food waste is negatively correlated with population density—as density increases, waste decreases—at both the city and the household level, which may have implications for urban planning and development.
- Retail sectors (grocery stores, small corner markets, and convenience stores) have the largest potential for rescuing surplus food to be redistributed to community members in need. In most cities, large supermarkets offer the greatest opportunity, averaging 75 percent of the total rescue potential; however, in some cities, aggregated small retail and convenience stores surpass or offer as much surplus food rescue potential as large markets. In more than half of the cities explored, small retail offers the second-highest opportunity for food rescue.
- Very few cities have enough rescuable surplus food within their borders to cover their meal gap (i.e., to fill the needs of all food-insecure households). On average, the maximum amount of food potentially available for food rescue would cover 72 percent of a city's meal gap.
- Small, dense cities with either high poverty rates or high food costs may be better positioned to implement successful food rescue efforts because the need is high and the proximity of donors makes such efforts easier to coordinate. Very large, sprawling cities, by contrast, have immense logistical challenges and very little surplus food relative to their needs, making a citywide food rescue effort difficult to operate.

Our recommendations for city action reflect the largest sources of food waste generation; the best environmental, social, and economic management practices for addressing food waste; opportunities for engaging new partners to assist in implementing strategies to reduce food waste; and approaches to support the efforts of local emergency food assistance organizations.

Key recommendations include the following:

- Cities should focus on preventing residential food waste to meet waste reduction goals.
- Cities should engage restaurants in food waste reduction strategies, as they collectively are the biggest commercial generator of food waste in nearly every city.
- Cities should identify generator hot spots where a small number of facilities are producing sizable amounts of food waste and provide targeted technical assistance in food waste prevention, rescue of surplus food, and recycling of food scraps. These specific hot spots will vary by city, but our investigation suggests that cities may want to start with the food manufacturing and processing sector if there is no obvious other large generator, like a sizable university.
- Cities should maximize surplus food rescue from retail, which includes supermarkets and, for some cities, small corner stores.
- Cities should work with surplus food rescue organizations to determine how much food is already being rescued and identify opportunities for improvement.

Food Waste in the United States

Up to 40 percent of all food in the United States is wasted, costing the nation $408 billion each year.[3] Producing food that we do not consume swallows up roughly 20 percent of America's cropland and 14 percent of its fresh water and generates about 207 million metric tons of CO_2 equivalent greenhouse gas emissions each year, the same output as 58 million passenger vehicles.[4]

In an August 2019 special report on *Climate Change and Land Use*, the Intergovernmental Panel on Climate Change (IPCC) highlighted the interconnectedness of food waste, climate change, nutrition, and hunger, stating that "coordinated action to address climate change can simultaneously improve land, food security and nutrition, and help to end hunger."[5] As noted in the IPCC special report, reducing food waste could also alleviate agricultural production pressure and change land use, which could result in further benefits to water, soil, climate, and biodiversity. The IPCC report reminds us—and we agree—that these issues cannot be solved in a vacuum from one another. Any policy efforts to address food waste or food insecurity must incorporate holistic solutions that simultaneously mitigate climate change and improve environmental resource use, food security, and racial equity.

There is more than enough food in the United States to feed everyone. Still, in 2019 some 35 million Americans lacked consistent access to adequate and nutritious food, and this number is projected to top 50 million when the data are in for 2020.[6] As businesses closed and millions of Americans lost their jobs due to the COVID-19 pandemic in 2020, household food insecurity in the United States skyrocketed.[7]

Food is wasted at every stage of the food supply chain. It goes to waste on farms; during processing, distribution, and storage; in retail stores and food service operations; and finally, in households.[8] In the United States, most food waste is caused by consumers and consumer-facing businesses: in grocery stores, in restaurants, and in our homes.[9]

Of the various food waste reduction strategies, preventing food from becoming waste in the first place typically offers the greatest financial and environmental benefits.[10] Prevention reduces the cost of purchasing, handling, and ultimately disposing of food that isn't eaten. If we can better match the amount of food grown to the food we eat, we can avoid the unnecessary use of water, agricultural chemicals, energy, and other resources required to produce, process, transport, package, and dispose of that eventually wasted food. We can also reduce air and water pollution associated with those activities. Focusing on waste prevention can help cities bring down costs incurred by processing and disposing of unnecessary waste.

FOOD MATTERS MODELS SOLUTIONS, STARTING WITH QUANTIFYING FOOD WASTE AND RESCUE POTENTIAL

Reducing food waste comes with significant benefits, particularly at the local level. Because cities are often responsible for waste management, land use, and local health and food regulations, they are the vanguard in reducing food waste. Strategies to reduce food waste are at the intersection of three common issues facing city governments: reducing the costs and logistics of managing municipal waste, meeting sustainability and climate goals, and addressing hunger. By reducing the amount of food that is thrown out, cities can reduce their waste management burdens and make progress toward climate and sustainability goals. By rescuing safe, healthy, and wholesome surplus food, municipalities can address food needs in local communities. And by recycling food scraps, cities can minimize what goes into landfills and incinerators and help improve soil health.

Created in 2017, NRDC's Food Matters project sought to fill a key information gap pertaining to food waste in cities and then help municipalities reduce this waste through a suite of policies

DEFINING "FOOD WASTE" IN THIS REPORT

For ease of reading, we use the term "food waste" instead of the global accounting standard preferred term "food loss and waste" throughout this report. "Food loss" typically refers to unavoidable loss, such as when crops are damaged by weather events on the farm. "Food waste" typically refers to food that could have been prevented from becoming waste. While our report naturally focuses more on food waste, we intend for this term to have the same meaning as "food loss and waste"—that is, all uneaten food as well as associated inedible parts removed from the food supply chain.

To further clarify this report's definition of "food waste," our assessment of food waste generation looked at all discarded food, regardless of destination, and included both discarded edible food and inedible parts. It is worth noting that edible food is not always the same as food that is suitable for rescue or donation. Rescuable food must meet basic health and safety requirements. Food from the residential sector or food that has already been served to a restaurant customer may be *edible*, but it does not meet those requirements and is not suitable for rescue.

Therefore "food waste" in this report includes both food that could have been eaten and food or food parts that belong in the waste stream.

and programs.[11] Even when there is interest in or a commitment to reducing food waste, few cities know how much food is going to waste locally, let alone where the waste originates or why it occurs. Waste audits and studies to answer these questions can be costly, time-consuming, and sometimes impractical. Yet, understanding this baseline level of food waste is important in order to determine where best to direct specific strategies and to assess progress. For example, in a city where residential food waste is the largest source, planners would be wise to do food waste prevention outreach to households in order to make strides toward a zero-waste goal.

Similarly, few cities have tried to estimate how much surplus food could potentially be rescued and directed to people in need. Having data on this potential clarifies the scale and sources of rescuable food and can inform strategies for increasing participation in food donation efforts and bolstering food rescue infrastructure.

Our 2017 research in Denver, Nashville, and New York City led to the creation of research models to estimate quantities of food waste generated per year from residences and 10 key food business sectors (e.g., restaurants, schools, health care, food manufacturing).[12] We also created models to quantify the scale of food that could potentially be rescued each year from food businesses within a given city rather than going to waste.[13]

Our 2017 research also recognized that while many cities have robust food rescue networks, there are significant logistical barriers to ramping up these efforts to safely secure more surplus food for redistribution. Therefore, the research modeled two scenarios: one focused on the maximum food available for rescue, and a scenario that was "ambitious" yet took into consideration current patterns of food donation and logistical barriers to rescuing food.

Throughout 2019 and 2020, we worked with additional cities, applying our 2017 research models to collect data and estimate food waste generation and rescue potential specific to each location. As we ran the models with these additional cities, patterns began to emerge. For this report, we then tried to understand the ways in which a city's demographics (such as size, population density, poverty rate, etc.) led to its resulting food waste and food rescue profile. We then created categories, or groups, of cities with similar demographic profiles or food waste trends. The criteria we used in forming these groups can be applied to other cities to help them identify where food waste prevention and food rescue efforts should be honed for maximal impact.

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Recognizing the interconnectedness of food surplus, food access, food security, sustainability, and racial discrimination, we endeavored to think about the issues holistically rather than focus solely on food waste. We also recognize that though there are many similarities among cities, there are also key differences that impact their priorities and opportunities and the size of barriers faced. Our hope is that this research provides important preliminary information for other cities looking to start food waste reduction efforts.

Results

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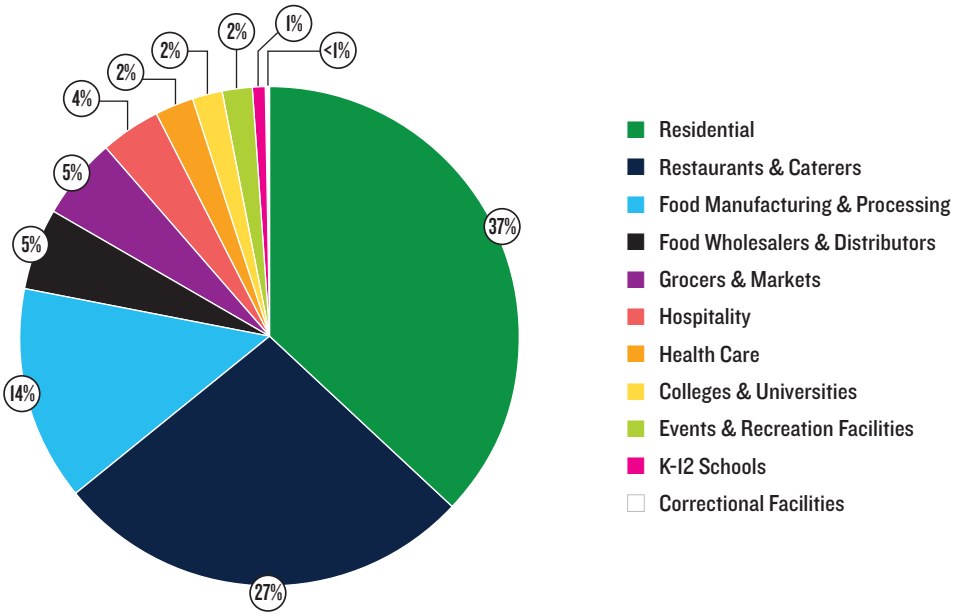
We first used our models to estimate food waste generation and food rescue potential across our subject cities. Armed with these estimates, we then looked for characteristics among the cities that might help us predict food insecurity and identify locations where food insecurity could be best alleviated with food rescue operations. Ultimately we emerged with a better understanding of where cities should concentrate their food waste prevention and food rescue efforts to meet the most need.

FOOD WASTE GENERATION: RESIDENTIAL SECTOR PRODUCES THE MOST

Our research explored food waste generation estimates from 11 key sectors: residential, colleges and universities, K–12 education, hospitality, health care, retail grocery, restaurants, food wholesalers and distributors, food manufacturing and processing, event facilities, and correctional facilities.[14] Because

FIGURE 1: AVERAGE DISTRIBUTION OF FOOD WASTE GENERATION BY SECTOR ACROSS ALL CITIES



To make progress on zero-waste goals, a city must include strategies to help residents prevent food from becoming waste.

most cities have similar structures in terms of the relative size of various sectors, we can apply these sector estimates to derive recommendations for U.S. cities in general.

On average, we estimated that the residential sector generates more than one-third of cities' food waste (Figure 1). To make progress on zero-waste goals, a city must include strategies to help residents prevent food from becoming waste. Additionally, as households better understand the importance of this work, customers may grow to expect changes throughout the food system to mirror the changes they are making at home; this can put pressure on consumer-facing businesses to also focus on reducing their food waste.

In nearly all cities, restaurants are the second-largest food waste–generating sector and the largest food waste generator of all commercial sectors, contributing more than one-quarter of all food waste tonnage on average. Cities of all sizes should engage their restaurant sector in preventing food waste, rescuing surplus food for individuals in need, and recycling food scraps.

Food manufacturing and processing is the most variable sector of those we investigated. Across the cities in our sample, the average food waste generation from food manufacturing and processing is 14 percent of the total, but by individual city, percentages range from 1 percent to 78 percent. In half of the cities we explored, food manufacturing and processing is among the top three food waste-producing sectors (with residential and restaurants), while about 10 percent of cities have very little food manufacturing and processing within their borders.

Three more sectors are highly variable among the cities we studied. Food wholesalers/distributors range from less than 1 percent to more than 10 percent of a city's total food waste generation, with the average at 5 percent. On average, colleges and universities contribute 2 percent of investigated cities' food waste, but in some cities, that sector's estimated generation is up to 7 percent of the total. Similarly, the event and recreational facilities sector on average generates just under 2 percent of all municipal food waste, but in some cities it ranges up to 5 percent of the total.

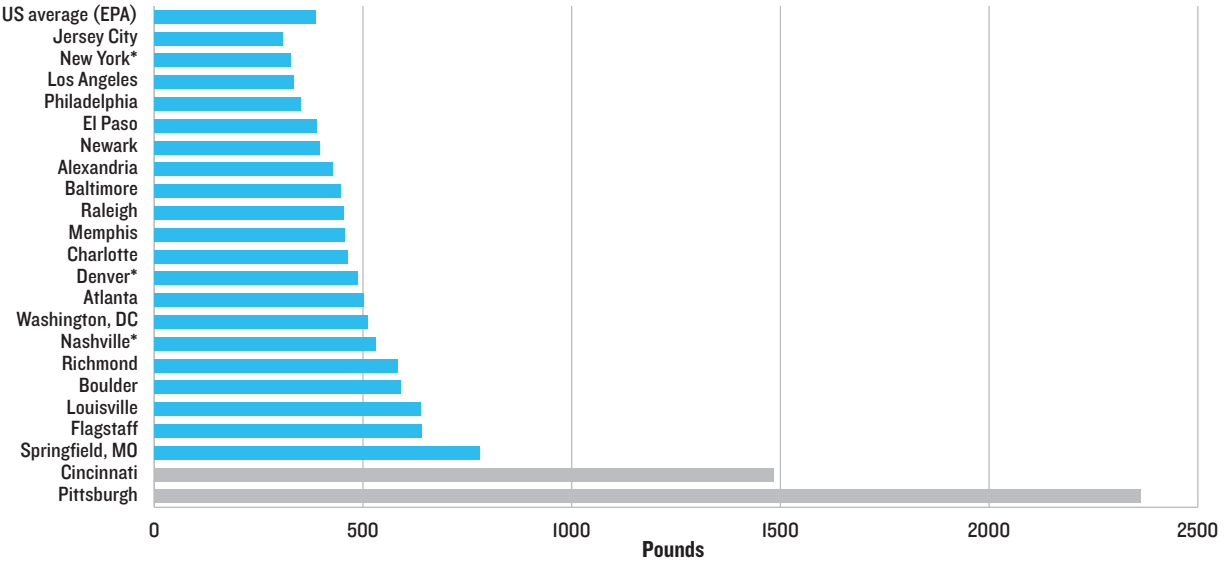
In some cases, including cities with a large university, a major sports team, or a primary event venue, spikes in the sector's food waste generation can be attributed to a single entity. In those cases, though the proportion of that facility's food waste generation relative to the city as a whole may not be all that significant, outreach and technical assistance to the single or few largest generators may provide more bang for the buck than an effort to reach all of the small contributors to residential or restaurant-sector waste.

Consistently, three sectors are the lowest estimated generators across all cities investigated. The lowest sector is correctional facilities, with a mean of 0.2 percent of total estimated city food waste generation. Although K–12 schools are a popular target for food waste reduction activity, we estimate that they represent less than 1 percent of the food waste generated in cities. Hospitals and skilled nursing facilities generate on average 2.5 percent of municipal food waste. That said, these smaller generators should not be discounted altogether for food waste reduction activity—they may offer inroads to other changemakers, they may spotlight champions whose successes could inspire other industries, or they may have an existing zero waste policy that already encourages food waste reduction.

The total estimated food waste generation across the 22 cities we studied is approximately 4.75 million tons, or about 8 percent of all U.S. food waste generated in 2018 according to the U.S. Environmental Protection Agency (EPA).[15] The combined population of these 22 cities represents about 7 percent of the total U.S. population.[16] Thus the food waste generation rate in our study is slightly higher, per capita, than the national rate according to the EPA (Figure 2). In part this may be explained by our two outlier cities with very large food manufacturing and processing sectors. A large component of these cities' food waste is not related to local consumer behavior but rather is attributable to a sector that is likely shipping much of its product outside the city. It may also be that our estimates of food waste are too high or that EPA's estimate is too low (in fact, it is lower than the projections from the U.S. Department of Agriculture, National Institutes of Health, and the U.N. Food and Agriculture Organization).[17]

FIGURE 2: FOOD WASTED PER PERSON IN 22 U.S. CITIES COMPARED WITH EPA ESTIMATE OF FOOD WASTE GENERATION IN THE UNITED STATES[18]

Cities marked with an asterisk were part of the original 2017 research; all others were assessed using the methodology developed in that research. Pittsburgh and Cincinnati are outliers.



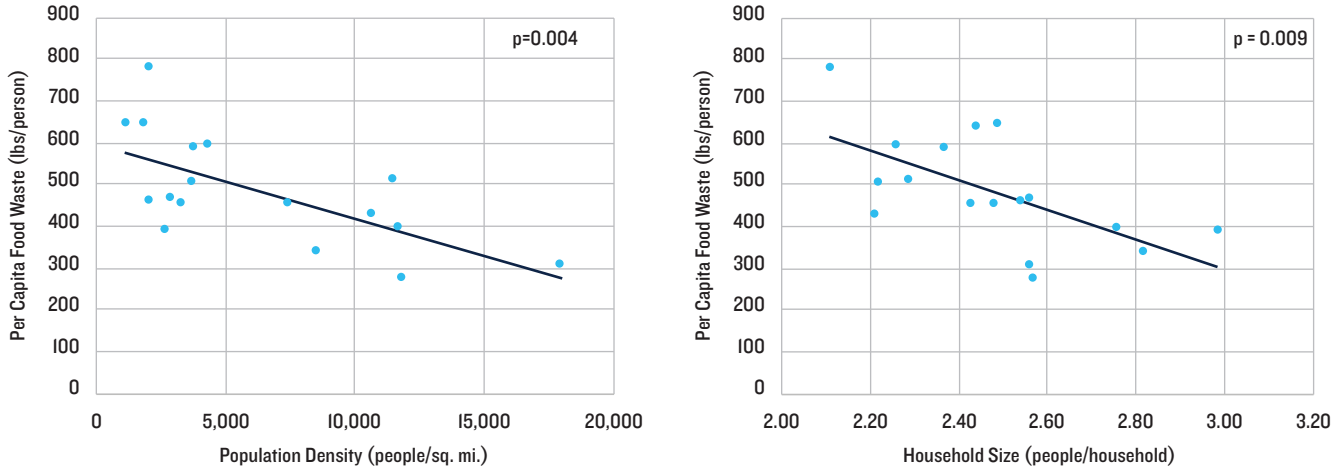
FOOD WASTE GENERATION: URBAN DENSITY IS LINKED TO LOWER FOOD WASTE

We found that food waste was lower in more densely populated cities and in cities with larger average household sizes (Figure 3). These results suggest that policies that increase population density at the city level, household level, and perhaps within key consumer-facing sectors may also indirectly reduce food waste, likely through more efficient management of food procurement.

The strong relationship between urban population density and food waste may not be surprising to urban planners. Higher density has already been linked to better health outcomes, stronger economic growth, and better environmental sustainability.[19] Urban density can have a multitude of interrelated benefits like increased transportation options, greater walkability, proximity to amenities, social cohesion with benefits in cultural vibrancy and lower crime, and more flexible housing options.[20] Greater urban density generally leads to more choice–which can allow households to more closely match their food purchases to their food needs and to support restaurants and food businesses, which typically are more efficient with their food stocks.[21]

FIGURE 3: THE EFFECTS OF CITY POPULATION DENSITY AND HOUSEHOLD SIZE ON THE AMOUNT OF FOOD WASTE PER PERSON PER YEAR

(n = 17; data set excludes original study cities of Denver, Nashville, and New York as well as outliers.)



THE IMPORTANCE OF TRANSIT IN REDUCING FOOD WASTE

A built environment that enables easy access to goods and services makes it easier for households to manage their food purchases, especially compared with sparsely populated regions with fewer food options located farther apart.

For example, when transit-oriented development projects situate mixed-use residential and commercial buildings around key transit stations, residents can access amenities within steps of their door and are also able to easily travel to other food options along the transit route. Imagine living in an apartment with retail on the first floor; within walking distance of schools, parks, workplaces, and recreation centers; and with a neighborhood market right down the street, enabling you to easily pick up something to eat each day based on what is fresh or most appealing. Meal planning can then rely on frequent grocery store visits and buying only what can easily be carried.

Smaller and more frequent trips to the grocery store and easy access to amenities like restaurants can in turn mean changes in waste habits at home. However, this vision relies on a corner store that stocks nutritious foods and is easily accessible via walking or transit—otherwise, residents are forced to rely on a car and infrequent, large grocery store visits.

However, urban density in and of itself is not a cure-all; in fact, if poorly planned, it can cause additional problems. First, density does not always mean that there is more access—indeed, several of the dense cities we investigated have very few food retail choices. When density occurs without amenities and multimodal transportation options, its strong relationship to food waste reduction will not hold up.

Moreover, if not properly planned—if residents are not able to access fresh food options within walking distance or easily via public transportation—development can lead to higher costs of living, which in turn can lead to segregation. Urban planning should always incorporate mixed-income housing policies and affordable multimodal transportation options so that growth does not push longtime residents out of the city.

Finally, though urban density provides an opportunity for a more accessible built environment, it will not come to fruition unless it coincides with community-led planning.[22] There are many political and historical challenges associated with creating livable, high-density urban spaces—including outdated zoning regulations, public perceptions around crime, and preference for single-family homes—that must be overcome in order to build the kind of urban environment that provides sustainable living options and reduces food waste.

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FOOD RESCUE POTENTIAL: LOOK TO LARGE SUPERMARKETS

Though the amount of surplus food in each city is highly variable based on the absolute size of the sectors and their distribution, some underlying trends are consistent across all the cities we explored. Significantly, retail grocery stores offer the greatest potential for food rescue. For most cities, expanding food rescue will mean working with large supermarkets to increase the frequency, quantity, or quality of their donations, but some cities may see equally great potential in small retail and convenience stores.

This research, and our 2017 rescue potential study, explored the possibilities for food rescue in a subset of food-related sectors: colleges and universities, K–12 education, hospitality, health care, retail grocery, convenience and small retail, and restaurants. Due to data limitations, we were not able to estimate the rescue potential for all sectors included in the food waste generation study, such as food wholesalers and distributors, food manufacturing and processing, and others. However, this lack of data does not mean that there is no potential to rescue surplus food from these facilities. Particularly among food wholesalers—a moderately large food waste–generating sector with business characteristics similar to those found in retail—there could be substantial untapped opportunities for food rescue. The residential sector was purposely excluded from this research because food wasted at home is typically not suitable for rescue.

Ideally, we would have subtracted current food rescue efforts from our estimates in order to identify how much *additional* surplus food could be rescued (as we did in our 2017 study), but we were not able to reliably measure existing food donations in all of the cities. We recommend that cities coordinate with local food rescuers in the future to identify the extent to which the scenarios outlined here are already in place and to determine how much untapped potential remains.

DEFINING AMBITIOUS AND MAXIMUM SCENARIOS

As mentioned in the introduction, the original research modeled two scenarios: one focused on the maximum food available for rescue and an "ambitious" scenario that took into consideration current patterns of food donation and logistical barriers to rescuing food. Both scenarios are driven by two factors: first, the percentage of locations in a given sector that we characterize as potential donors (i.e., the participation rate), and second, the estimated rate of potential donation by participants within that sector (the donation rate).

Here are the descriptions of the two scenarios as defined in the original report.

MAXIMUM SCENARIO: Our maximum scenario characterizes the maximum amount of surplus food in the retail, restaurant, and institutional sectors in each city that we believe could hypothetically be donated. This scenario assumes 100 percent participation among area businesses and institutions in those sectors and reflects our most optimistic assumptions about the amounts of surplus food suitable for donation under optimal conditions. As such, the maximum scenario describes the uppermost limit of what we believe to be theoretically possible.

AMBITIOUS SCENARIO: The ambitious scenario uses more realistic assumptions and existing donation patterns to describe an ambitious yet attainable amount of rescuable food. As such, the ambitious scenario is more rooted in current rescue realities and embodies a more middle-of-the-road set of assumptions. It acknowledges, for instance, that donation activity in sectors such as restaurants is currently limited and will take time to grow given the challenges of rescuing prepared food from many disparate locations.

In the 22 cities in this study, we identified more than 175,000 tons of food as rescuable per year under the maximum scenario. On average across all cities, the maximum rescue potential is 8 percent of the estimated food waste generation in the corresponding sectors. Given the enormous logistical challenges of food rescue—including transportation from food businesses to redistribution sites, adequate cold storage capacity, shelf life concerns from some sectors, and current low participation in donation from many types of food businesses—a much more humble 73,000 tons were identified for rescue under the ambitious scenario.

Retail sectors have the largest potential amount of surplus food that could be redistributed to community members in need (Figure 4). For most cities, large supermarkets offer the greatest opportunity for food rescue; however, in some cities, small retail or convenience stores collectively equaled or surpassed the potential of large markets in our maximum rescue scenario. In our ambitious scenario, large supermarkets offer on average 75 percent of a city's potential for food rescue.

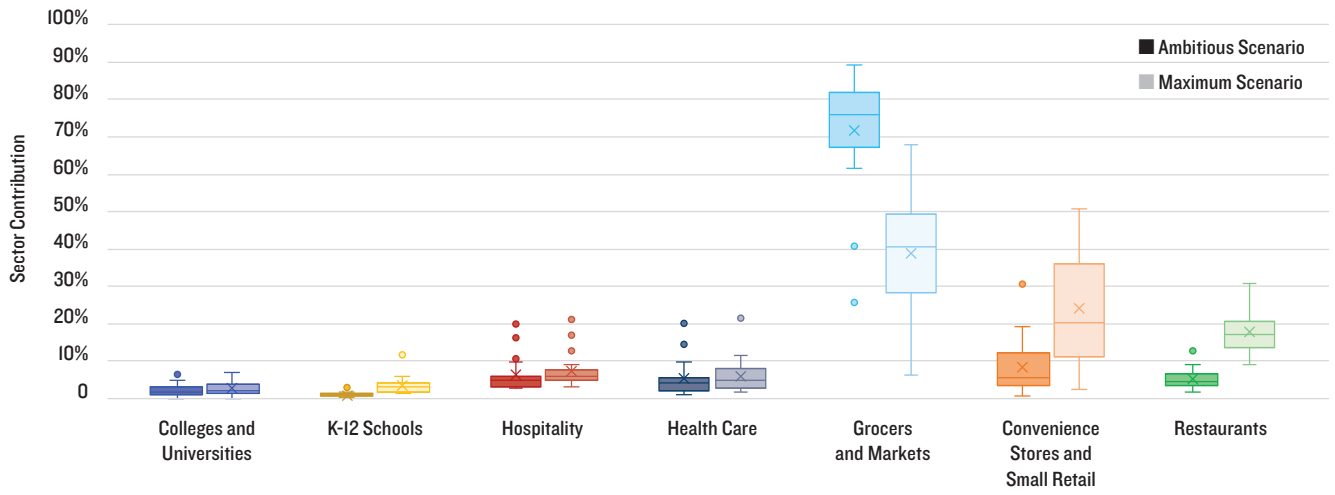
Large retailers are often already connected to a food rescue organization, and many grocery stores donate some surplus food (often nonperishables and bakery items), yet most grocery stores have large amounts of additional, perishable food that goes to waste. Grocery stores that donate at the highest rates are often able to do so by ramping up donation of perishable items, including produce, dairy, meat, and deli. Perishables represent a substantial percentage of U.S. grocery sales; input from industry leaders suggests that donation rates could expand greatly if rescue infrastructure for perishables were fully scaled up.[23] Furthermore, many grocery stores do not donate surplus at the rate at which they generate it, meaning that highly perishable foods with a short shelf life may no longer be suitable for donation by the time it is picked up by food rescue entities—often volunteer-based organizations with limited capacity. Other barriers to increased donation cited by food rescuers include confusion and miscommunication between departments within a store or between store managers and headquarters.

For more than half of the cities explored, small retail, including corner markets, bodegas, and convenience stores, offered the second-largest opportunity for food rescue under the ambitious scenario (though its food rescue potential, at 7 percent on average in the ambitious scenario, was dwarfed in comparison with large supermarket retail). Often, operators of small retail stores are less familiar with donation incentives, and fewer of them currently donate, making them a largely untapped sector for food rescue (unlike large supermarkets). That said, nutritional quality and shelf-life concerns may be significant, and the combination of small amounts of donatable food per location and many disparate locations can make rescue logistics challenging in the small retail sector.

As mentioned earlier, despite representing a large portion of municipal food waste, food waste from households is not suitable for rescue and redistribution due to quality and safety concerns. Similarly, while plate waste in restaurants is estimated to account for 30 percent of all restaurant food waste, food previously served to customers at restaurants or other food service businesses also cannot be redistributed.[24] As for pre-consumer commercial kitchen food waste, much of it consists of trim and inedible food scraps, which are typically not appropriate for donation either. As with small retailers, the logistical challenges to rescuing small amounts of donatable food from many far-flung locations, in addition to misconceptions about liability protections and safe food donation practices, make the restaurant sector problematic for surplus food rescue.

Education, health care, and hospitality sectors are all relatively minor contributors to potential food rescue under both ambitious and maximum scenarios, due to their relatively small generation of food waste and questions about the quality of the surplus food.

FIGURE 4: FOOD RESCUE BY SECTOR FOR THE MAXIMUM SCENARIO AND AMBITIOUS SCENARIO



Two cities in this data set (Pittsburgh and Cincinnati) have an outsize manufacturing and processing sector that dominates their waste profiles. It is unknown whether this outsize sector also contributes to an outsize surplus of food available for rescue. We did not endeavor to determine whether the quality of surplus food from the manufacturing and processing sector would make it appropriate for donation.

Finally, for the sake of simplicity, our analysis looked at raw tonnages of surplus food, but weight is not always the most important characteristic of rescued food. While we tried to eliminate from our tally food that would not meet food safety standards, we did not assess the nutritional quality or desirability of rescued food. Furthermore, we did not attempt to assess the degree to which future food waste prevention efforts or industry consolidation may influence the supply of food available for rescue. Nor did we investigate whether the rescue infrastructure is currently in place in each city to handle the food volumes estimated here; in most cities across the nation, it is not.

FOOD INSECURITY: CITIES WITH HIGH POVERTY RATES AND HIGH COSTS OF LIVING HAVE THE LARGEST FOOD GAPS

The need for food assistance in our cities is currently immense. Food insecurity exists at different levels of severity; however, all levels are detrimental to physical and mental health.[25] Across all age groups, there are significant negative and persistent health outcomes associated with food insecurity, such as diabetes, hypertension, mental health challenges, and behavioral problems in children.[26] Together, the multitude of negative individual and societal ramifications of food insecurity should make its resolution a leading priority for public health. We endeavored to explore which cities have the greatest need for surplus food to fill their gaps in food security and found that those with high poverty rates and high costs of living often have the greatest need.

We examined a set of indicators across cities to create discrete groupings based on common characteristics. Creating these groups allowed us to better understand the landscape of need in cities and to evaluate the likely scope of food rescue efforts in addressing hunger relief. It also brought to the fore some root causes of food insecurity and yielded a list of metrics by which we can evaluate additional cities in the future.

We clustered cities on the basis of four attributes: poverty level, food cost relative to median income, housing cost relative to median income, and estimated meal gap.[a] We then compared each attribute to the national average. The cluster analysis on these four metrics suggested five main groupings of cities based on overall need (Table 1). Though no other cities in our small sample group share the profile of Newark, New Jersey, we expect there are other cities in the United States with similar attributes that were not featured in our assessment.

Food insecurity exists at different levels of severity; however, all levels are detrimental to physical and mental health.

a Poverty level and housing costs were taken from U.S. Census data. Food costs and meal gaps were estimated by Feeding America.

TABLE I: NEED CLUSTER ANALYSIS: City groupings resulting from cluster analysis of four metrics indicative of food need: poverty rate, food affordability, housing affordability, and meal gap

Cluster Group	Need	Cities	Drivers of Need			
			Poverty	Food Cost	Housing Cost	Meal Gap
A	Extreme	Newark	Very high	Most expensive	Expensive	High
B	High	Baltimore, Cincinnati, El Paso, Memphis, Pittsburgh, Philadelphia, Springfield, MO	High	Expensive	Most affordable	High
C	High	Boulder, Los Angeles, New York	Moderate	Moderately affordable	Most expensive	Moderately high
D	Moderate	Alexandria, Atlanta, Denver, Flagstaff, Jersey City, Richmond, Washington, D.C.	Moderate	Most affordable	Expensive	Moderate
E	Low	Charlotte, Louisville, Nashville, Raleigh	Low	More affordable	More affordable	Low

Food insecurity exists across all the cities in our study; 4.5 million people in these 22 cities had difficulty procuring enough food to eat at some point in 2018. All the cities in our study but one, Alexandria, had food insecurity rates above the national average. But three cluster groups stand out for their particularly high need: groups A, B, and C. Though these cities have many differences, they all face high poverty levels and high expenses in terms of food, housing, or both—attributes that appear to be linked to an inability to afford adequate food. Newark (group A) has the greatest overall need of all cities. Group B also has high unmet need. Extremely expensive housing defines group C, likely explaining the relatively high unmet food need in those three cities. Groups D and E also have community members who face food insecurity, but the causes may be different from the variables addressed in this assessment and require further research and unique solutions to food insecurity.

Other cities that demonstrate the same attributes as those in groups A, B, and C are likely to have high levels of food insecurity and are also likely to benefit the most from surplus food rescue. Anti-hunger advocates, funders, and policymakers should focus on food access and food rescue in cities sharing these attributes.

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WHY IT IS IMPORTANT TO LOOK BEYOND POVERTY

While our study shows a link between poverty levels and food need, poverty is too often seen as the *only* predictive measure of food insecurity. The U.S. Census, following a directive by the Office of Management and Budget, determines poverty status on the basis of income and family size.[27] In 2018 the poverty threshold for a family of two adults and two children under the age of 18 was $25,465, and 11.8 percent of the U.S. population had family income below that threshold.[28] For that same year, the poverty rates for cities included in this study ranged from 11 percent to 28 percent, with a mean of 20 percent, well in excess of the nationwide poverty rate.[29]

However, poverty on its own is not a sufficient indicator of food insecurity. First, the poverty level does not take into consideration variable expenses like housing or medical costs. Furthermore, the official poverty level is the same throughout the United States and does not include regional differences in the cost of core expenses like food or utilities. For example, food costs vary widely across the cities in our study, from $2.84 per meal in El Paso, Texas, to $4.04 per meal in Newark, New Jersey. Households in high-food-cost cities that are on the cusp of poverty or on the margin of eligibility for food assistance programs may have greater difficulty budgeting for sufficient food than low-income households in cities with lower food costs, where the same food budget and food assistance funds go farther.

Second, food insecurity is driven not only by a lack of adequate income—due to low wages, underemployment, or unemployment—but by excessive expenses (for things like medical care, housing, or child care), which limit the available budget for food.[30] However, it is income alone, not expenses, that typically determines household eligibility for the three main government food programs: the Supplemental Nutrition Assistance Program (SNAP), Women, Infants, and Children (WIC), and the National School Lunch Program (NSLP).[31] Therefore, households with excessive expenses may not benefit from poverty-related food assistance programs. For households that

Food security, nutritional quality, and the most expensive chronic diseases are interconnected; the lack of attention to all three issues is a failure of both our health care system and our food system.

are ineligible for government assistance, food pantries, which often rely on donations of surplus food, constitute their primary substantive option for relief.[32]

Feeding America's Map the Meal Gap, which we used to estimate how much food is needed in cities to relieve food insecurity, describes in detail how factors like housing costs and medical costs can drive up expenses for groups beyond those living in poverty.[33] Feeding America warns that estimates of food need are conservative and may understate both the number of food-insecure people and the total size of the meal gap.

Excessive medical expenses are a leading cause of poverty and may also cause food insecurity.[34] Food security, nutritional quality, and the most expensive chronic diseases are interconnected; the lack of attention to all three issues is a failure of both our health care system and our food system. However, we were unable to determine a method of including a medical cost metric in our cluster analysis.

Extremely high housing costs in some cities also widen the meal gap. Cities such as San Francisco, Los Angeles, Seattle, Boulder, New York, and Washington, D.C., have exceptionally high housing costs relative to median household income.[35] These costs strain family budgets and cause food insecurity, not only for those living in poverty but also in households with incomes in excess of government assistance program thresholds.

In addition to income and expenses, there are a multitude of other factors not captured by poverty metrics that can cause or increase food insecurity, such as insufficient transportation to or proximity of grocery stores and markets.[36] Age, ability, and economic status all interact with and can exacerbate transportation-related food insecurity. Systemic racism and historical disinvestment from Indigenous, Black, and brown communities have also aggravated food insecurity because of the effects of redlining, predatory bank lending practices, limited access to wealth-building opportunities, insufficient transportation infrastructure, and disproportionate engagement with the criminal justice system.[37]

Furthermore, irrespective of poverty level, several demographic factors such as gender, race, presence of children in the household, educational attainment, and age also impact food security.[40] Food security is stratified along racial lines, with Black, Hispanic, and American Indian/Alaska Native households (as defined by the U.S. Census) twice as likely as white households to experience it.[41] Households led by single women, especially ones with young children, experience food insecurity more frequently than households led by single men or households without children.[42] For households with young children, costs of child care and housing often leave insufficient income for food. According to Angela M. Odoms-Young, an expert in diet and health among people of color and low-income communities:

> "The relationship between race/ethnicity and food insecurity is complex and is clearly intertwined with other established determinants of food insecurity including poverty, unemployment, incarceration, and disability. Concentration of social and economic disadvantage among people of color over the life course is clearly a significant driver of higher rates of food insecurity. Nevertheless, despite the intersectionality of race/ethnicity and other social/economic determinants, some evidence suggests that the higher risk of food insecurity . . . among people of color continue even when these other social and economic factors are removed."[43]

By grouping cities on the basis of more than one metric of need (poverty, food costs, housing costs, and estimated meal gap), we aim to reflect the root causes of hunger and the need to address these roots to truly eliminate it. Food rescue provides an immediate, albeit temporary, fix to a very timely issue. At the same time, we shouldn't forget that in order to create systemic change to permanently address food insecurity, we need to also employ solutions that lift wages, moderate housing costs, improve health care, and transform structural inequity.

THE UNEMPLOYMENT IMPACT OF COVID-19

The year 2020 saw unprecedented job losses in the United States due to COVID-19. Cities in this study had baseline unemployment rates from under 3 percent to 7 percent in 2018, but we know that 2020 numbers were much higher. Unemployment is a known risk factor for food insecurity.[38] If we use unemployment as a proxy for food insecurity, present food needs in cities may eclipse pre-pandemic needs in the poorest communities according to the data available at the time of this research. This change underscores the urgency to expand effective strategies for increasing food rescue in cities and the need for robust government safety net programs to prevent hunger in times of emergency.

If employment recovery from the last recession is any indication, food insecurity may continue to rise for years, and a return to pre-downturn levels may take a decade or longer.[39] Given the much greater magnitude and rate of job losses resulting from the COVID-19 pandemic, it is possible we are entering an era of extreme food insecurity in the United States.

FOOD RESCUE POTENTIAL: CITY SIZE AND DENSITY DICTATE OPPORTUNITY

Where surplus food is available, it should be redistributed to community members in need. However, rescuing and distributing surplus food is logistically complex, and certain city characteristics can make these operations more or less feasible. For example, one common barrier to food donation is availability of labor and equipment to safely transport surplus food from businesses to food banks, pantries, and emergency food distributors like shelters; this barrier may be higher in small cities with fewer resources, and it may be lower in dense cities where the same hours of labor can reach a greater number of food donors and distribution points.

We conducted a second cluster analysis to group cities according to need, quantity of food that could potentially be rescued for redistribution, and logistical difficulty of rescuing surplus food by comparing our modeled ambitious rescue potential with criteria that could facilitate food rescue activities. Five groups emerged from this second analysis, as shown in Table 2. Overall, food rescue potential is impacted by numerous variables, but city area and population density may be the most prominent factors for designing programs to successfully rescue surplus food.

Our analysis found that the need for surplus food doesn't always align with food rescue opportunities. Groups F and G have the greatest alignment between need and opportunity, though need (poverty and food cost) outweighs opportunity (city size and density) in group F and opportunity may be greatest in group G. Food rescue may be more difficult in the other groups because a city is sprawling, because the amount of rescuable food is very low, or for a combination of reasons.

Density and area matter when it comes to matching food rescue need and opportunity. In small cities and small, dense cities (such as groups F and G), businesses are relatively close together, and it may be easier for food rescuers to collect from multiple locations and bring them to nearby food distribution centers. When potential food donor businesses are spread out, such as in group I, transportation logistics and the low cost of food can thwart food rescue.

For cities with a large area, such as those in Groups I and J, coordinating the rescue of surplus food across the city as a whole may be too logistically challenging. Instead, food rescue efforts should focus on neighborhoods or smaller subsections of the city. Additionally, multiple rescue groups may exist in these large cities, and coordination among these groups to optimize collection of surplus food can add an additional level of complexity in ensuring that surplus food is picked up and redistributed to food-insecure residents.

Though our research focused on urban cores, there are opportunities for rescuing surplus food beyond city borders. This is especially noteworthy for group J cities and others where food insecurity is high and excess food within city borders is quite limited; therefore, food rescue organizations would need to capture food outside the city limits to meet the food needs of their communities. Many food rescue operations already span regions distinct from city boundaries, such as a metropolitan area, the unincorporated zone around a city, a county, or a multicounty district.

This project would have yielded different results if we had been able to assess food availability that more closely resembled the way in which people procure it. Much of the food that is eaten by city dwellers is produced and processed outside of the city limits. Food fluidly crosses these borders, as do consumers, workers, and eaters. All cities seeking to end hunger, but especially those resembling our groups H, I, and J, would benefit from an analysis of surplus food within their entire foodshed—the region that produces food for the population—and not just within their city borders. However, we were not equipped to map regional foodsheds to quantify the potential surplus, chiefly because the U.S. food supply is highly complex and traverses the globe.

TABLE 2: NEED AND OPPORTUNITY CLUSTER ANALYSIS: City groupings resulting from cluster analysis based on six metrics: city area, population density, household size, poverty rate, food affordability, and ambitious rescue potential. For some variables, the cities in a group presented a wide range of outcomes; rather than assigning them a single level, we described the variable as "mixed."

Cluster Group	Need and Opportunity	Cities	Drivers of Need and Opportunity					
			City Area	Household Size	Population Density	Poverty	Food Cost	Ambitious Scenario Potential
F	Highest Need and Opportunity	Cincinnati, Flagstaff, Pittsburgh, Richmond, Springfield	Small	Small	Medium	High	Low	Mixed
G	High Opportunity	Alexandria, Boulder, Jersey City, Newark, Washington, D.C.	Very Small	Mixed	High	Mixed	High	Mixed
H	Some Opportunity	Atlanta, Baltimore, Charlotte, Denver, Philadelphia, Raleigh	Medium	Mixed	Mixed	Mixed	Medium	Medium
I	Little Opportunity	El Paso, Louisville, Memphis, Nashville	Large	Large	Low	Mixed	Low	Mixed
J	High Need but Very Little Opportunity	Los Angeles, New York	Large	Large	High	Medium	High	Very Low

While there is likely a significant amount of surplus food available in cities, our current research shows that very few have enough surplus, rescuable food within their borders to fill their meal gaps.

Additionally, beyond the identification of willing and proximate food donors, there are a number of logistical challenges complicating food rescue that are not captured in the data set we have collected. Labor, refrigeration, and storage space, for instance, are also necessary components of expanded food rescue. Availability of volunteer labor—or funds to support a paid staff—is critical to increasing food rescue, as is the ability to transport food at temperatures that meet health and safety standards, a frequently cited barrier to increased food rescue. We were not able to assess these factors within our clusters. Unwilling donors also complicate food rescue efforts; despite federal protections and additional statutes in all 50 states, food businesses often cite concern about legal liability as a reason for not donating surplus food.[44]

Though we had expected to find a direct statistical relationship, these clusters suggest that neither poverty level nor the amount of surplus food available (in our ambitious scenario) are closely linked with city density, city size, household size, or food costs; hence the numerous "mixed" outcomes within cluster groups. If we had found a stronger correlation among these variables, we would have been able to make stronger recommendations for food rescue efforts based on these characteristics; however, these connections do not appear to exist.

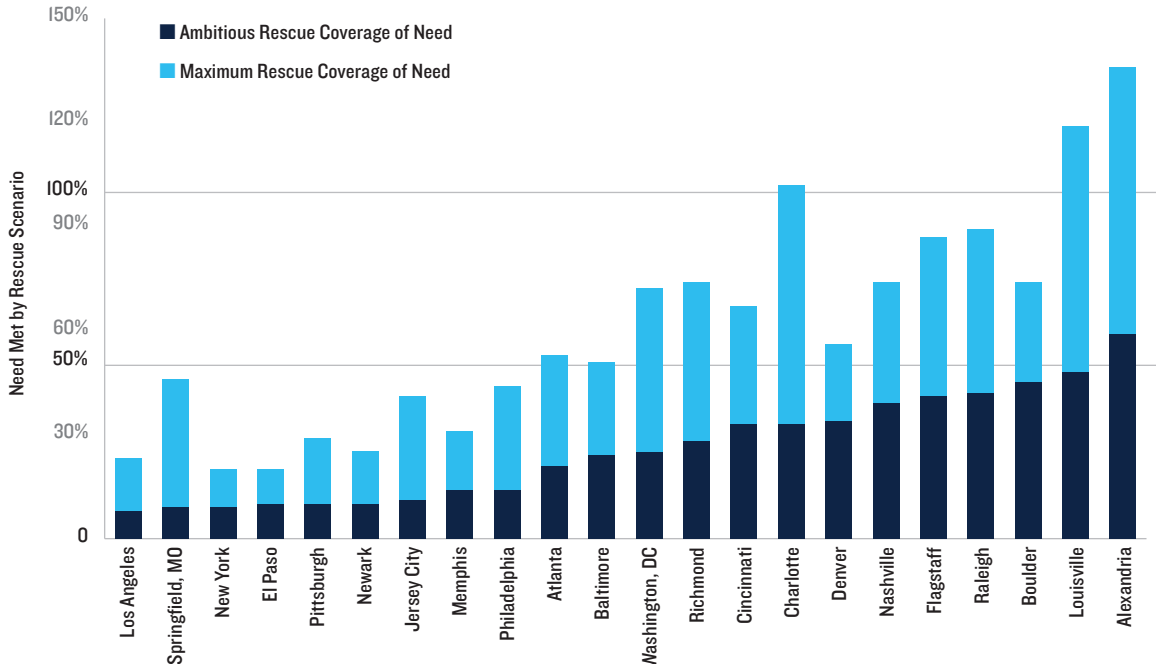
FOOD RESCUE ALONE CANNOT SOLVE URBAN HUNGER

Food need is immense. Approximately 813 million meals per year are lacking in the 22 cities in our study, and the total food budget shortfall for these cities in 2018 was more than $2.9 billion.[45] Getting adequate food on the plates of food-insecure families is an enormous fiscal undertaking. Thus, rescuing surplus food that has already been paid for and would otherwise go to waste is an important tool in addressing the hunger people experience today.

NRDC's previous analyses on food waste in the United States found that we have enough food for every food-insecure person's entire diet.[46] However, while there is likely a significant amount of surplus food available in cities, our current research shows that very few have enough surplus, rescuable food within their borders to fill their meal gaps.

In fact, there was enough food available in our maximum rescue scenario to meet the needs of the food-insecure population in only 3 of the 22 cities studied (Figure 5). On average, food rescued in the maximum scenario could fill 72 percent of the meal gap.[47] However, as noted previously, this includes *all* the available surplus food in a city. The ambitious scenario shows an even bleaker picture. Under the ambitious scenario, only one city could fill even half of its meal gap through food rescue, and the majority of cities would fill less than one-quarter of it.

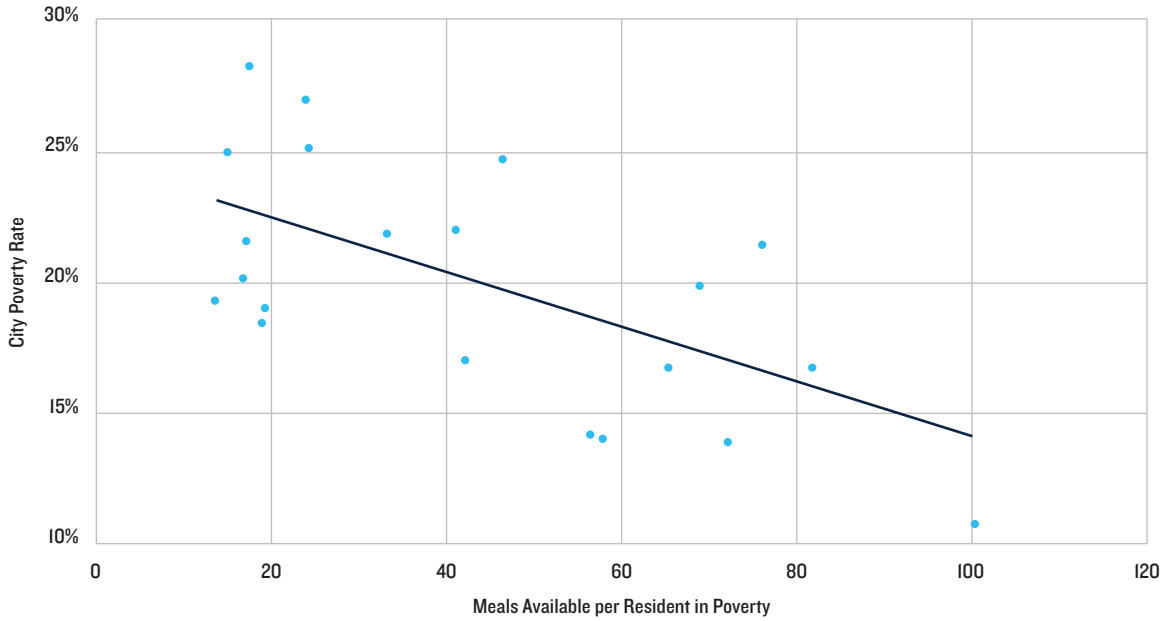
FIGURE 5: POTENTIAL COVERAGE OF NEED BY RESCUE SCENARIOS IN ALL CITIES



As noted above, food insecurity stems from a wide variety of issues including demographics, food cost, food availability, and access; the distribution of food across cities is neither even nor predictable. If food supply were distributed evenly, there would be more surplus food in places with high food insecurity because individuals who couldn't afford it wouldn't be purchasing their share. We normalized the amount of food available under the ambitious scenario by the number of people in poverty in the city to yield meals-per-person values and charted them as a function of poverty level in Figure 6. When we look at potential food available for rescue under the ambitious scenario as a function of poverty, we see that cities with lower poverty rates also tend to have higher amounts of surplus food available per person in poverty; these lower-poverty cities have fewer people in need of additional meals and the available surplus food can go farther. But the other end of the spectrum does not have the same correlation: The cities with the highest poverty rates are highly variable in how much food they have available for those in poverty. This may indicate a causal relationship between food insecurity and food supply. Many of these cities may have high food insecurity because they lack an adequate food supply, especially in the large retail sector; in other words, a lack of food access may be a major driver of the meal gap. These cities need an improved food supply before there are even opportunities for food rescue.

In addition to simply not capturing enough food in most cities, food rescue cannot be the sole solution to hunger because it does not address the underlying causes of hunger: inadequate wages, high costs of housing and health care, and discriminatory fiscal and urban planning policies inhibiting access to quality food. That said, donation and redistribution of safe, nutritious surplus food remains an important tool in maximally utilizing the food that has been produced to nourish local communities and in ensuring the financial viability of local anti-hunger efforts, which can stretch their activities further when supported by a steady stream of donated food.

FIGURE 6: THE RATIO OF FOOD AVAILABLE FOR RESCUE UNDER THE AMBITIOUS SCENARIO FOR EACH PERSON IN POVERTY AS A FUNCTION OF CITY POVERTY LEVELS



Conclusion

The goal of NRDC's Food Matters project is to help cities reduce food waste by implementing proven policies and programs. By obviating the need to start from scratch in each location, we can scale efforts for a greater impact across the country. Through our work with a broad array of cities, we have identified commonalities that can help other cities choose strategies that will work best for their specific characteristics, even if they lack the resources to conduct their own food waste generation and rescue potential assessments.

In analyzing these commonalities, we reached these conclusions about food waste and food rescue in American cities:

1. Of all food waste management practices, preventing food from becoming waste in the first place should be the highest priority for all sectors because it has the highest environmental and economic benefits. Where surplus food that meets health and safety requirements does exist, it should be rescued for redistribution to those in need of food assistance.
2. Typically the residential and restaurant sectors together contribute nearly two-thirds of a city's food waste generation. However, these sectors generate largely postconsumer waste, which is not appropriate for food rescue and redistribution. To make progress on zero-waste goals, a city must include strategies to help residents prevent food from becoming waste at home and when eating out.
3. Most of the surplus food available for rescue in cities comes from large retail grocery stores—on average, 75 percent of the total under our ambitious scenario.
4. Cities with a high poverty rate and a high cost of living have the greatest need. However, poverty is not a sufficient proxy for food need; some cities face multiple and compounding root causes of hunger.
5. Some cities have characteristics that facilitate food rescue—including a small area and high population density, —but others—like large, sprawling cities with very low surplus food availability—should reconsider the appropriate scale for activity, either at the neighborhood level or metropolitan regional level. Further, most cities do not have enough surplus food within their borders to meet the needs of their food-insecure populations. Food rescue efforts alone cannot be the solution to hunger.

City-level policymakers and other stakeholders working to address food waste and hunger should keep these city-specific conclusions in mind.

RECOMMENDATIONS FOR CITY ACTION

In addition to our suggestion that cities use our findings to tailor policies to their individual demographics and characteristics, we can recommend actions for all cities to take to prevent food from becoming waste, rescue surplus food for redistribution to community members in need, and enable food scrap recycling to avoid disposal in landfills or incineration.

- In accordance with the EPA's Food Waste Management Hierarchy (and to address the largest sources of food waste), cities should **focus on wasted food prevention education targeting households and food service businesses.** Once food waste prevention has been maximized, food scrap recycling of inedible parts is needed to keep organic material out of landfill and achieve local sustainability goals. Engaging residents in wasted food prevention and food scrap recycling both at home and while eating out will be critical to improved waste management.
- Cities should **identify second-tier generator hot spots**—smaller-sector businesses that each generate a large amount of food waste. These specific large generators will vary by city but may include a food manufacturing or processing plant, a university, a sports or event venue, or a district with many hotels in proximity.
- Local government, trade groups, or green business associations should **provide technical assistance to the food manufacturing and processing sector.**[48] Due to the large size of some manufacturing and processing facilities, food waste prevention in this sector could significantly curtail the amount of food going to waste in some cities as a whole. To provide inspiration to companies, researchers and policy advocates should write case studies on how prominent U.S. food manufacturers have changed their product designs or manufacturing processes to reduce food waste.[49] High-visibility commitments and technical assistance, such as from the federal U.S. Food Loss and Waste 2030 Champions program, could be a motivator for engaging these companies to improve their business operations and reduce food waste.[50] Some of them may already be implementing food waste prevention techniques; trade groups should develop peer-to-peer learning workshops to ramp up solutions and share best practices widely.
- In most cities, food rescuers should **target large grocery stores as potential suppliers of the largest quantities of donatable food.** Large grocery stores have the greatest potential for food rescue on average, and those that donate at the highest levels do so by maximizing donation of perishables. In some cities, there may also be a significant amount of

rescuable food in small retail stores, including corner markets, bodegas, and convenience stores. Small retailers are generally less familiar with donation incentives, and few of them currently donate. Therefore, **when there is a sizable corner store sector, cities should do outreach to small retail businesses to encourage donation** and should pair food donation education with these outreach efforts.

- Where the large retail sector's surplus food is already being maximally rescued, **food rescuers should pursue donations from food wholesalers and distributors**. In many cities, the food wholesale and distributor sector is estimated to generate about as much food waste as the large grocery sector. Though our analysis could not quantify how much food is potentially rescuable from this sector, it is likely to be significant and currently not accessed for rescue.
- Cities should improve communication with and education of the food service sector to reach their local food waste reduction goals. New food donors may need technical assistance to overcome actual or perceived barriers to donating surplus food, including finding a suitable food rescue partner, accessing information on liability protections and tax incentives, and garnering support for staff training. Uncertainty around food handling is often cited as a reason why businesses are not donating their surplus food, but this concern could be easily addressed through education. **Local government, including sustainability departments, business development offices, health inspectors, or others who already communicate with local businesses, should play a key role in educating licensed food facilities on how to safely store food to prevent it from prematurely spoiling and ensure safe donation of surplus.**[51]
- Local rescue organizations likely have information about what food is currently being donated and from where. **City governments should coordinate with rescue organizations to identify current donation levels within the city and use our analysis to assess where the greatest potential may exist for increasing capture of surplus food.** NRDC's Food Matters project has case studies describing successful models that could be replicated elsewhere.
- **Cities should adopt holistic urban planning policies that address the root causes of hunger.** Urban design can improve quality of life, expand access to service, and widen choice, and it may also reduce food waste.

FUTURE RESEARCH

The need for further investigation is vast, and many of the research needs articulated in our 2017 work on municipal food waste remain relevant. Several of these ideas were first presented in our original NRDC reports, and we have chosen to repeat them here because they provide important context as to the limitations of this study and the direction in which we believe future research should progress.[52]

It is our hope that as this work advances, cities will be able to identify more precise data sources; more accurate data could somewhat alter the analysis presented here. The list below highlights areas where more research or information could be particularly helpful.

- **Broader and deeper data for key sectors:** Research on additional sectors, such as agriculture, is needed to provide a more complete picture of both food waste generation and potential for increased food rescue. Some sectors—including convenience stores, food banks and pantries, coffee shops, airports, corporate cafeterias, and more—were not included in our city-level food waste generation estimates, even though they may substantially contribute to the total. Other sectors—such as food manufacturing and processing, food distributors and wholesalers, corporate cafeterias, etc.—were not included in our rescue potential models, even though they may have surplus food available for redistribution. While our models are based on some of the best existing data, the research is quite sparse and, in some cases, fairly dated. More research must be done to confirm present-day industry averages of food waste generation and the role of various interventions in driving it down.
- **Greater validation of business informatics data:** The business sector inputs we collected to run our calculations may have limitations in terms of the data's completeness or accuracy. Future studies may wish to integrate multiple sources of data on food-related businesses or rely solely on direct measurement (e.g., waste audits).
- **Impact of regional food systems on food waste:** Our research was limited by city borders, but as noted, food sheds go well beyond such boundaries. Future research is needed to understand the impact of regional food systems, food hubs, and shorter food chains on food waste generation, food security, and sustainability.
- **Underlying cause of density's impact on food waste:** Our model saw restaurant, grocery store, household, and population density correlations with food waste generation. More research is needed to better understand the reasons for these correlations and to identify potential intervention opportunities.
- **Further drivers of food insecurity:** Our research explored some common drivers of food insecurity but was not able to account for all potential variables. Additional research is needed to explore the impacts of housing costs, food costs, medical costs, and child and elderly care costs as well as age, ability, adequacy of transportation, and proximity of affordable and nutritious food on food security.
- **Edibility of and reasons for wasted food:** Our commercial food waste generation estimates do not break down baseline food waste generation by edibility. There may be some need to estimate how much commercial food waste is potentially edible, with an eye toward identifying possible food waste prevention strategies. (Note that, as discussed earlier, edible food is different from rescuable food. Rescuable food is a subset of edible food, and edible food is defined as food that could have been eaten, as opposed to inedible food parts.) Another way to approach this area of research may be to focus on determining the reasons for food waste in commercial sectors.

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- **Nutritional considerations:** Our research considered donated food largely by weight, including when it was described as a meal, and did not include characteristics such as nutritional content or desirability to food-insecure individuals or the organizations that serve them. Future studies should address these considerations to allow better prioritization of food types targeted for rescue.
- **Integration of political/economic trends with donation potential:** Our scenario analysis did not factor in broader trends such as possible future changes in government policy, food rescue innovation, or the potential effect of waste prevention on the supply of food that could be rescued. Future studies could incorporate these considerations.
- **Spatiotemporal variation related to donation:** We have not attempted to directly model or describe geographic variation in donation rates or how donation may change over time or as a function of the seasons. Models based on national donation data as a function of sales volumes may not appropriately account for differences in product costs across individual cities. Additional geography-specific research could bolster this analysis.

Appendix A—Methods

OBJECTIVE

The primary goal of this research was to apply the models developed through our previous research in Denver, Nashville, and New York City to estimate food waste and food rescue potential in other cities. We then investigated whether demographic characteristics, such as population density, household size, food costs, or poverty levels, affected food waste and food rescue potential, with the objective of developing information that would help additional cities better target their activities to address food waste and improve surplus food rescue.

DATA SOURCES

The bulk of the data for this study came from applying NRDC's city food waste generation and rescue potential models developed during our previous work in Denver, Nashville, and New York City.[53] We ran the models for 19 additional cities across the United States to estimate baseline food waste generation as well as rescue potential scenarios by sector.

The cities included in this report are:

- Alexandria, VA
- Atlanta, GA
- Baltimore, MD
- Boulder, CO
- Charlotte, NC
- Cincinnati, OH
- Denver, CO
- El Paso, TX
- Flagstaff, AZ
- Jersey City, NJ
- Los Angeles, CA
- Louisville, KY
- Memphis, TN
- Nashville, TN
- Newark, NJ
- New York, NY
- Philadelphia, PA
- Pittsburgh, PA
- Raleigh, NC
- Richmond, VA
- Springfield, MO
- Washington, DC

The sectors modeled in this report based on attributes such as revenue, population, or number of employees include:

- Colleges and Universities
- K–12 Schools
- Hospitality
- Health Care
- Grocers and Markets
- Convenience Stores and Small Retail
- Restaurants (Full Service, Limited Service, Coffee Shop, Caterer)
- Food Wholesalers and Distributors
- Food Manufacturing and Processing
- Event and Recreation Facilities
- Correctional Facilities
- Residential

Convenience stores and small retail was only included in the rescue analysis. Food wholesalers and distributors, food manufacturing and processing, event and recreation facilities, correctional facilities, and residential sectors were only part of the food waste generation analysis.

In some cases, we worked closely with city staff to help them collect the data needed to run the models. We also pulled information for cities from publicly accessible business databases to bolster our data set.[54] Collecting the data required to run our model and estimate food waste and surplus was difficult, and though we attempted to access the best data available, the reliability of our sources was uncertain.

Additionally, we collected 2018 U.S. Census data on population size, population density, city area, median income, housing costs, and poverty rates for all studied cities. We used Feeding America data on food insecurity and meal cost.[55]

CITY CHARACTERISTICS

Cities in this study varied widely in area size, population, and geography. Population was the widest-ranging variable across cities, going from Flagstaff, Arizona, with just over 73,000 people, to New York City, with more than 8.3 million residents. Cities varied greatly in area as well, with footprints ranging from less than 50 square miles (e.g., Jersey City and Alexandria) to an expansive 450 square miles (e.g., Nashville and Los Angeles). Given the range in both population and area, population density varied widely across cities, from lowest-density Louisville to highest-density Jersey City. Mean household size went from 2 people per household in Pittsburgh, Cincinnati, and Springfield

to close to 3 in El Paso. Our sample was somewhat concentrated in the East (13 cities), especially the mid-Atlantic corridor from Alexandria to New York City, and was under-representative of the West, Southwest, northern non-coastal cities, and cities outside the contiguous states.

Food industry structure, defined as the relative revenue represented by each sector, was largely consistent across cities. Pittsburgh and Cincinnati were outliers in this regard, with extremely large food manufacturing and processing sectors. Restaurants were the largest food sector overall. Convenience and small retail were not the dominant sector in terms of revenue in any city, although both Philadelphia and Charlotte had convenience and small retail sectors that were almost as large as their traditional grocery sectors.

ANALYSES

We characterized cities by key geographic, demographic, and food industry profiles including population, household size, median household income, poverty rate, land area, median housing cost, meal cost, and the results produced by running our models to estimate food waste generation and rescue potential.

For each city, we repeated the models set forth in the 2017 reports *Estimating Quantities and Types of Food Waste at the City Level* and *Modeling the Potential to Increase Food Rescue: Denver, New York City and Nashville* to estimate food waste generation or the potential for food rescue in each sector.[56] For example, the food waste generation model estimates five pounds of food waste for every $100 of revenue in the food manufacturing and processing sector. In another example, the food rescue model's maximum scenario expects four pounds of donatable food per K–12 student per year with 100 percent participation from all schools.

We summarized food waste generation amounts per year both in absolute quantities per city and normalized by population. We explored the relationships between population density, household density, grocery store density, and food waste using simple, pairwise linear regression analyses of per capita food waste. Two cities with large food manufacturing and processing sectors (Pittsburgh and Cincinnati) were identified as outliers and were excluded from the regression analyses.

We used cluster analyses to identify underlying similarities among cities with common attributes. We endeavored to explore which cities have the greatest need for rescue of surplus food to fill the immediate gaps. We examined a set of indicators across cities to create discrete profiles of common characteristics.

We explored food need through calculation and summary of key indicators, root causes, or exacerbating factors: unmet meal need, housing affordability, food affordability, and city poverty rate. We followed Feeding America's methodology and analysis in determining the local unmet meal need and relied on its county estimates of food costs and meals needed per food-insecure person ("meal gap" or "meal need" refers to the amount of food that is needed by food-insecure households).[57] To understand which cities shared similar need profiles, we performed a cluster analysis using Ward's method on those four variables.[58] We then summarized the potential of food rescue scenarios to fill the yearly unmet food needs of each city.

We conducted a second cluster analysis using Ward's method to group cities on the basis of indicators that we deemed reflective of both need and opportunity to facilitate the rescue and redistribution of surplus food. For this analysis we included city poverty rate, food cost, quantity of food that could potentially be rescued (as identified by running our ambitious rescue potential model), and logistical difficulty of rescuing food because of the city's size, city density, and average household size.

Appendix B—Additional Graphs and Figures

FIGURE A-1: CHARACTERISTICS OF 22 U.S. CITIES INCLUDING A) POPULATION, B) CITY AREA, C) POPULATION DENSITY, AND D) HOUSEHOLD SIZE

Cities marked with an asterisk were part of the original 2017 research.

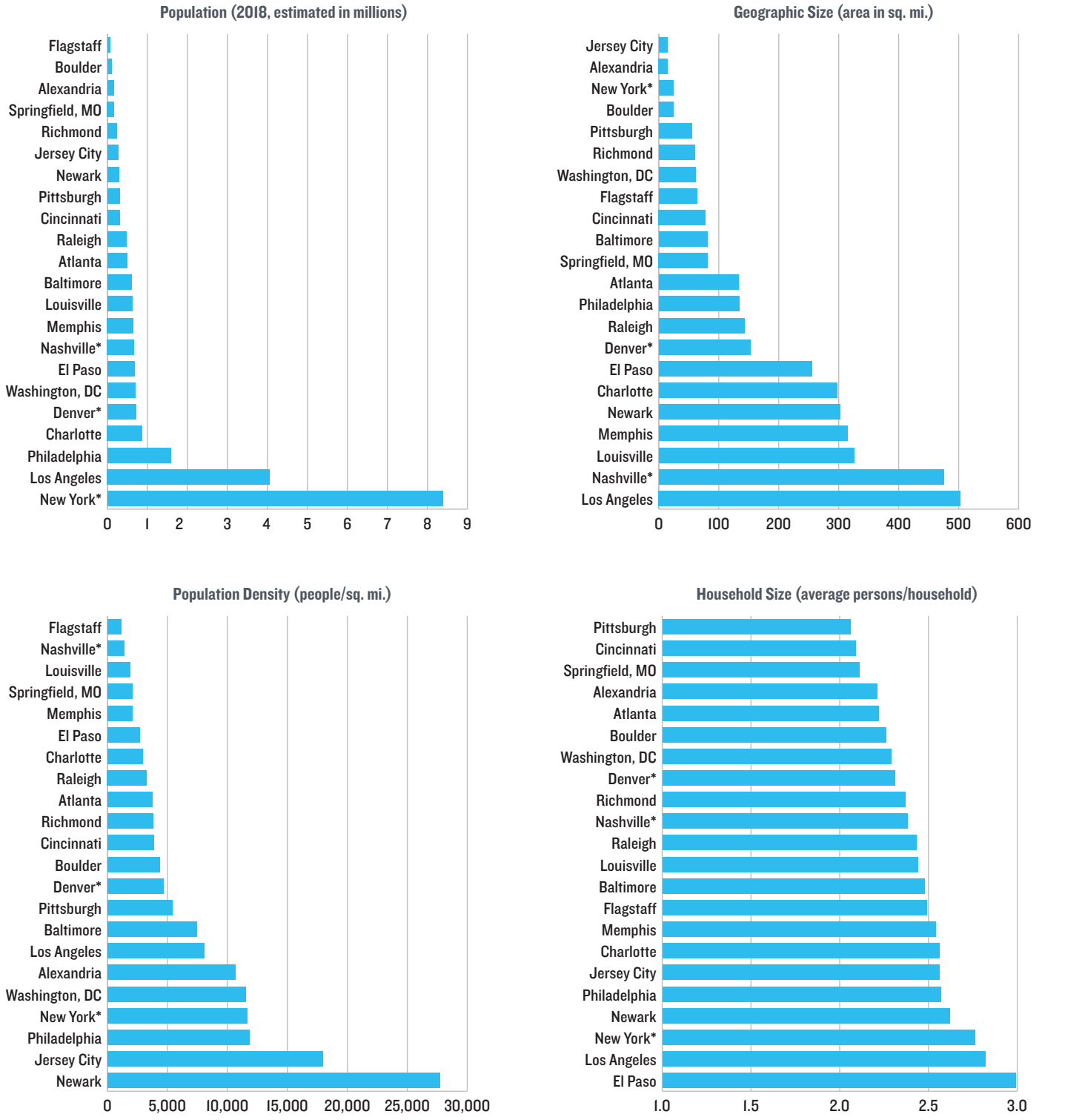
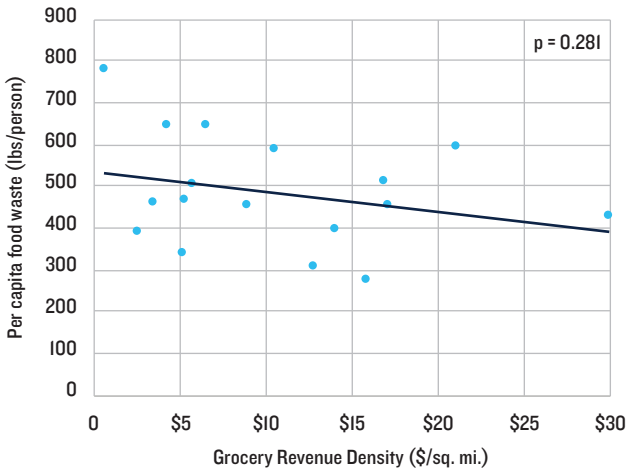


FIGURE A-2: THE EFFECTS OF GROCERY REVENUE DENSITY ON THE AMOUNT OF PER CAPITA FOOD WASTE PER YEAR

(n = 17; data set excludes original study cities of Denver, Nashville, and New York as well as outliers.)



Unlike the negative correlation of food waste with higher population density and larger household size (Figure 3), food waste was not significantly affected by the relative size of the grocery sector compared with the city land area. Recent economics literature supports a related finding that higher grocery store density reduces food waste, as well as a finding that most cities are well below the ideal threshold density.[59] However, our assessment of grocery store revenue, as opposed to physical location, was not correlated with per capita food waste, even when controlled for city size.

FIGURE A-3: CITIES BROKEN INTO CLUSTERS (CLUSTER ANALYSIS #1) BASED ON SIMILARITY IN RELATIVE NEED METRICS
POVERTY RATE, FOOD AFFORDABILITY, HOUSING AFFORDABILITY, AND MEAL GAP

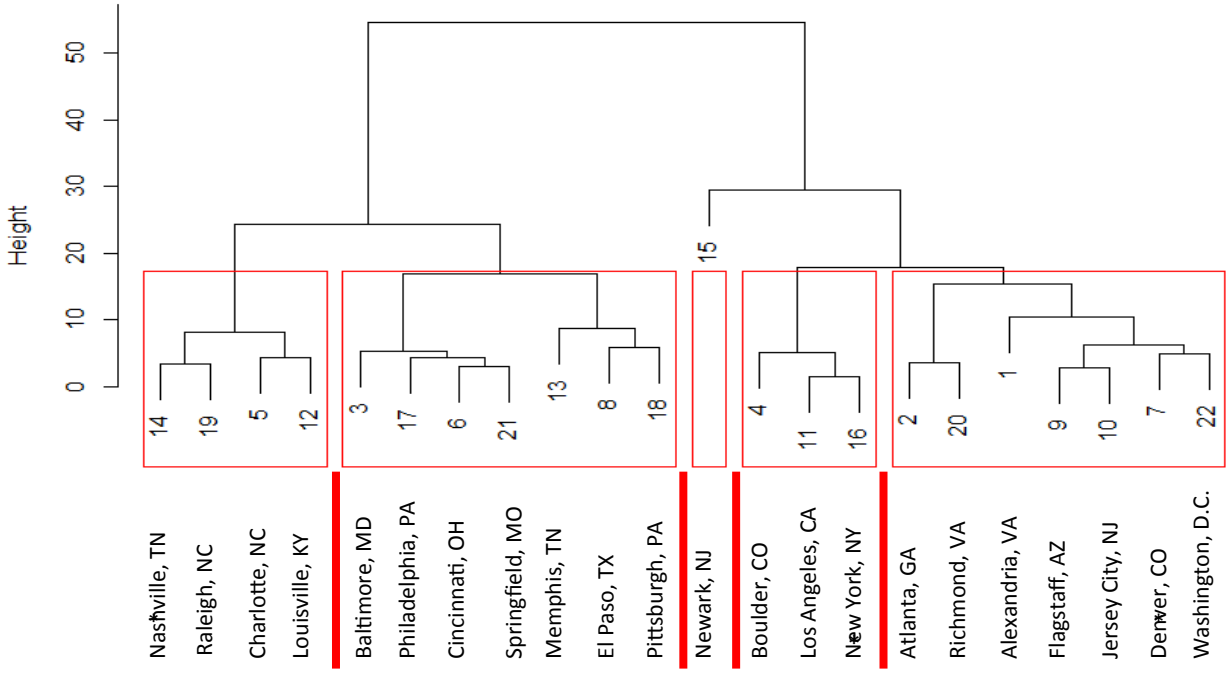
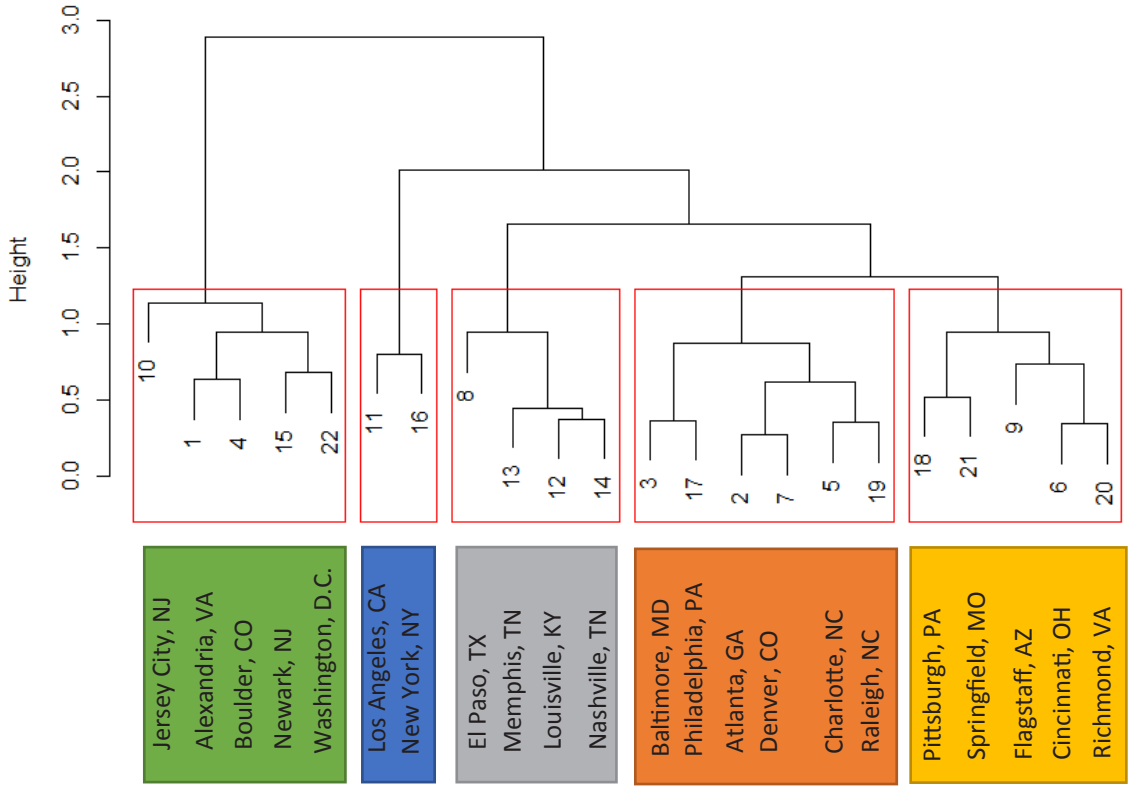


FIGURE A-4: CITY CLUSTERS (CLUSTER ANALYSIS #2) BASED ON NEED AND OPPORTUNITY
INCLUDING CITY AREA, CITY DENSITY, HOUSEHOLD DENSITY, POVERTY RATE, FOOD AFFORDABILITY, AND AMBITIOUS RESCUE POTENTIAL DENSITY



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