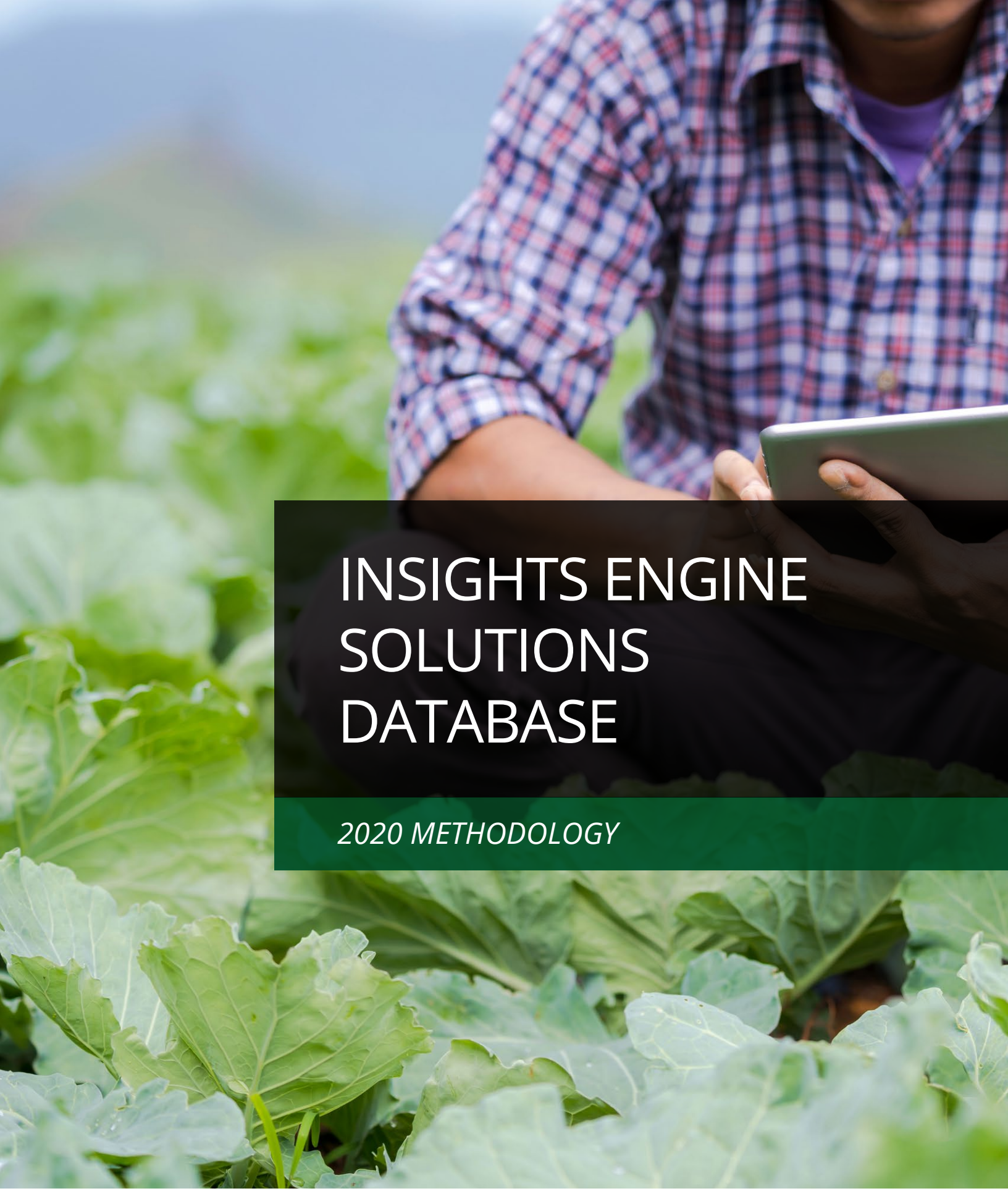

INSIGHTS ENGINE SOLUTIONS DATABASE

2020 METHODOLOGY

ReFED

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This Technical Appendix describes the methodology used to quantify the potential financial, environmental, and social benefits of food waste solutions in the U.S. by stakeholder group, food type, and state in an effort to achieve the national goal to cut food waste in half by 2030. The resulting data is available via the Solutions Database, which is part of the ReFED Insights Engine online platform.

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Contract Partners & Data Contributors

Juniata Analytics is a tech start-up working at the intersection of business, sustainability, and software to help organizations calculate, analyze, and share sustainability information across internal operations and supply chains. Juniata was responsible for crafting the initial vision for the ReFED Insights Engine, managing the project and coordinating contractors, developing the methodologies, collecting and processing data, and developing a web application to automate the data modeling.

Deloitte.

Deloitte provided in-kind consulting services in addition to their contracted services to create the base cost-benefit analysis for the 40+ modeled solutions in the ReFED Insights Engine Solutions Database. In addition to many of the other solutions, they drew upon extensive experience in perishable supply chains to quantify several solutions that are new in this analysis, as well as fleshed out solutions in our Solution Fact Sheets. Deloitte also conducted the analysis for the original 2016 ReFED Roadmap.

Quantis

Quantis is a sustainability consulting group that guides top organizations to define, shape and implement intelligent environmental sustainability solutions. In a nutshell, their creative geeks take the latest science and make it actionable. They employ internationally renowned experts in life cycle assessment and sustainability quantification. Quantis was commissioned to support the development of Greenhouse Gas emissions factors of food loss and waste specific to supply chain stage, product type, and end destination.

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OVERVIEW

In 2016, ReFED launched its landmark *Roadmap to Reduce U.S. Food Waste by 20%*. That initial report became a touchstone for those in the food waste space, but there was a growing need for more - and more granular - data about the issue to fill in knowledge gaps and move the food system from awareness about the issue to insight-driven action. The newly developed ReFED Insights Engine is the next generation of data, insights, and guidance on U.S. food waste. This online data and solutions hub for food loss and waste is designed to provide anyone interested in food waste reduction with the information and insights they need to take meaningful action to address the problem and move a step forward towards achieving national and international goals of reducing food waste by 50 percent by 2030.

Current ReFED Insights Engine tools include:

- **Food Waste Monitor:** Centralized, trusted repository of information built with data from more than 50 public and proprietary datasets that shows how much food is being wasted in the U.S., why it's happening, and where it goes.
- **Impact Calculator:** Quantifies the impact of wasted food on the climate, natural resources, and recoverable meals.
- **Solutions Database:** Provides a stakeholder-specific, comprehensive analysis of 40+ food waste reduction solutions based on impact goals, along with detailed fact sheets on each.
- **Solution Provider Directory:** Connects users with a vetted list of 700+ nonprofit and for-profit organizations ready to help implement food waste reduction solutions.

Solutions Database

The Solutions Database quantifies the potential financial, environmental, and social benefits of actionable solutions to reduce food waste in the U.S. This document describes the methodology used to quantify the Tons Diversion Potential, Net Financial Benefit, Greenhouse Gas Emissions (GHG) Reduction Potential, Water Savings Potential, Meal Equivalents, and Job Creation Potential of each solution.

ReFED included solutions that have been demonstrated as feasible to implement and having a measurable impact on food waste reduction. The data analysis was limited to solutions that ReFED was able to model using available data. For each solution, ReFED researched publicly available sources and consulted experts to find the best available data. Some solutions were excluded from the analysis because the available data was proprietary and could not be publicly disclosed. Others were excluded because there was no available data or because they were deemed to be best practices that are already widely adopted. To make sure that solutions with data gaps are prioritized for future research, ReFED maintains a list of unmodeled solutions in the Solutions Database. These solutions have qualitative fact sheets available, but they are not included in the data modeling. While the list of modeled solutions is not exhaustive and is intended to be continuously improved and expanded, the proposed solutions provide a practical roadmap to achieve the national goal to cut food waste in half by 2030.

Before starting development, the ReFED team sought feedback from its network of industry professionals from businesses, capital providers, government, nonprofits, and academia. The Solutions Database was designed to incorporate this feedback and maintain the strengths of the 2016 Roadmap report while filling previous information gaps with new data and models in a continuously improved, digital format. The following thematic areas summarize the major additions and improvements made:

Roadmap to 50% Reduction by 2030

- **Aligned with national and international goals**: The previous Roadmap outlined a path to reduce U.S. food waste by 20%. This new solutions Roadmap provides a path to 50% reduction by 2030, in alignment with U.S. and international goals. This assumes, however, that there is 100% adoption of all the solutions in the database.

New and More Granular Information

- **Quantified causes of food waste**: Quantifying the reasons why food waste is happening is a necessary precursor to calculating the potential benefit of food waste solutions. Until now, this causal information has not been quantified. ReFED applied solutions only to the portions of surplus where the solution applied. For instance, a donation solution was only applied to overproduced food in restaurant kitchens, not the waste left on customers plates. By gaining this understanding, ReFED is now able to more accurately estimate the potential impact of solutions.
- **Results tailored to specific sectors and stakeholders**: Stakeholders can now quickly filter and view information that is relevant specifically to them. The previous Roadmap aggregated the costs and benefits of solutions across all stakeholders involved. It was not always clear when misaligned incentives existed (e.g., When implementing a solution required one stakeholder to bear most of the cost while others benefited). Now users are able to break out the costs and benefits for each stakeholder involved, providing a better understanding of the misaligned incentives and financial barriers that still exist for many solutions. This allows misaligned incentives to be identified and collectively addressed.
- **Food type specific data**: Improved decision making requires food type specific information (e.g., developing a strategy to increase donations of produce specifically). In the past, much of the modeling was not food type specific. ReFED's models now take food type into account at much more granular levels, leading to more accurate insights.
- **Geographically specific (state-level) data**: ReFED data now reflects major differences between states (e.g., California has a large agricultural produce sector, Wisconsin has a large dairy manufacturing sector, Hawaii has a large foodservice and hospitality sector). This analysis now enables state-level actors to filter and prioritize different solutions based on their state's local economy and food waste patterns.

Interactivity and Automation

- **Interactive digital format**: Different audiences have different needs. ReFED has moved to interactive online tools that allow stakeholders to quickly obtain data tailored to their specific needs. Some materials will still be provided in PDF format as well.
- **Quick updates and rapid feedback loop**: A custom, automated web application allows the models to be rerun and the platform to be quickly updated with the latest information. This reduces the time required to produce new results to hours instead of months or years. This rapid feedback loop allows solutions to be quickly reprioritized according to the latest learnings as solutions are implemented and scaled. ReFED is planning to update results once or twice annually.

Transparency

- Data quality scores: ReFED developed data quality scores to communicate how confident ReFED is in the data being shared based on the quality of the underlying data sources and how they were used. These scores are now displayed front-and-center on the website rather than only in the documentation. This addition allows ReFED to share newly emerging data while maintaining transparency about the data confidence.
- Open source data: Raw data and documentation is now made publicly available as much as legally possible. Confidential data is only used in cases where it yielded significant advantages over publicly available data.

Research Opportunities

- Setting a research agenda: ReFED's new models and data quality scores are able to succinctly highlight what data is most critical and where it is lacking. ReFED hopes that this information will be used to prioritize research funding and advance new research projects.

Adaptable Framework

- Platform can be expanded to other countries if needed: Because the first version of the Roadmap served as inspiration for many other food waste initiatives at the international level, this platform was intentionally designed to be expanded to other countries using geographically specific data.

NOTICE AN ISSUE WITH THE DATA?

Send us an email! The Insights Engine was designed to be radically transparent so that the community of people using this work can help spot issues and identify opportunities to continually improve the data over time. If you see any mistakes, have additional information, or have recommendations for how to improve this resource, please let us know.

TONS DIVERSION POTENTIAL

Definition:
The Diversion Potential of a solution is the amount of food surplus that ReFED estimates a particular solution could avoid if fully implemented along with other ReFED-proposed solutions. It is applied only to the portions of food surplus that are considered addressable by that solution. For a solution that applies only to foodservice kitchens, for instance, the diversion rate would only be applied to back-of-house surplus, not to surplus that is plate waste or that occurs in other sectors.

Master Diversion Potential Equation:
*Solution Diversion Potential = Addressable Surplus * Solution Diversion Rate*

In ReFED's data model, the following calculations are repeated for every sector, cause, food type, and state before any aggregation is done.

Table 1. Calculations Performed to Estimate Diversion Potential of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Tons Addressable Surplus	Food Waste Monitor, Solutions Database Modeling	According to the Food Waste Monitor, there were 3,405 tons of surplus Prepared Food in the Limited Service Mexican Foodservice sector (e.g., Taco Bell, Chipotle, etc.) due to Catering Overproduction in Florida in 2020. After subtracting the amount of this Catering Overproduction that ReFED estimates could be addressed by higher priority solutions (e.g., Prevention solutions), ReFED estimates that there would be 2,304 tons of Prepared Food Catering Overproduction in the Florida Limited Service Mexican Foodservice sector left for the solution 'Donation Storage Handling & Capacity' to address.
Solution Diversion Rate	Multiple data sources (See Appendix G for the Solution Diversion Rate data sources for each solution)	ReFED assumed that 'Donation Storage Handling & Capacity' could reduce the amount of food that goes uneaten due to Foodservice Overproduction by 3.64%.
Annual Solution Diversion Potential	= Tons Addressable Surplus * Solution Diversion Rate	= 2,304 tons addressable surplus * 3.64% diversion = 83.87 tons of Prepared Food Catering Overproduction could be prevented in the Florida Limited Service Mexican Foodservice sector annually if 'Donation Storage Handling & Capacity' was fully implemented. **Reminder:** This example calculation is not the total diversion potential for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total diversion potential for each solution.

NET FINANCIAL BENEFIT

Definition:
The Net Financial Benefit of a solution is the financial benefit that ReFED estimates a particular stakeholder (or all stakeholders combined) could acquire after incurring the necessary costs to implement the solution as well as any potential cost savings, added revenue generation, etc.

Master Net Financial Benefit Equation:
Net Financial Benefit = Gross Financial Benefit - Cost
(Note that all annual costs and benefits are calculated using Net Present Value over 10 years with a 4% discount rate.)

In ReFED's data model, the following calculations are repeated for every sector, state, food type, and stakeholder before any aggregation is done.

Table 2. Calculations Performed to Estimate Net Financial Benefit of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Cost per Ton Diverted	Multiple data sources (See Appendix G for the data sources for each solution)	Estimated costs for each stakeholder involved in 'Donation Storage Handling & Capacity' in the Foodservice sector: Foodservice: = $137 per ton for labor Solution Providers: = $1,196 per ton to store food Government: = $163 per ton for reduced tax revenue from donations tax deductions Consumers: $0 cost All Stakeholders Combined: = $137 + $1,196 + $163 = $1,496 per ton

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Gross Financial Benefit per Ton Diverted	Multiple data sources (See Appendix G for the data sources for each solution)	Estimated financial benefits for each stakeholder involved in implementing 'Donation Storage Handling & Capacity' in the Foodservice sector: Foodservice: = $163 per ton for cash tax savings from enhanced tax deductions as opposed to taking a regular loss deduction + $45 per ton for waste hauling savings Solution Providers: = $0 (most donations organizations do not charge businesses to donate food so they do not generate revenue) Government: = $0 Consumers: = $4,432 per ton from the retail value acquired from donated food All Stakeholders Combined: = $163 + $45 + $4,432 = $4,639 per ton
Annual Solution Diversion Potential	See Diversion Potential calculations above.	ReFED estimates that 'Donation Storage Handling & Capacity' could divert 83.87 tons of Prepared Food Catering Overproduction annually in the Florida Limited Service Mexican Foodservice sector.

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Annual Cost to Implement	= Cost per Ton Diverted * Annual Solution Diversion Potential	Foodservice: = $137 per ton for labor * 83.87 tons diverted = $11,508 Solution Providers: = $1,196 per ton to store food * 83.87 tons diverted = $100,318 Government: = $163 per ton for reduced tax revenue from donations tax deductions * 83.87 tons diverted = $13,641 Consumers: = $0 * 83.87 tons diverted = $0 All Stakeholders Combined: = $11,508 + $100,318 + $13,641 = $125,466
Annual Gross Financial Benefit	= Gross Financial Benefit per Ton Diverted * Annual Solution Diversion Potential	Foodservice: = ($163 per ton for cash tax savings + $45 per ton for waste hauling savings) * 83.87 tons diverted = $17,406 Solution Providers: = $0 * 83.87 tons diverted = $0 Government: = $0 * 83.87 tons diverted = $0 Consumers: = $4,432 per ton from the retail value acquired from donated food * 83.87 tons diverted = $371,689 All Stakeholders Combined: = $17,406 + $371,689 = $389,095

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Annual Net Financial Benefit	= Annual Gross Financial Benefit - Annual Cost to Implement	Foodservice: = $17,406 gross financial benefit - $11,508 cost = $5,899 net financial benefit Solution Providers: = $0 gross financial benefit - $100,318 cost = -$100,318 net financial benefit **Note**: Notice that Solution Providers are not usually profitable for this solution. Since most donations organizations do not generate revenue from donated food, their costs are usually covered by grants so that they can remain operational. Government: = $0 gross financial benefit - $13,641 cost = -$13,641 net financial benefit Consumers: = $371,689 gross financial benefit - $0 cost = $371,689 net financial benefit All Stakeholders Combined: = $5,899 + -$100,318 + -$13,641 + $371,689 = $263,629 net financial benefit **Reminder**: This example calculation is not the total net financial benefit potential for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total net financial benefit for each solution.

GHG REDUCTION POTENTIAL

Definition:
The Greenhouse Gas Emissions (GHG) Reduction Potential of a solution is the net emissions reduction that would result from the implementation of a particular solution as opposed to the food being disposed of according to the status quo.

Master GHG Reduction Potential Equation:
GHG Reduction Potential = (Status Quo GHG Footprint per Ton - Solution GHG Footprint per Ton) * Solution Diversion Potential

In ReFED's data model, the following calculations are repeated for every sector, state, and food type before any aggregation is done.

Table 3. Calculations Performed to Estimate GHG Reduction Potential of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Status Quo GHG Footprint per Ton of Surplus Food Going to Worse Destinations	Food Waste Monitor, GHG Factors developed by ReFED in partnership with Quantis[2,3] See Appendix D for more information. The example calculations described here are the same approach that is used in the Insights Engine Impact Calculator: refed.com/insights-engine/impact-calculator	ReFED estimates that the status quo average GHG footprint per ton of Prepared Food being sent to "worse" destinations in the Florida Limited Service Mexican Foodservice sector in 2020 was: 4.750943 MTCO2e per ton **Note:** "Worse" destinations means that the destination is lower priority than the destination that the solution would otherwise divert the food to. See Appendix C for a list of ReFED's destination priorities. For this example, the solution diverts food to Donations, so "worse" destinations include anything from Animal Feed and below.
GHG Footprint per Ton for Food Waste Solution	GHG Factors developed by ReFED in partnership with Quantis	The GHG footprint factor for Donations of Prepared Foods in the Foodservice sector is: 0.390236 MTCO2e per ton
GHG Benefit per Ton for Food Waste Solution	= Status Quo GHG Footprint per Ton of Surplus Food Going to Worse Destinations - GHG Footprint per Ton for Food Waste Solution	= 4.750943 MTCO2e per ton status quo - 0.390236 MTCO2e per ton for donations = 4.360706 MTCO2e avoided per ton

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Annual Solution Diversion Potential	See Diversion Potential calculations above.	ReFED estimates that 'Donation Storage Handling & Capacity' could divert 83.87 tons of Prepared Food Catering Overproduction annually in the Florida Limited Service Mexican Foodservice sector.
GHG Reduction Potential of Food Waste Solution	= GHG Benefit per Ton for Food Waste Solution * Annual Solution Diversion Potential	= 4.360706 MTCO2e avoided per ton * 83.87 tons diverted = 366 MTCO2e avoided **Reminder**: This example calculation is not the total GHG reduction potential for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total GHG reduction potential for each solution.

WATER SAVINGS POTENTIAL

Definition:
The Water Savings Potential of a solution is the estimated amount of water use that would be avoided if a particular solution was fully implemented.

Master Water Savings Potential Equation:
Water Savings Potential = (Status Quo Water Footprint per Ton - Solution Water Footprint per Ton) * Solution Diversion Potential

In ReFED's data model, the following calculations are repeated for every sector, state, and food type before any aggregation is done.

Table 4. Calculations Performed to Estimate Water Reduction Potential of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Status Quo Water Footprint per Ton of Surplus Food Production	Food Waste Monitor, Water Footprint Network[4,5] water use factors See Appendix E for more information. Currently, these water factors only account for the water used to produce the food. They do not account for any water use required for disposal.	ReFED estimates that the status quo average water footprint per ton of Prepared Food being sent to "worse" destinations in the Florida Limited Service Mexican Foodservice sector in 2020 was: 239,950 gallons of water use per ton **Note:** "Worse" destinations means that the destination must be lower priority than the destination that the solution would otherwise divert the food to. See Appendix C for a list of ReFED's destination priorities. For this example, the solution diverts food to Donations, so "worse" destinations include anything from Animal Feed and below.
Water Footprint per Ton for Food Waste Solution	Water Footprint Network[4,5] water use factors	The Water footprint factor for Donations is: 0 gallons per ton **Note:** ReFED is assuming that one ton of food prevention or donations results in one less ton of food production, which cancels out upstream water use.
Water Savings per Ton for Food Waste Solution	= Status Quo Water Footprint per Ton of Surplus Food Going to Worse Destinations - Water Footprint per Ton for Food Waste Solution	= 239,950 gallons of water use per ton status quo - 0 gallons of water use per ton for donations = 239,950 gallons of water use avoided per ton

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Tons Prevented or Donated	For Prevention and Donations solutions: = Annual Solution Diversion Potential See Diversion Potential calculations above. For Recycling solutions: = 0 Because recycling food (composting, anaerobic digestion, etc.) won't lead to less food production.	ReFED estimates that 'Donation Storage Handling & Capacity' could divert 83.87 tons of Prepared Food Catering Overproduction annually in the Florida Limited Service Mexican Foodservice sector.
Water Savings Potential of Food Waste Solution	= Water Savings per Ton for Food Waste Solution * Annual Solution Diversion Potential	= 239,950 gallons of water use avoided per ton * 83.87 tons diverted = 20,124,606 gallons of water saved **Reminder**: This example calculation is not the total water savings potential for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total water savings potential for each solution.

MEAL EQUIVALENTS

Definition:
The Meal Equivalents for a solution is the estimated number of meals that would be eaten by people instead of wasted or recycled (e.g., composted, fed to animals) if a particular solution was fully implemented.

Master Meal Equivalents Equation (for Prevention and Donation solutions only):
Meal Equivalents = Solution Diversion Potential Tons / 1.2 lbs per meal / 2,000 lbs per ton

In ReFED's data model, the following calculations are repeated for every sector, state, and food type before any aggregation is done.

Table 5. Calculations Performed to Estimate Water Savings Potential of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Annual Solution Diversion Potential	See Diversion Potential calculations above.	ReFED estimates that 'Donation Storage Handling & Capacity' could divert 83.87 tons of Prepared Food Catering Overproduction annually in the Florida Limited Service Mexican Foodservice sector.
Meal Equivalents	For Prevention and Donation solutions: = Solution Diversion Potential (Annual Tons) * 2,000 lbs per ton / 1.2 lbs per meal[46] For Recycling solutions: = 0 Because recycling food (composting, animal feed, etc.) won't lead to meals for people.	= 83.87 tons diverted * 2,000 lbs per ton / 1.2 lbs per meal = 139,783 meal equivalents **Reminder:** This example calculation is not the total meal equivalents for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total meal equivalents for each solution.

JOB CREATION POTENTIAL

Definition:
The Job Creation Potential of a solution represents the total number of permanent jobs that could be created by a solution once fully implemented.

Master Job Creation Potential Equation:
Job Creation Potential = Solution Jobs Created per Ton Diverted * Solution Diversion Potential Tons

In ReFED's data model, the following calculations are repeated for every sector, state, and food type before any aggregation is done.

Table 6. Calculations Performed to Estimate Job Creation Potential of U.S. Food Waste Solutions

DATA ITEM	DATA SOURCE OR CALCULATION	EXAMPLE
Solution Jobs Created per Ton Diverted	Multiple data sources (See Appendix F for the data sources for each solution)	ReFED estimates that 3.72 jobs are created for every thousand tons of food donated. This is the equal to: 0.00372 jobs created per ton of food donated
Annual Solution Diversion Potential	See Diversion Potential calculations above.	ReFED estimates that 'Donation Storage Handling & Capacity' could divert 83.87 tons of Prepared Food Catering Overproduction annually in the Florida Limited Service Mexican Foodservice sector.
Job Creation Potential	= Solution Jobs Created per Ton Diverted * Annual Solution Diversion Potential	= 0.00372 jobs created per ton of food donated * 83.87 tons diverted = 0.312 jobs created per ton of food donated This is equal to: 312 jobs per *thousand* tons of food donated **Reminder**: This example calculation is not the total job creation potential for the solution. These calculations were repeated for every sector, cause, food type, and state before aggregating and summing the total job creation potential for each solution.

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APPENDIX

Appendix A: GHG Factors for U.S. Food Production and Surplus Disposal

ReFED developed the following weighted average GHG factors (Table A1-A5) for each sector by using the individual food category GHG factors developed by Quantis (Table A6) as proxies for different food types in each sector. After assigning the Quantis factors as proxies (e.g., Bananas were used as a proxy for all heavily imported tropical fruits), ReFED used the surplus tonnage results from the Food Waste Monitor to weight and aggregate the factors to less granular food types (e.g., Produce). This was also useful for developing a single 'Standard Mix' GHG factor for each sector, as this is one of the most common requests from businesses in cases when their waste data may not be broken down into multiple food types. Negative GHG values indicate a GHG reduction.

Raw Data and Documentation for Weighted Average GHG Factors (the individual Quantis factors with additional decimal places can also be found here):
https://refed-roadmap.s3-us-west-2.amazonaws.com/public_documentation/Documentation_Solutions_GHGFactors.xlsx

N/A = "Not Applicable"

Table A1. Farm (Produce Only) Weighted Average GHG Factors for Food Production and Disposal

SECTOR			FARM		
FOOD TYPE			DRY GOODS (NUTS ONLY)	PRODUCE	STANDARD MIX (PRODUCE AND NUTS ONLY)
Upstream Life Cycle Emissions (MTCO2e per Ton)			2.37874	0.21499	0.33212
Destination Emissions (MTCO2e per Ton)	Donations	Footprint	0.16959	0.41586	0.40253
		Source Reduction Offset	-2.37874	-0.21499	-0.33212
		Combined*	-2.09132	0.19577	0.07197
	Animal Feed		-0.05942	0.00302	-0.00036
	Industrial Uses**		-0.05942	0.00302	-0.00036
	Composting		-0.13769	-0.2333	-0.22812
	Anaerobic Digestion		-0.33529	-0.02561	-0.04237
	Not Harvested		-2.4246	-0.1652	-0.2875
	Land Application		0.11031	0.0147	0.01988
	Sewer		1.3741	0.18311	0.24758
	Incineration		-0.96038	0.08919	0.03238
	Landfill		0.59629	0.07946	0.10744
	Dumping***		0.11031	0.0147	0.01988

*Donations numbers account for transportation to a food bank plus storage, and they assume that every ton of food donated results in one less ton of production to meet food demand. Donations numbers also assume that 4.2% of food donated to food banks actually gets landfilled[1] as opposed to distributed to people as intended.

**Industrial Use numbers were estimated by modeling the impacts of rendering.

***ReFED reused the Land Application numbers to estimate the impacts of Dumping. More research is needed to account for the differences in emissions between the two destinations.

Table A2. Manufacturing Weighted Average GHG Factors for Food Production and Disposal

SECTOR			MANUFACTURING								
FOOD TYPE			BREADS & BAKERY	DAIRY & EGGS	PREPARED FOODS	DRY GOODS	FRESH MEAT & SEAFOOD	FROZEN	PRODUCE	READY-TO-DRINK BEVERAGES	STANDARD MIX
Upstream Life Cycle Emissions (MTCO2e per Ton)			2.78603	2.81308	4.81705	2.05585	9.86996	4.45967	0.68615	2.59793	2.74541
Destination Emissions (MTCO2e per Ton)	Donations	Footprint	0.15501	0.43965	0.43374	0.15996	0.45948	0.47838	0.42228	0.17339	0.36298
		Source Reduction Offset	-2.78603	-2.81308	-4.81705	-2.05585	-9.86996	-4.45967	-0.68615	-2.59793	-2.74541
		Combined*	-2.50083	-2.27002	-4.18991	-1.79726	-9.00539	-3.80231	-0.24929	-2.32106	-2.27396
	Animal Feed		-0.07558	-0.04305	-0.15681	-0.06486	-0.23242	-0.18828	0.00346	-0.03619	-0.05658
	Industrial Uses**		-0.07558	-0.04305	-0.47026	-0.06486	-0.87	-0.6464	0.00346	-0.03619	-0.11425
	Composting		-0.1613	-0.23157	-0.20704	-0.16432	-0.20459	-0.19617	-0.23264	-0.24074	-0.21098
	Anaerobic Digestion		-0.25881	-0.0312	-0.11065	-0.24903	-0.11859	-0.14587	-0.02776	-0.00152	-0.0979
	Not Harvested		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Land Application		0.0867	0.01643	0.04096	0.0838	N/A	0.05183	0.01536	0.00726	0.03705
	Sewer		1.07995	0.20461	0.51017	1.04246	0.54068	0.64559	0.19139	0.09045	0.46116
	Incineration		-0.70115	0.07024	-0.19904	-0.66935	-0.22592	-0.31837	0.08189	0.17084	-0.15617
	Landfill		0.46864	0.08879	0.22139	0.45245	0.23463	0.28015	0.08305	0.03925	0.20014
	Dumping***		0.0867	0.01643	0.04096	0.0838	N/A	0.05183	0.01536	0.00726	0.03705

*Donations numbers account for transport to a food bank plus storage, and they assume that every ton of food donated results in one less ton of production to meet food demand. Donations numbers also assume that 4.2% of food donated to food banks actually gets landfilled as opposed to distributed to people as intended.

**Industrial Use numbers were estimated by modeling the impacts of rendering.

***ReFED reused the Land Application numbers to estimate the impacts of Dumping. More research is needed to account for the differences in emissions between the two destinations.

Table A3. Retail Weighted Average GHG Factors for Food Production and Disposal

SECTOR			RETAIL								
FOOD TYPE			BREADS & BAKERY	DAIRY & EGGS	PREPARED FOODS	DRY GOODS	FRESH MEAT & SEAFOOD	FROZEN	PRODUCE	READY-TO-DRINK BEVERAGES	STANDARD MIX
Upstream Life Cycle Emissions (MTCO2e per Ton)			2.94104	3.23498	5.25079	2.68935	10.38716	7.1559	1.10956	2.77132	3.02607
Destination Emissions (MTCO2e per Ton)	Donations	Footprint	0.15501	0.44074	0.43374	0.2259	0.45948	1.17438	0.42228	0.17339	0.42467
		Source Reduction Offset	-2.94104	-3.23498	-5.25079	-2.68935	-10.38716	-7.1559	-1.10956	-2.77132	-3.02607
		Combined*	-2.64933	-2.67321	-4.60544	-2.34511	-9.50087	-5.72175	-0.65493	-2.48717	-2.48584
	Animal Feed		-0.07558	-0.05353	-0.15681	-0.0519	-0.23242	-0.08513	0.00346	N/A	-0.0445
	Industrial Uses**		-0.07558	-0.05353	-0.47026	-0.06711	-0.87	-0.30163	0.00346	N/A	-0.08971
	Composting		-0.1613	-0.23182	-0.20704	-0.18246	-0.20459	-0.21032	-0.23264	-0.24074	-0.22026
	Anaerobic Digestion		-0.25881	-0.03041	-0.11065	-0.19029	-0.11859	-0.10003	-0.02776	-0.00152	-0.06784
	Not Harvested		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Land Application		0.0867	0.01618	0.04096	0.06563	N/A	0.03768	0.01536	0.00726	0.02775
	Sewer		1.07995	0.20158	0.51017	0.81653	0.54068	0.46932	0.19139	0.09045	0.34551
	Incineration		-0.70115	0.07292	-0.19904	-0.46988	-0.22592	-0.16304	0.08189	0.17084	-0.05405
	Landfill		0.46864	0.08747	0.22139	0.35438	0.23463	0.20366	0.08305	0.03925	0.14994
	Dumping***		0.0867	0.01618	0.04096	0.06563	N/A	0.03768	0.01536	0.00726	0.02775

*Donations numbers account for transport to a food bank plus storage, and they assume that every ton of food donated results in one less ton of production to meet food demand. Donations numbers also assume that 4.2% of food donated to food banks actually gets landfilled as opposed to distributed to people as intended.

**Industrial Use numbers were estimated by modeling the impacts of rendering.

***ReFED reused the Land Application numbers to estimate the impacts of Dumping. More research is needed to account for the differences in emissions between the two destinations.

Table A4. Foodservice Weighted Average GHG Factors for Food Production and Disposal

SECTOR			FOODSERVICE								
FOOD TYPE			BREADS & BAKERY	DAIRY & EGGS	PREPARED FOODS	DRY GOODS	FRESH MEAT & SEAFOOD	FROZEN	PRODUCE	READY-TO-DRINK BEVERAGES	STANDARD MIX
Upstream Life Cycle Emissions (MTCO2e per Ton)			2.27366	4.5324	4.65454	2.79204	11.69978	7.84213	1.02606	3.29628	4.64687
Destination Emissions (MTCO2e per Ton)	Donations	Footprint	0.15501	0.45768	0.39024	0.28485	0.45948	1.45392	0.40312	0.23301	0.38745
		Source Reduction Offset	-2.27366	-4.5324	-4.65454	-2.79204	-11.69978	-7.84213	-1.02606	-3.29628	-4.64687
		Combined*	-2.01034	-3.89743	-4.07625	-2.39003	-10.75891	-6.11035	-0.59361	-2.92536	-4.07153
	Animal Feed		-0.07558	-0.09322	-0.07175	-0.03813	-0.23242	N/A	0.00345	N/A	-0.07321
	Industrial Uses**		-0.07558	-0.09322	-0.15698	-0.04337	-0.87	N/A	0.00345	N/A	-0.16272
	Composting		-0.16291	-0.22091	-0.20856	-0.19583	-0.20702	-0.20591	-0.23406	-0.20724	-0.20841
	Anaerobic Digestion		-0.25361	-0.06575	-0.10573	-0.14698	-0.11072	-0.11432	-0.02316	-0.11001	-0.10623
	Not Harvested		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Land Application		0.08509	0.02709	0.03949	0.05232	N/A	0.04209	0.01394	0.04076	0.03964
	Sewer		1.05996	0.33746	0.49128	0.65004	0.51043	0.52425	0.17366	0.50771	0.49322
	Incineration		-0.68354	-0.04683	-0.18291	-0.32374	-0.19926	-0.21144	0.09751	-0.19687	-0.1846
	Landfill		0.45997	0.14644	0.21322	0.28217	0.2215	0.2275	0.07536	0.22032	0.21406
	Dumping***		0.08509	0.02709	0.03949	0.05232	N/A	0.04209	0.01394	0.04076	0.03964

*Donations numbers account for transport to a food bank plus storage, and they assume that every ton of food donated results in one less ton of production to meet food demand. Donations numbers also assume that 4.2% of food donated to food banks actually gets landfilled.

**Industrial Use numbers were estimated by modeling the impacts of rendering.

***ReFED reused the Land Application numbers to estimate the impacts of Dumping. More research is needed to account for the differences in emissions between the two destinations.

Table A5. Residential Weighted Average GHG Factors for Food Production and Disposal

SECTOR			RESIDENTIAL								
FOOD TYPE			BREADS & BAKERY	DAIRY & EGGS	PREPARED FOODS	DRY GOODS	FRESH MEAT & SEAFOOD	FROZEN	PRODUCE	READY-TO-DRINK BEVERAGES	STANDARD MIX
Upstream Life Cycle Emissions (MTCO2e per Ton)			3.60002	4.26661	5.88088	4.3864	11.15953	8.76774	1.79612	3.28705	4.93957
Destination Emissions (MTCO2e per Ton)	Donations	Footprint	0.15501	0.45081	0.43295	0.24129	0.45948	0.90873	0.41718	0.19684	0.42924
		Source Reduction Offset	-3.60002	-4.26661	-5.88088	-4.3864	-11.15953	-8.76774	-1.79612	-3.28705	-4.93957
		Combined*	-3.28055	-3.65113	-5.21108	-3.95831	-10.24092	-7.51972	-1.31719	-2.95841	-4.31311
	Animal Feed		-0.07558	-0.07861	-0.14435	-0.04827	-0.23242	-0.17039	0.00377	N/A	-0.08059
	Industrial Uses**		-0.07558	-0.07861	-0.4843	-0.06203	-0.87	-0.56388	0.00377	N/A	-0.21495
	Composting		-0.1609	-0.22858	-0.21256	-0.19211	-0.20514	-0.20743	-0.23112	-0.23914	-0.21372
	Anaerobic Digestion		-0.2601	-0.0409	-0.09277	-0.15902	-0.11681	-0.10939	-0.03268	-0.00668	-0.08903
	Not Harvested		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Land Application		0.0871	0.01942	0.03544	0.05612	N/A	0.04057	0.01688	0.00886	0.03433
	Sewer		1.08493	0.24192	0.44141	0.69643	0.53385	0.50531	0.21028	0.11032	0.42705
	Incineration		-0.70555	0.03736	-0.13844	-0.3655	-0.2199	-0.19475	0.06524	0.15334	-0.12624
	Landfill		0.47081	0.10498	0.19155	0.30235	0.23166	0.21928	0.09125	0.04787	0.18534
	Dumping***		0.0871	0.01942	0.03544	0.05612	N/A	0.04057	0.01688	0.00886	0.03433

*Donations numbers account for transport to a food bank plus storage, and they assume that every ton of food donated results in one less ton of production to meet food demand. Donations numbers also assume that 4.2% of food donated to food banks actually gets landfilled as opposed to distributed to people as intended.

**Industrial Use numbers were estimated by modeling the impacts of rendering.

***ReFED reused the Land Application numbers to estimate the impacts of Dumping. More research is needed to account for the differences in emissions between the two destinations.

Quantis developed the following GHG factors. See the methodology[2,3] to learn more.

Table A6. Individual Food Category GHG Factors for Food Production and Disposal

FOOD CATEGORY		UPSTREAM LIFE CYCLE EMISSIONS (MTCO2E PER TON)					DESTINATION EMISSIONS (MTCO2E PER TON)									
		FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL	DONATIONS	ANIMAL FEED	INDUSTRIAL USES	COMPOSTING	ANAEROBIC DIGESTION	NOT HARVESTED	SEWER	INCINERATION	LANDFILL	LAND APPLICATION
Breads & Bakery	Bread	N/A	1.74	1.89	1.89	2.38	0.16	-0.08	-0.08	-0.16	-0.25	-0.22	1.05	-0.67	0.46	0.08
	Cake	N/A	6.74	6.89	6.89	7.39	0.16	-0.08	-0.08	-0.15	-0.29	-0.44	1.2	-0.81	0.52	0.1
Dairy & Eggs	Almond drink	N/A	0.89	1.05	1.05	1.54	0.16	0.02	0.02	-0.24	0	-0.44	0.07	0.18	0.03	0.01
	Cheese	1.76	9.83	10.29	10.29	10.8	0.46	-0.23	-0.23	-0.17	-0.23	-0.44	0.97	-0.61	0.42	0.08
	Eggs	2.08	2.47	2.93	2.93	4.79	0.46	-0.23	-0.23	-0.24	-0.02	-0.62	0.15	0.12	0.07	0.01
	Milk	1.76	2.37	2.83	2.83	3.34	0.46	0	0	-0.24	-0.02	-0.52	0.15	0.12	0.07	0.01
	Yogurt	1.76	2.37	2.83	2.83	3.35	0.46	-0.23	-0.23	-0.24	-0.02	-0.03	0.15	0.12	0.07	0.01
Dry Goods	Almonds	2.49	2.9	3.06	3.06	3.55	0.16	-0.06	-0.06	-0.13	-0.35	-2.54	1.44	-1.02	0.62	0.12
	Beans	0.72	1.12	1.43	1.43	3.29	0.31	-0.06	-0.06	-0.24	-0.02	-0.11	0.15	0.12	0.07	0.01
	Cereal	N/A	1.99	2.15	2.15	2.64	0.16	-0.06	-0.06	-0.13	-0.36	N/A	1.47	-1.04	0.64	0.12
	Chocolate	20.54	12.23	12.38	12.38	12.88	0.16	N/A	N/A	-0.24	-0.02	-0.12	0.15	0.12	0.07	0.01
	Coffee	N/A	6.88	7.03	7.03	7.53	0.16	-0.06	-0.06	-0.13	-0.36	-0.12	1.47	-1.04	0.64	0.12
	Flour	0.43	0.99	1.14	1.14	2.98	0.16	-0.06	-0.06	-0.14	-0.32	-0.02	1.3	-0.9	0.57	0.1
	Garlic	0.24	0.63	0.94	0.94	1.46	0.31	0	0	-0.2	-0.14	-0.06	0.63	-0.3	0.27	0.05
	Ketchup	0.06	1.16	1.32	1.32	1.81	0.16	-0.06	-0.06	-0.21	-0.1	-0.07	0.46	-0.16	0.2	0.04
	Olive oil	0.3	1.69	1.84	1.84	2.33	0.16	-0.06	-0.06	-0.2	-0.14	-0.11	0.63	-0.3	0.27	0.05
	Pasta	0.43	2.29	2.44	2.44	4.28	0.16	-0.06	-0.06	-0.14	-0.34	-0.27	1.38	-0.96	0.6	0.11
	Peanuts	0.92	1.81	1.96	1.96	2.46	0.16	-0.06	-0.06	-0.13	-0.35	-0.01	1.42	-1	0.62	0.11
	Rice	1.1	1.51	1.66	1.66	2.16	0.16	-0.06	-0.06	-0.14	-0.33	-0.18	1.35	-0.94	0.59	0.11
	Salt	N/A	0.47	0.63	0.63	1.12	0.16	-0.44	-0.44	-0.25	0.02	-0.23	0.02	0.01	0.02	0.02
	Sugar	0.07	1.03	1.18	1.18	1.67	0.16	-0.06	-0.06	-0.13	-0.37	-0.62	1.5	-1.07	0.65	0.12
	Vanilla	10.17	10.64	10.8	10.8	11.29	0.16	-0.06	-0.06	-0.19	-0.16	-2.54	0.7	-0.37	0.31	0.06

FOOD CATEGORY		UPSTREAM LIFE CYCLE EMISSIONS (MTCO2E PER TON)					DESTINATION EMISSIONS (MTCO2E PER TON)									
		FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL	DONATIONS	ANIMAL FEED	INDUSTRIAL USES	COMPOSTING	ANAEROBIC DIGESTION	NOT HARVESTED	SEWER	INCINERATION	LANDFILL	LAND APPLICATION
Fresh Meat & Seafood	**Beef**	12.03	26.72	27.18	27.18	29.04	0.46	-0.23	-0.87	-0.19	-0.17	N/A	0.75	-0.41	0.33	0.06
	Chicken	1.76	3.93	4.39	4.39	6.25	0.46	-0.23	-0.87	-0.22	-0.08	N/A	0.37	-0.08	0.16	0.03
	Meat alternatives (soy based)	N/A	3.5	3.96	3.96	5.82	0.46	-0.23	-0.87	-0.22	-0.06	N/A	0.3	-0.01	0.13	0.02
	Pork	2.32	5.08	5.54	5.54	7.4	0.46	-0.23	-0.87	-0.19	-0.17	N/A	0.75	-0.41	0.33	0.06
	Sausage	N/A	4.98	5.44	5.44	7.3	0.46	-0.23	-0.87	-0.22	-0.08	N/A	0.37	-0.08	0.16	0.03
	Tilapia	5.67	6.1	6.56	6.56	8.42	0.46	-0.23	-0.87	-0.22	-0.08	-0.11	0.37	-0.08	0.16	0.03
	Tuna	2.99	3.47	3.92	3.92	5.79	0.46	-0.23	-0.87	-0.22	-0.08	N/A	0.37	-0.08	0.16	0.03
Frozen	**Ice cream**	N/A	6.39	7.84	7.84	8.4	1.45	N/A	N/A	-0.21	-0.11	-1.25	0.52	-0.21	0.23	0.04

FOOD CATEGORY		UPSTREAM LIFE CYCLE EMISSIONS (MTCO2E PER TON)					DESTINATION EMISSIONS (MTCO2E PER TON)									
		FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL	DONATIONS	ANIMAL FEED	INDUSTRIAL USES	COMPOSTING	ANAEROBIC DIGESTION	NOT HARVESTED	SEWER	INCINERATION	LANDFILL	LAND APPLICATION
Processing Stages	Baking: Initial	0.9	0.9	0.9	0.9	0.9	N/A									
	Boiling: Initial	0.27	0.27	0.27	0.27	0.27										
	Canning: Initial	0.81	0.81	0.81	0.81	0.81										
	Chilled Goods: CFB	0.75	0.75	0.75	0.75	0.75										
	Chilled Goods: DC	0.23	0.23	0.23	0.23	0.23										
	Chilled Goods: Residential	1.26	1.26	1.26	1.26	1.26										
	Dry Goods: CFB	0.12	1.12	2.12	3.12	4.12										
	Dry Goods: DC	0.08	0.08	0.08	0.08	0.08										
	Dry Goods: Residential	0.12	1.12	2.12	3.12	4.12										
	Freezing: Initial	0.18	0.18	0.18	0.18	0.18										

FOOD CATEGORY		UPSTREAM LIFE CYCLE EMISSIONS (MTCO2E PER TON)					DESTINATION EMISSIONS (MTCO2E PER TON)									
		FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL	DONATIONS	ANIMAL FEED	INDUSTRIAL USES	COMPOSTING	ANAEROBIC DIGESTION	NOT HARVESTED	SEWER	INCINERATION	LANDFILL	LAND APPLICATION
Processing Stages	Frozen Goods DELTA: CFB	1	1	1	1	1	N/A									
	Frozen Goods DELTA: DC	0.68	0.68	0.68	0.68	0.68										
	Frozen Goods DELTA: Residential	1.34	1.34	1.34	1.34	1.34										
	Frozen Goods: CFB	1.75	1.75	1.75	1.75	1.75										
	Frozen Goods: DC	0.91	0.91	0.91	0.91	0.91										
	Frozen Goods: Residential	2.6	2.6	2.6	2.6	2.6										
	Processing: Initial	0.86	0.86	0.86	0.86	0.86										
Produce	Apples	0.11	0.52	0.83	0.83	1.34	0.31	0	0	-0.23	-0.04	-0.04	0.22	0.05	0.1	0.02
	Bananas	0.14	0.61	1.07	1.07	1.59	0.46	0	0	-0.22	-0.08	-0.03	0.37	-0.08	0.16	0.03
	Carrots	0.11	0.59	0.89	0.89	1.41	0.31	0	0	-0.24	-0.02	-0.06	0.15	0.12	0.07	0.01
	Grapes	0.34	0.74	1.2	1.2	1.71	0.46	0	0	-0.23	-0.04	-0.04	0.22	0.05	0.1	0.02
	Lemons	0.24	0.68	1.14	1.14	1.66	0.46	0	0	-0.24	-0.02	0	0.15	0.12	0.07	0.01
	Lettuce	0.28	0.7	1.16	1.16	1.67	0.46	0	0	-0.24	0	-0.06	0.07	0.18	0.03	0.01
	Mandarins	0.1	0.54	1	1	1.52	0.46	0	0	-0.23	-0.04	-0.04	0.22	0.05	0.1	0.02
	Mushrooms	4.23	4.64	5.1	5.1	5.61	0.46	0	0	-0.24	-0.02	-0.03	0.15	0.12	0.07	0.01
	Potatoes		0.54	0.85	0.85	2.71	0.31	0	0	-0.22	-0.06	-0.07	0.3	-0.01	0.13	0.02
	Strawberries	0.47	0.91	1.37	1.37	1.88	0.46	0	0	-0.24	-0.02	-0.03	0.15	0.12	0.07	0.01
	Tomatoes	0.16	0.56	1.02	1.02	1.53	0.46	0	0	-0.24	-0.01	-0.09	0.1	0.16	0.05	0.01
	Watermelons	0.23	0.67	1.13	1.13	1.64	0.46	0	0	-0.24	-0.02	-1.06	0.15	0.12	0.07	0.01

FOOD CATEGORY		UPSTREAM LIFE CYCLE EMISSIONS (MTCO2E PER TON)					DESTINATION EMISSIONS (MTCO2E PER TON)									
		FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL	DONATIONS	ANIMAL FEED	INDUSTRIAL USES	COMPOSTING	ANAEROBIC DIGESTION	NOT HARVESTED	SEWER	INCINERATION	LANDFILL	LAND APPLICATION
Ready-to-drink Beverages	Orange juice	0.12	1.79	1.94	1.94	2.44	0.16	N/A	N/A	-0.24	0	-0.02	0.07	0.18	0.03	0.01
	Tea	0.07	0.97	1.28	1.28	1.77	0.31	N/A	N/A	-0.25	0.02	-5.13	0.01	0.24	0.01	0

Appendix B: Water Footprint Factors for U.S. Food Production

ReFED developed the following weighted average water factors by using individual food category water factors developed by the Water Footprint Network (WFN)[4,5] as proxies for different food types. The WFN factors include water use throughout the supply chain (farm to end-of-life) and are not broken down by supply chain stage (sector). Therefore, these factors do not account for differences between sectors (e.g., Water use for manufacturing is embedded in the water factors and is used to estimate the water footprint of farm surplus.). The WFN factors used are specific to the United States. ReFED chose to only include WFN's blue water footprint factors[6].

After assigning the WFN factors as proxies (e.g., Wheat bread was used as a proxy for bread and bakery items), ReFED used USDA survey farm production tonnages[7] and Nielsen IQ grocery retail sales[8] to weight and aggregate them to less granular food types (e.g., Produce, Breads & Bakery). This was also useful for developing a single 'Standard Mix' water factor for each sector, as this is one of the most common requests from businesses in cases when their waste data may not be broken down into multiple food types. With additional research, future iterations of this work could take a more robust approach similar to the previous section on Greenhouse Gas Emissions (Appendix A) so that the water factors vary by sector and destination.

Table B1. Weighted Average Water Footprint Factors for U.S. Food Production

FOOD TYPE	GALLONS OF WATER USE PER TON				
	FARM	MANUFACTURING	RETAIL	FOODSERVICE	RESIDENTIAL
Breads & Bakery	--	19,380			
Dairy & Eggs	--	251,457			
Dry Goods	**570,973***	96,759			
Fresh Meat & Seafood	--	1,239,239			
Frozen	--	169,017			
Prepared Foods	--	239,950			
Produce	**27,300**	40,650			
Ready-to-drink Beverages	--	16,433			
Standard Mix	**58,859****	198,622			

*Only includes nuts and olives

**Only includes produce, nuts, and olives

Appendix C: ReFED Food Destinations in Order of Priority

Table C1. Food Destination Order of Priority

ORDER OF PRIORITY	FOOD DESTINATION
1	Prevention
2	Donations
3	Animal Feed
4	Industrial Uses
5	Composting
6	Anaerobic Digestion
7	Not Harvested
8	Land Application
9	Incineration
10	Landfill
11	Sewer
12	Dumping

Appendix D: Example Calculation of Status Quo GHG Footprint

The solution 'Donation Storage Handling & Capacity' sends food to the destination 'Donations'. This food would have otherwise gone to destinations that are "worse" than donations. Everything from Animal Feed and below is considered "worse" than donations according to ReFED's Food Destination priorities (See Appendix C).

Table D1. Example calculation of the status quo GHG footprint per ton of Prepared Food surplus in the Florida Limited Service Mexican Foodservice sector in 2020:

STATUS QUO FOOD DESTINATION	ANNUAL TONS SENT TO EACH DESTINATION*	UPSTREAM MTCO2E FOOTPRINT PER TON**	DOWNSTREAM MTCO2E FOOTPRINT PER TON***	TOTAL MTCO2E FOOTPRINT****
Prevention	N/A - These destinations are not lower priority than donations.	0	0	N/A
Donations			0.390236	
Animal Feed	0.513202	4.654545	-0.07175	2
Industrial Uses	0		-0.156979	0
Composting	9.237153		-0.208564	41
Anaerobic Digestion	0.513202		-0.105729	2
Land Application	0		0.039488	0
Sewer	0		0.491284	0
Incineration	3100.755749		-0.182913	13,865
Landfill	7446.032512		0.213223	36,246
Dumping	0		0.039488	0
Total	**10,557**	**--**	**--**	**50,157**
Average Status Quo	= 50,157 MTCO2e / 10,557 tons **= 4.751018 MTCO2e per ton**			

*Status quo tons sent to each destination was determined from the Food Waste Monitor: refed.com/insights-engine/food-waste-monitor

**These factors were derived from research by Quantis and can be found in Table A4 in Appendix A. ReFED is assuming that one ton of food prevention or donations results in one less ton of food production, which cancels out upstream emissions.

***These factors can also be found in Table A4 in Appendix A. Negative GHG values indicate a GHG reduction.

****Total MTCO2e Footprint = (Upstream + Downstream Footprint per Ton) * Annual Tons

Appendix E: Example Calculation of Status Quo Water Footprint

The solution 'Donation Storage Handling & Capacity' sends food to the destination 'Donations'. This food would have otherwise gone to destinations that are "worse" than donations. Everything from Animal Feed and below is considered "worse" than donations according to ReFED's Food Destination priorities (See Appendix C).

Table E1. Example calculation of the status quo water footprint per ton of Prepared Food surplus in the Florida Limited Service Mexican Foodservice sector in 2020:

STATUS QUO FOOD DESTINATION	ANNUAL TONS SENT TO EACH DESTINATION*	UPSTREAM GALLONS WATER FOOTPRINT PER TON**	DOWNSTREAM GALLONS WATER FOOTPRINT PER TON***	TOTAL GALLONS WATER FOOTPRINT****
Prevention	N/A - These destinations are not lower priority than donations.	0		N/A
Donations				
Animal Feed	0.513202	239,950	--	123,143
Industrial Uses	0			0
Composting	9.237153			2,216,459
Anaerobic Digestion	0.513202			123,143
Land Application	0			0
Sewer	0			0
Incineration	3100.755749			744,027,595
Landfill	7446.032512			1,786,678,510
Dumping	0			0
Total	**10,557**	**--**	**--**	**2,533,168,850**
Average Status Quo	= 2,533,168,850 gallons / 10,557 tons **= 239,950 gallons per ton**			

*Status quo tons sent to each destination was determined from the Food Waste Monitor: refed.com/insights-engine/food-waste-monitor

**These factors were derived from Water Footprint Network[4,5] data and can be found in Table B1 in Appendix B. ReFED is assuming that one ton of food prevention or donations results in one less ton of food production, which cancels out upstream water use.

***Water footprint factors have not yet been developed for food destinations (e.g., water use required to compost food), so this is not yet accounted for in ReFED's modeling.

****Total Gallons Water Footprint = Upstream Footprint per Ton * Annual Tons

Appendix F: Job Creation Potential

ReFED determined potential job creation by reviewing current employment numbers of food waste solution providers, where organizations have provided data that fell under the buckets of Prevention, Rescue, and Recycling.

Table F. Job Creation Potential

SOLUTION OR CATEGORY	JOBS PER THOUSAND TONS
Prevention Solutions	1.5165
Rescue Solutions	3.72
Centralized Composting, Community Composting	1.03
Centralized Anaerobic Digestion, Co-digestion at Wastewater Treatment Plants	1.026
Consumer Education Campaigns	0.379125

Prevention solutions assumption (1.5165 jobs / thousand tons) was determined with current employment data of 40+ solution providers at the earlier stages of development. This figure was determined by dividing the sum of jobs with the sum of tons. The data set included solutions at varying levels of maturity which would factor in scaled solutions (which may yield lower jobs per thousand tons). Given the diverse set of business models that can be found in Prevention solutions such as software, hardware, or service-based, the job estimate was made to be from a conservative perspective.

Rescue solutions assumption (3.72 jobs / thousand tons) was determined with current employment data of a group of food banks varying in size (volume of food distributed) from local to larger organizations. The average employee per thousand tons was determined with this dataset. Note this does not include volunteers that they contribute a significant amount of labor to food banks. These organizations require more employees per thousand tons as the work tends to be more manual and processing-related.

Centralized and community composting assumption (1.03 jobs / thousand tons) was determined through the work of the Institute for Local Self-Reliance (ILSR), 2013. These reflect jobs created at composting sites and due to compost use. Note: this information is based on the state of Maryland.

Centralized Anaerobic Digestion and Co-digestion at Wastewater Treatment Plants (1.026 jobs / thousand tons) was implied using the data from ReFED's 2016 Roadmap[18] of over 1,900 jobs created through anaerobic digestion facilities (excluding potentially hundreds of additional jobs related to composting digestate from these facilities). This information was also based on the ILSR data mentioned above for centralized and community composting.

Consumer Education Campaigns assumption (0.379125 jobs / thousand tons) was determined using the jobs / thousand tons of prevention solutions with an applied discount of 75%. It was the expectation that implementation of Consumer Education Campaigns would not require as many jobs as other Prevention solutions on a per-ton basis.

Appendix G: Implementation Order

Business can choose to manage surplus food in many different ways. For example, changes could be made to prevent the surplus in the first place, it could be donated, or it could be recycled via composting, animal feed, etc. When businesses prevent surplus or donate food, that leaves less surplus available to be recycled. In order to model this relationship between solutions and to avoid double counting the reduction potential of multiple solutions working in tandem, ReFED implemented a "waterfall" approach. In this approach, solutions are ordered and modeled one after the other so that food surplus reduced by the first solution is subtracted from the total surplus available to be addressed by the next solution. Solutions are ordered according to their destination priority as documented in Appendix C (e.g. prevention before donations, donations before recycling), their chronological intervention point within the supply chain, and their net financial benefit. This waterfall ordering only takes place when multiple solutions address a single cause of surplus in a specific sector, because each cause is modeled independently and represents a discrete quantity of surplus. See Table G1 below for specific examples.

Table G1. Solution Implementation Order

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FARM SECTOR CAUSES AND SOLUTIONS			
BUYER REJECTIONS			
Buyer Rejections	Prevention	1	Buyer Specification Expansion
		2	Imperfect & Surplus Produce Channels
		3	Partial Order Acceptance
		4	Temperature Monitoring (pallet Transport)
		5	Intelligent Routing
		6	Decreased Transit Time
		7	Reduced Warehouse Handling
	Rescue	8	Donation Education
		9	Donation Transportation
		10	Donation Storage Handling & Capacity
	Recycling	11	Livestock Feed
		12	Centralized Composting
		13	Centralized Anaerobic Digestion

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FARM SECTOR CAUSES AND SOLUTIONS			
EXCESS			
Packhouse Losses (not Marketable)	Prevention	1	Buyer Specification Expansion
		2	Imperfect & Surplus Produce Channels
	Rescue	3	Donation Education
		4	Donation Transportation
		5	Donation Storage Handling & Capacity
		6	Donation Value-added Processing
	Recycling	7	Livestock Feed
		8	Centralized Composting
		9	Centralized Anaerobic Digestion
NOT HARVESTED			
Fields Never Harvested (market Dynamics)	Prevention	1	Imperfect & Surplus Produce Channels
		2	Gleaning
	Rescue	3	Donation Education
		4	Donation Transportation
		5	Donation Storage Handling & Capacity
		6	Donation Value-added Processing
Fields Never Harvested (other)	Prevention	1	Gleaning
Left Behind After Harvest (inedible)	Recycling	1	Livestock Feed
Left Behind After Harvest (marketable)	Prevention	1	Imperfect & Surplus Produce Channels
		2	Gleaning
	Rescue	3	Donation Education
		4	Donation Transportation
		5	Donation Storage Handling & Capacity
		6	Donation Value-added Processing
	Recycling	7	Livestock Feed
Left Behind After Harvest (not Marketable)	Prevention	1	Buyer Specification Expansion
		2	Imperfect & Surplus Produce Channels
		3	Gleaning
	Rescue	4	Donation Education
		5	Donation Transportation
		6	Donation Storage Handling & Capacity
		7	Donation Value-added Processing
	Recycling	8	Livestock Feed

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FARM SECTOR CAUSES AND SOLUTIONS			
SPOILED			
Packhouse Losses (inedible)	Recycling	1	Livestock Feed
		2	Centralized Composting
		3	Centralized Anaerobic Digestion
MANUFACTURING SECTOR CAUSES AND SOLUTIONS			
BUYER REJECTIONS			
Buyer Rejections	Prevention	1	Buyer Specification Expansion
		2	Partial Order Acceptance
		3	Temperature Monitoring (pallet Transport)
		4	Intelligent Routing
		5	Decreased Transit Time
		6	Reduced Warehouse Handling
		7	Assisted Distressed Sales
	Rescue	8	Donation Education
		9	Donation Transportation
		10	Donation Storage Handling & Capacity
	Recycling	11	Livestock Feed
		12	Centralized Composting
		13	Centralized Anaerobic Digestion
		14	Co-digestion At Wastewater Treatment Plants
EXCESS			
Unshipped Finished Product	Prevention	1	Buyer Specification Expansion
		2	Reduced Warehouse Handling
		3	First Expired First Out
		4	Assisted Distressed Sales
		5	Standardized Date Labels
	Rescue	6	Donation Education
		7	Donation Transportation
		8	Donation Storage Handling & Capacity
	Recycling	9	Livestock Feed
		10	Centralized Composting
		11	Centralized Anaerobic Digestion
		12	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FARM SECTOR CAUSES AND SOLUTIONS			
TRIMMINGS & BYPRODUCTS			
Byproducts & Production Line Waste	Prevention	1	Manufacturing Line Optimization
		2	Manufacturing Byproduct Utilization (upcycling)
	Recycling	3	Livestock Feed
		4	Centralized Composting
		5	Centralized Anaerobic Digestion
		6	Co-digestion At Wastewater Treatment Plants
RETAIL SECTOR CAUSES AND SOLUTIONS			
DATE LABEL CONCERNS			
Date Label Concerns	Prevention	1	Temperature Monitoring (pallet Transport)
		2	Intelligent Routing
		3	Decreased Transit Time
		4	First Expired First Out
		5	Enhanced Demand Planning
		6	Decreased Minimum Order Quantity
		7	Minimized On Hand Inventory
		8	Increased Delivery Frequency
		9	Dynamic Pricing
		10	Assisted Distressed Sales
		11	Markdown Alert Applications
		12	Active & Intelligent Packaging
		13	Standardized Date Labels
	Rescue	14	Donation Coordination & Matching
		15	Donation Education
		16	Donation Transportation
		17	Donation Storage Handling & Capacity
	Recycling	18	Livestock Feed
		19	Centralized Composting
		20	Centralized Anaerobic Digestion
		21	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
RETAIL SECTOR CAUSES AND SOLUTIONS			
EXCESS			
Overproduction	Rescue	1	Donation Coordination & Matching
		2	Donation Education
		3	Donation Transportation
		4	Donation Storage Handling & Capacity
	Recycling	5	Livestock Feed
		6	Centralized Composting
		7	Centralized Anaerobic Digestion
FOOD SAFETY			
Food Safety Recall	Recycling	1	Centralized Anaerobic Digestion
MISTAKES & MALFUNCTIONS			
Cooking Issues	Recycling	1	Livestock Feed
		2	Centralized Composting
		3	Centralized Anaerobic Digestion
Equipment Issues	Recycling	1	Centralized Composting
		2	Centralized Anaerobic Digestion
Handling Errors	Prevention	1	Reduced Warehouse Handling
	Recycling	2	Livestock Feed
		3	Centralized Composting
		4	Centralized Anaerobic Digestion
		5	Co-digestion At Wastewater Treatment Plants
OTHER			
Other	Recycling	1	Livestock Feed
		2	Centralized Composting
		3	Centralized Anaerobic Digestion

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
RETAIL SECTOR CAUSES AND SOLUTIONS			
SPOILED			
Spoiled	Prevention	1	Temperature Monitoring (pallet Transport)
		2	Intelligent Routing
		3	Decreased Transit Time
		4	Reduced Warehouse Handling
		5	First Expired First Out
		6	Enhanced Demand Planning
		7	Decreased Minimum Order Quantity
		8	Minimized On Hand Inventory
		9	Increased Delivery Frequency
		10	Dynamic Pricing
		11	Markdown Alert Applications
		12	Active & Intelligent Packaging
	Recycling	13	Livestock Feed
		14	Centralized Composting
		15	Centralized Anaerobic Digestion
		16	Co-digestion At Wastewater Treatment Plants
TRIMMINGS & BYPRODUCTS			
Trimmings & Byproducts	Recycling	1	Livestock Feed
		2	Centralized Composting
		3	Centralized Anaerobic Digestion
		4	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FOODSERVICE SECTOR CAUSES AND SOLUTIONS			
DATE LABEL CONCERNS			
Date Label Concerns	Prevention	1	Temperature Monitoring (pallet Transport)
		2	Intelligent Routing
		3	Decreased Transit Time
		4	First Expired First Out
		5	Decreased Minimum Order Quantity
		6	Increased Delivery Frequency
		7	Waste Tracking (foodservice)
		8	Standardized Date Labels
	Rescue	9	Donation Coordination & Matching
		10	Donation Education
		11	Donation Transportation
		12	Donation Storage Handling & Capacity
	Recycling	13	Livestock Feed
		14	Centralized Composting
		15	Centralized Anaerobic Digestion
		16	Co-digestion At Wastewater Treatment Plants
EXCESS			
Catering Overproduction	Prevention	1	Waste Tracking (foodservice)
	Rescue	2	Donation Coordination & Matching
		3	Donation Education
		4	Donation Transportation
		5	Donation Storage Handling & Capacity
	Recycling	6	Livestock Feed
		7	Centralized Composting
		8	Centralized Anaerobic Digestion
		9	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FOODSERVICE SECTOR CAUSES AND SOLUTIONS			
EXCESS			
Overproduction	Prevention	1	Waste Tracking (foodservice)
		2	Markdown Alert Applications
	Rescue	3	Donation Coordination & Matching
		4	Donation Education
		5	Donation Transportation
		6	Donation Storage Handling & Capacity
	Recycling	7	Livestock Feed
		8	Centralized Composting
		9	Centralized Anaerobic Digestion
		10	Co-digestion At Wastewater Treatment Plants
Plate Waste	Prevention	1	Waste Tracking (foodservice)
		2	Portion Sizes
	Recycling	3	Livestock Feed
		4	Centralized Composting
		5	Centralized Anaerobic Digestion
		6	Co-digestion At Wastewater Treatment Plants
FOOD SAFETY			
Food Safety Recall	Recycling	1	Centralized Anaerobic Digestion
		2	Co-digestion At Wastewater Treatment Plants
MISTAKES & MALFUNCTIONS			
Cooking Issues	Rescue	1	Donation Coordination & Matching
		2	Donation Education
		3	Donation Transportation
		4	Donation Storage Handling & Capacity
	Recycling	5	Livestock Feed
		6	Centralized Composting
		7	Centralized Anaerobic Digestion
		8	Co-digestion At Wastewater Treatment Plants
Equipment Issues	Recycling	1	Centralized Composting
		2	Centralized Anaerobic Digestion

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FOODSERVICE SECTOR CAUSES AND SOLUTIONS			
MISTAKES & MALFUNCTIONS			
Handling Errors	Recycling	1	Livestock Feed
		2	Centralized Composting
		3	Centralized Anaerobic Digestion
		4	Co-digestion At Wastewater Treatment Plants
OTHER			
Other	Prevention	1	Waste Tracking (foodservice)
	Recycling	2	Livestock Feed
		3	Centralized Composting
		4	Centralized Anaerobic Digestion
SPOILED			
Spoiled	Prevention	1	Temperature Monitoring (pallet Transport)
		2	Intelligent Routing
		3	Decreased Transit Time
		4	Reduced Warehouse Handling
		5	First Expired First Out
		6	Decreased Minimum Order Quantity
		7	Increased Delivery Frequency
		8	Temperature Monitoring (foodservice)
		9	Waste Tracking (foodservice)
	Recycling	10	Centralized Composting
		11	Centralized Anaerobic Digestion
		12	Co-digestion At Wastewater Treatment Plants
TRIMMINGS & BYPRODUCTS			
Trimmings & Byproducts	Prevention	1	Waste Tracking (foodservice)
	Recycling	2	Livestock Feed
		3	Centralized Composting
		4	Centralized Anaerobic Digestion
		5	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
FOODSERVICE SECTOR CAUSES AND SOLUTIONS			
EXCESS			
Plate Waste	Prevention	1	Buffet Signage
		2	Trayless
		3	Small Plates
		4	K-12 Lunch Improvements
		5	K-12 Education Campaigns
RESIDENTIAL SECTOR CAUSES AND SOLUTIONS			
DATE LABEL CONCERNS			
Date Label Concerns	Prevention	1	Active & Intelligent Packaging
		2	Standardized Date Labels
		3	Consumer Education Campaigns
		4	Package Design
		5	Meal Kits
	Recycling	6	Home Composting
		7	Centralized Composting
		8	Community Composting
		9	Centralized Anaerobic Digestion
		10	Co-digestion At Wastewater Treatment Plants
EXCESS			
Didn't Taste Good	Prevention	1	Consumer Education Campaigns
		2	Meal Kits
	Recycling	3	Home Composting
		4	Centralized Composting
		5	Community Composting
		6	Centralized Anaerobic Digestion
Didn't Want Leftovers	Prevention	1	Consumer Education Campaigns
		2	Meal Kits
	Recycling	3	Home Composting
		4	Centralized Composting
		5	Community Composting
		6	Centralized Anaerobic Digestion
		7	Co-digestion At Wastewater Treatment Plants

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
RESIDENTIAL SECTOR CAUSES AND SOLUTIONS			
EXCESS			
Too Little To Save	Prevention	1	Consumer Education Campaigns
	Recycling	2	Home Composting
		3	Centralized Composting
		4	Community Composting
		5	Centralized Anaerobic Digestion
FOOD SAFETY			
Food Safety Recall	Recycling	1	Home Composting
		2	Centralized Composting
		3	Community Composting
		4	Centralized Anaerobic Digestion
		5	Co-digestion At Wastewater Treatment Plants
Left Out Too Long	Recycling	1	Home Composting
		2	Centralized Composting
		3	Community Composting
		4	Centralized Anaerobic Digestion
		5	Co-digestion At Wastewater Treatment Plants
MISTAKES & MALFUNCTIONS			
Cooking Issues	Recycling	1	Home Composting
		2	Centralized Composting
		3	Community Composting
		4	Centralized Anaerobic Digestion
		5	Co-digestion At Wastewater Treatment Plants
OTHER			
Other	Prevention	1	Consumer Education Campaigns
	Recycling	2	Home Composting
		3	Centralized Composting
		4	Community Composting
		5	Centralized Anaerobic Digestion

CAUSE NAME	SOLUTION TYPE	ORDER	SOLUTION NAME
RESIDENTIAL SECTOR CAUSES AND SOLUTIONS			
SPOILED			
Spoiled	Prevention	1	Active & Intelligent Packaging
		2	Consumer Education Campaigns
		3	Package Design
		4	Meal Kits
	Recycling	5	Home Composting
		6	Centralized Composting
		7	Community Composting
		8	Centralized Anaerobic Digestion
		9	Co-digestion At Wastewater Treatment Plants
TRIMMINGS & BYPRODUCTS			
Considered Inedible	Prevention	1	Consumer Education Campaigns
	Recycling	2	Home Composting
		3	Centralized Composting
		4	Community Composting
		5	Centralized Anaerobic Digestion
		6	Co-digestion At Wastewater Treatment Plants
Inedible Parts	Recycling	1	Centralized Composting
		2	Centralized Anaerobic Digestion

Appendix H: Solutions Modeling Assumptions

Overall Approach

To create the ReFED Solutions Database, ReFED, Juniata, and Deloitte first established a list of approximately 80 solutions that contribute to food waste reduction. We then conducted a literature review and outreach to dozens of practitioners, experts, and solution providers to determine diversion rates, costs, and benefits for each solution. Below are the data sources and assumptions used for each of the 42 solutions that we were able to model. Our goal is to improve the information behind this model over time, and we welcome input to that end.

Applicable Sectors and Causes

Various solutions can only be applied to certain portions of surplus food. For instance, a restaurant may have overproduction in its kitchen and plate waste in the front of the house. A donation solution could only be applied to the overproduction, not the plate waste. For each of our solutions, we establish both the applicable sectors (e.g., Foodservice, in this example) and the applicable causes (e.g., Overproduction) and then apply the diversion rate only to the quantities of surplus food estimated for those sectors and causes.

Because distribution happens throughout a food product supply chain, ReFED included food distribution surplus in each relevant sector (e.g. manufactured food products shipped and then rejected by a retail buyer are included as manufacturing sector surplus). The only distribution surplus that is not included in ReFED's model is food lost during transit and during storage at third-party distribution facilities.

Diversion Rates

Diversion rates were derived from the best sources available and applied only to the sectors and causes as described above. Where diversion rates were provided by a solution provider directly, a 25% "discount" was applied to account for case studies and results typically being selected to demonstrate best results.

"Waterfall" Implementation Order

In many cases, if a business has surplus food, a variety of things could happen to that food. Changes could be made within business operations to prevent surplus or that food could be donated, for instance. In order to avoid double counting the same food, our model implements solutions in order, removing food saved by that solution from the total that the next solution considers. Solutions are ordered considering their position within the EPA food waste hierarchy[10], their logical implementation order, and their net financial benefit.

It's important to note that this happens within the applicable causes. For instance, the Imperfect & Surplus Produce Channels solution is applied to the produce that is Left Behind After Harvest (Marketable). Then the Gleaning solution is applied to the amount left over in that Left Behind After Harvest (Marketable) cause category. This would not affect Assisted Distressed Sales, however, since that solution is not applied to the same cause category. Implementation order can be seen in Appendix G above.

Cost and Benefit Assumptions

Our analysis was conducted on a per-ton-diverted basis. All costs and benefits were estimated at that level.

Solutions were considered over a 10-year timeframe. Upfront costs were divided over the tons diverted over that 10 year period and all costs and benefits are considered through a lens of the net present value over those 10 years, with a 4% discount rate. The values provided in the tables below represent the costs/benefits before the NPV has been applied.

To generate estimates of the costs and revenue/savings for various solutions, the following assumptions were made throughout:

- **Tip fee savings** - The value of avoided landfill tip fees were derived from the Environmental Research & Education Foundation (EREF) 2019 "Analysis of MSW Landfill Tipping Fees" report[9]. EREF maintains a database of Municipal Solid Waste (MSW) landfills across the United States. This database was used to draw a sample of active facilities for analysis of MSW landfill (MSWLF) tipping fees. MSWLF tip fee data were compiled by geographic region and basic statistical data were computed. For 2019, the national MSW landfill tip fee average was $55.36/ton.
- **Wholesale and retail price assumptions** - Retail prices were derived from the 2019 Nielsen IQ retail sales data set[8]. Wholesale prices were derived from that same data set, assuming gross margins as reported by the U.S. Census Bureau Annual Retail Trade Survey[11]. Importantly, prices for food cost savings for each solution are derived from an average of the product type categories that are considered applicable. So, if a solution only applies to produce and dairy, the food costs for only those two product types would be averaged to generate estimates of food cost savings. The price estimates are as follows:

Table H1. Retail and Wholesale Price Assumptions

FOOD TYPE	WHOLESALE	RETAIL
Standard Retail Mix*	$2.15	$2.73
Ready to drink beverages	$0.55	$0.76
Breads & Bakery	$1.85	$2.36
Dairy & Eggs	$1.00	$1.28
Dry Goods	$2.47	$3.19
Fresh Meat & Seafood	$3.47	$4.44
Produce	$1.18	$1.57
Frozen	$1.85	$2.36
Prepared Foods	$4.84	$5.89
Food service	$2.27	$7.14

* Standard Retail Mix of food and beverage products sold at grocery stores in the U.S. according to data from Nielsen IQ[8].

Data Quality Scores

Data in the field of food waste reduction is challenging. In many cases, only case studies or anecdotal evidence is available, while in others third-party, peer-reviewed academic studies have been performed or many proof points are available. In modeling our solutions, we aimed to get the best data we could, but recognize that significant assumptions and extrapolations are involved. We therefore developed a Data Quality Rubric to rank our sources and how we were using them. Scores are included below for each solution. A full description of the rubric can be found in Appendix I.

Financing

Effective action against food waste requires a smart matching of the correct type of capital with the appropriate opportunity, and in many cases, multiple types of capital are required to fund food waste reduction solutions from conception to adoption. ReFED's Insights Engine and Roadmap to 2030 calculated the total financing required for each solution across nine sources of capital; allocating the quantified investment required from the Solutions Database to various capital types. ReFED's intent is that this can galvanize the funding required to fill financing gaps and achieve the benefits highlighted in the Insights Engine.

ReFED's analysis first starts by acknowledging that there are different capital types - each with varying goals and investment theses. As a result, certain types of capital are more appropriate depending on the financing opportunity and can depend on a variety of factors including, but not limited to growth potential, market size, solution maturity, and business model. The chart below defines the nine sources of capital analyzed and their expected rates of return.

Table H2. Capital Types

SOURCE	DEFINITION	RATE OF RETURN
Tax Incentives	Tax incentives and deductions related to donations. R&D tax credits are not factored in this analysis.	-100%
Government Grants	Public funding in the form of grants and payment for on-going services (e.g, municipal compost collection).	-100%
Non-Government Grants	Philanthropic grants from non-government sources, including high networth individuals, family offices, and foundations.	-100%
Impact-First Investments	Investments that seek some sort of financial return, but are willing to accept more risk or potentially lower returns in pursuit of measurable social or environmental impact. Examples include low- or no-interest loans, loan guarantees, variable payment options, program-related investments (PRIs), etc.	2%
Venture Capital	A type of financing that investors provide to startup companies and other for-profit businesses that are believed to have long-term, high growth potential. Investors in this asset class have a perceived higher risk as companies are at an earlier stage and therefore require a high rate of return.	30%
Private Equity	Composed of funds and investors that directly finance private companies. Organizations receiving this type of capital are established organizations or ones requiring growth equity.	15%

SOURCE	DEFINITION	RATE OF RETURN
Corporate Finance and Spending	Spending by for-profit corporations with the intent to return the cost of capital. Examples include spending on solutions (through paying solution providers or internally developing capabilities) and corporate acquisitions (M&A). Marketing type spending (non-foundation spending) would be considered part of this category as an operating cost despite not directly leading to market returns. Additionally, ReFED has considered traditional lending (leases, working capital loans) as part of corporate finance and spending.	10%
Government Project Finance	Direct municipal, state, or federal project financing.	4%
Commercial Project Finance	Financing provided for projects with the cash flows of the specific project paying down the project loan. This is sourced from for-profit financiers.	10%

Note: *there are types of capital that are hybrids or exist outside of the types listed above. Mission Related Investments (MRIs), for instance, would fall under the broad definition of "Impact Investments", but require market-rate returns. Therefore, it could arguably be a form of venture capital or its own capital type.*

ReFED's proposed allocation of capital for each solution was determined by analyzing historical funding, stakeholder feedback, and industry knowledge. This exercise provides a rough, directional estimate of the total amount of funding needed for each solution, by funding source, and in aggregate. The proposed allocations are not meant to be prescriptive, as actual financing is highly dependent on funder interest and relative costs of capital. As external market and environmental factors change – a national spotlight on food waste, for example – funding availability may shift to favor more or less expensive forms of financing.

First, in order to estimate allocations of financing across capital types, desk research and analysis was conducted and applied to each solution according to what typical organizational and business model (e.g., for-profit or non-profit) exist in each solution bucket, historical examples of funding, level of maturity for each solution, and if the solution is asset light or requires significant capital expenditure/ infrastructure spending. For example, *Manufacturing Byproduct Utilization (Upcycling)* is a nascent, yet growing solution often adopted using for-profit business models within large corporate entities or startups in the early stages of maturity, and requiring a large amount of capital expenditure.

According to these factors, solutions were allocated a qualitative weighting of 0-Low, Low, Medium, Medium-High, High, and All for the amount of capital required by each capital type which had corresponding numerical weightings.

Lastly, ReFED sought and received feedback from 15+ capital providers (including foundations, impact investors, venture capitalists, private equity firms, and institutional investors) and food businesses on the proposed weights, methodology, and appropriateness of finance amount by capital type.

The table below represents the results of this exercise, including the resulting recommended financing mix for each solution, and the assumptions underscoring this analysis.

ReFED was particularly interested in the concept of catalytic capital as a way to influence further capital entering the food waste space. According to The MacArthur Foundation, catalytic capital is defined as "investment capital that is patient, risk-tolerant, concessionary, and flexible in ways that differ from conventional investment" and "is an essential tool to bridge capital gaps and achieve breadth and depth of impact, while complementing conventional investing." ReFED has measured catalytic capital by totaling Non-Government Grants, Government Grants, and Impact-First Investments. Additionally, incubators, accelerators, and challenge platforms that provide funding, as well as seed/angel rounds can be considered catalytic.

Table H3. Financing Breakdown

SOLUTION NAME	GOVERNMENT PROJECT FINANCE	TAX INCENTIVES	GOVERNMENT GRANTS	NON-GOVERNMENT GRANTS	IMPACT-FIRST INVESTMENTS	VENTURE CAPITAL	PRIVATE EQUITY	CORPORATE FINANCE AND SPENDING	COMMERCIAL PROJECT FINANCE
PREVENTION									
Buyer Specification Expansion	-	-	-	6%	6%	-	-	88%	-
Partial Order Acceptance	-	-	-	-	-	-	-	100%	-
Gleaning	-	-	10%	52%	34%	-	-	3%	-
Imperfect & Surplus Produce Channels	-	-	5%	5%	14%	14%	14%	48%	-
Temperature Monitoring (Pallet Transport)	-	-	-	11%	11%	11%	11%	56%	-
First Expired First Out	-	-	-	-	-	-	-	100%	-
Decreased Transit Time	-	-	-	-	-	14%	14%	71%	-
Intelligent Routing	-	-	4%	4%	12%	12%	12%	58%	-
Reduced Warehouse Handling	-	-	-	6%	-	18%	18%	59%	-
Markdown Alert Applications	-	-	-	7%	-	21%	-	71%	-
Waste Tracking (Foodservice)	-	-	4%	4%	18%	11%	11%	54%	-
Decreased Minimum Order Quantity	-	-	-	-	-	-	-	100%	-

SOLUTION NAME	GOVERNMENT PROJECT FINANCE	TAX INCENTIVES	GOVERNMENT GRANTS	NON-GOVERNMENT GRANTS	IMPACT-FIRST INVESTMENTS	VENTURE CAPITAL	PRIVATE EQUITY	CORPORATE FINANCE AND SPENDING	COMMERCIAL PROJECT FINANCE
PREVENTION									
Improved Recipe Planning	-		4%	12%	12%	12%	-	60%	-
Enhanced Demand Planning	-	-	-	5%	-	14%	14%	68%	-
Minimized On Hand Inventory	-	-	-	-	-	17%	-	83%	-
Inventory Traceability	-		9%	9%	9%	15%	15%	44%	-
Packaging Materials	-		9%	9%	9%	15%	15%	44%	-
Increased Delivery Frequency	-	-	-	-	-	-	-	100%	-
Dynamic Pricing	-	-	-	6%	6%	19%	6%	63%	-
Assisted Distressed Sales	-	-	5%	14%	24%	5%	5%	48%	-
Temperature Monitoring (Foodservice)	-	-	-	4%	4%	13%	13%	65%	-
Active & Intelligent Packaging	-	-	5%	5%	5%	14%	5%	68%	-
Micro Fulfillment	-		-	-	-	14%	14%	71%	-
Manufacturing Byproduct Utilization (Upcycling)	-	-	4%	4%	4%	12%	19%	58%	-
Manufacturing Line Optimization	-	-	4%	4%	4%	13%	13%	63%	-
Consumer Education Campaigns	-	-	71%	24%	-	-	-	5%	-
Buffet Signage	-	-	33%	33%	-	-	-	33%	-
K-12 Education Campaigns	-	-	48%	48%	-	-	-	5%	-
K-12 Lunch Improvements	-	-	48%	48%	-	-	-	5%	-
Secondary Resale	-		4%	12%	12%	20%	12%	40%	-
Portion Sizes	-	-	6%	6%	-	-	-	88%	-
Small Plates	-	-	5%	5%	15%	-	-	75%	-

SOLUTION NAME	GOVERNMENT PROJECT FINANCE	TAX INCENTIVES	GOVERNMENT GRANTS	NON-GOVERNMENT GRANTS	IMPACT-FIRST INVESTMENTS	VENTURE CAPITAL	PRIVATE EQUITY	CORPORATE FINANCE AND SPENDING	COMMERCIAL PROJECT FINANCE
PREVENTION									
Trayless	-	-	5%	5%	14%	5%	-	71%	-
Package Design	-	-	4%	4%	4%	13%	13%	63%	-
Standardized Date Labels	-	-	20%	20%	-	-	-	60%	-
Meal Kits	-	-	-	-	-	14%	14%	71%	-
RESCUE									
Donation Coordination & Matching	-	27%	2%	36%	24%	2%	-	7%	-
Donation Education	-	11%	30%	60%	-	-	-	-	-
Donation Transportation	-	2%	13%	44%	22%	4%	-	13%	-
On-site Anaerobic Digestion	-		5%	-	5%	-	-	23%	68%
In-vessel/Containerized Anaerobic Digestion	-		7%	7%	7%	36%	7%	36%	-
Donation Storage Handling & Capacity	-	7%	11%	54%	18%	-	-	11%	-
Insect Farming	14%		8%	8%	8%	27%	8%	14%	14%
Donation Value-Added Processing	-	-	3%	47%	47%	-	-	3%	-
RECYCLING									
Centralized Anaerobic Digestion	36%	-	7%	2%	7%	-	-	12%	36%
Co-digestion at Wastewater Treatment Plants	23%	-	5%	-	5%	-	-	-	68%
Livestock Feed	-	-	-	-	-	16%	16%	53%	16%
Centralized Composting	32%	-	32%	3%	3%	3%	-	10%	16%
Community Composting	45%	-	45%	5%	5%	-	-	-	-
Home Composting	-	-	75%	5%	15%	5%	-	-	-

Table H4. Funding Allocation

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
PREVENTION SOLUTIONS	
Buyer Specification Expansion	Corporate finance and spending-type funding is most appropriate for this solution as it can be implemented internally by food organizations and create additional revenue opportunities. Food retailers have a significant amount of influence upstream in the supply chain and can implement these solutions alongside appropriate operational changes. Given that adoption requires a shift in thinking and originally undervalued / overlooked product to be sold, non-government grants and impact-first investments can support marketing and educational efforts to farmers and consumers to stimulate adequate supply and demand for food related to Buyer Specification Expansion.
Partial Order Acceptance	Corporate finance and spending-type funding is most appropriate for this solution as it can be implemented internally by food organizations and would be adopted as a potentially profitable choice.
Gleaning	Gleaning organizations can be financed through charitable giving and "donations" by growers due to their non-profit nature. Gleaning initiatives with earned revenue potential can also be catalyzed through impact-first investments; often requiring funding for tools, transportation, and storage infrastructure. Additionally, program-specific government grant funding can aid in the ongoing costs associated with on-farm gleaning and donation efforts.
Imperfect & Surplus Produce Channels	Corporate finance and spending-type funding is most appropriate for this solution, as it can be implemented internally by food businesses and create additional revenue streams. The Imperfect & Surplus Produce Channels space is now at the point of scaling, requiring more attention from private capital. Regional and direct box delivery players have been gaining traction supported by early stage and later-stage venture funding. Potential models of Imperfect & Surplus Produce Channels may require large amounts of infrastructure, given that they are warehousing and transporting a significant volume of product, which can be appealing funding opportunities for private equity. Government grants, non-government grants, and impact-first investments have previously assisted initiatives focused on creating markets for imperfect produce. This will likely continue, as others form and incentives need to be provided to encourage producers to harvest produce that would otherwise be left behind; often requiring additional picking and packing costs.
Temperature Monitoring (Pallet Transport)	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit. Technology solutions and innovation will be financed with venture capital, but are mature enough where they are revenue generating (thus earning capital from corporate spending). Additionally, potential solution adopters such as retailers, manufacturers, and distributors can be incentivized through non-government grants, particularly smaller-to-medium sized firms. Reducing perceived risk by providing capital can help organizations run pilot programs to make distribution efforts more efficient – thereby giving these businesses the opportunity to understand the return on investment before financing the solution themselves.
First Expired First Out	Corporate finance and spending-type funding can provide all the capital for this solution, as this is mostly a corporate decision with financial benefit going to the implementer.

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
PREVENTION SOLUTIONS	
Decreased Transit Time	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit (e.g., reduced shipping costs, cost of goods sold, loss from spoilage). Additionally, optimization of the supply chain can be pursued by private equity, given major food supply chain actors can be acquired through this financing mechanism. Venture capital may also play a role to finance solution innovation and continued product development.
Intelligent Routing	Given many providers of this solution are revenue generating, a material amount of funding is expected from corporate finance and spending as adopters will receive direct financial benefits. Venture capital and private equity are expected to continue to play a role in either funding innovation or recommending established players in adopting/implementing this solution. Potential solution adopters such as retailers, manufacturers, and distributors can be incentivized through non-government grants, government grants and impact-first investments, particularly small-to-medium sized firms. Reducing perceived risk by providing catalytic capital can help organizations to run pilot programs to make distribution efforts more efficient – thereby giving these businesses the opportunity to understand the return on investment before financing the solution themselves.
Reduced Warehouse Handling	Corporate finance and spending-type funding is most appropriate for this solution to develop automation and processes. Venture capital can finance the early-stage technology solutions that may one day help reduce handling. Non-government grants will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially solutions in the earlier stages of product development. Private equity is also expected to play a small role in scaling solutions which are both from innovative startups and more established manufacturers/food service providers that are taken private with leverage.
Markdown Alert Applications	With markdown alert application technology readily available, food businesses are expected to use corporate finance and spending-type funding to purchase or adopt these solutions. Venture capital and private equity will also fund this solution as there is a level of innovation still needed in the space related to continued product development and end-customer acquisition. Additionally, early stage, mission-driven Markdown Alert Applications solutions which have a food access angle may also benefit from the assistance of non-government grants and impact-first investments.
Waste Tracking (Foodservice)	Corporate finance and spending-type funding is most appropriate for this solution (particularly implementation) as businesses themselves receive most of the financial benefit. Technology solutions and innovation will be financed with venture capital, private equity and sales from selling to corporations as product development continues and solutions scale. These recurring revenue business models are appealing to both venture capital and private equity investors. Small amounts of grants and impact-first investors will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially in the earlier stages of product development. There is the expectation that mature, for-profit organizations (particularly point-of-sale firms) will add this capability through internal development, partnerships with earlier stage companies, and mergers and acquisitions.
Decreased Minimum Order Quantity	Corporate finance and spending-type funding is expected to finance this solution given corporations can bear the implementation costs for this while also receiving a great portion of the financial benefits (more options to sell product).

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
PREVENTION SOLUTIONS	
Enhanced Demand Planning	Corporate finance and spending-type funding is most appropriate for this solution (particularly implementation) as businesses themselves receive most of the financial benefit. The recurring revenue business model is appealing to venture capital, while the potential of requiring investments in capital assets would be appealing to private equity investors. Venture capital is expected to play a meaningful role in funding continued product development and innovation through the application of AI, and the scaling of business models. Small amounts of non-government grants will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially in the earlier stages of product development and adoption.
Minimized On Hand Inventory	Corporate finance and spending-type funding is most appropriate for this solution (particularly implementation) as businesses themselves receive most of the financial benefit. Technology innovation (supply chain monitoring, optimizing stores, more direct-to-consumer models) to enable this solution is expected to be financed with venture capital.
Increased Delivery Frequency	Corporate finance and spending-type funding is most appropriate for this solution (particularly implementation) as businesses themselves receive most of the financial benefit. While increasing the frequency of deliveries may increase the cost of transport, this may be offset by increased revenue opportunities and reduced costs associated with less wasted food.
Dynamic Pricing	Corporate finance and spending-type funding is most appropriate for this solution (particularly implementation) as businesses themselves receive most of the financial benefit. A meaningful level of venture capital is expected to help scale further innovation, however many solutions are now at a revenue generating stage where corporate spending is funding the scaling of solutions. Both government and non-government grants will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially in the earlier stages of new product development and adoption. Additionally, private equity can provide growth capital.
Assisted Distressed Sales	A meaningful level of funding is needed from corporate finance and spending, as these businesses ultimately sell the distressed product (thereby reaping financial benefits), and venture capital for funding new business model development. Non-government grants and impact investments are also needed for their role as catalytic, risk-taking capital ahead of more traditional investors, especially in the earlier stages of new product development. Additionally, non-government grants may fund initiatives that support efforts in lower-income neighborhoods which address hunger and food insecurity.
Temperature Monitoring (Foodservice)	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit. Technology solutions and innovation will be financed with venture capital, but these solutions are generally mature enough where they are revenue generating (thus earning capital from corporate spending). Additionally, potential solution adopters such as restaurants, quick service chains, and corporate cafeterias (particularly small-to-medium sized firms) can be incentivized to adopt these solutions through non-government grants.

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
PREVENTION SOLUTIONS	
Active & Intelligent Packaging	Implementing this solution is a corporate decision with a likelihood to result in net economic benefit; therefore investment in this would be most appropriate in the form of corporate finance and spending. Although Active & Intelligent Packaging solutions are generally in the later stages of development, continued innovation and improvements (e.g., different applications and product types) to existing solutions can also be appropriate for venture capital. Grants will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially for solutions in the earlier stages of product development, R&D, and pilot projects.
Manufacturing Byproduct Utilization (upcycling)	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit. While corporations view upcycling as an opportunity to innovate product development, uptake is not yet widespread. Venture capital funding is also expected to play a role as this solution remains relatively early-stage, requiring more R&D and time to prove out business models, supply chain logistics, and ingredient sourcing channels. This solution requires a build out of capital assets and has the potential for cash flow generation, which makes it an appropriate funding target for private equity. Government grants, non-government grants, and impact investing will continue to act as catalytic, risk-taking capital ahead of more traditional investors, especially in the earlier stages of product development, consumer education, and adoption.
Manufacturing Line Optimization	Corporate finance and spending-type funding likely is most appropriate for this solution as businesses themselves receive most of the financial benefit. Although Manufacturing Line Optimization solutions are generally in the later stages of development, continued innovation and improvements (e.g.,: different product applications) to existing solutions can also be appropriate for venture capital. The asset-heavy nature of this solution results in opportunities for private equity. Government grants, non-government grants, and impact-first investments can also help reduce the upfront costs (e.g., costs related to service disruptions, capital expenditures, etc.) associated with the change-over of operations, particularly for small and medium enterprises.
Consumer Education Campaigns	Significant contributions of grants from both government and non-government sources are expected for this solution as the return on investment is mostly derived from societal good and lacks a direct financial return. Corporate finance and spending can be provided to develop in-store campaigns in partnership with national efforts to educate consumers on the issue of food waste and ways to save money by wasting less at point-of-sale.
Buffet Signage	Significant contributions of grants from both government and non-government sources are expected for this solution as the return on investment is mostly derived from societal good and lacks a direct financial return. A larger role is expected for corporate finance and spending, relative to Consumer Education Campaigns, as corporations would likely have to bear the full cost of sign changes, etc.
K-12 Education Campaigns	Significant contributions of grants from both government and non-government sources are expected for this solution as the return on investment is mostly derived from societal good and lacks a direct financial return. Corporate finance and spending could play a role from a Corporate Social Responsibility perspective on branded nutrition campaigns. However, the role would be limited due to concerns of overt corporate influence in classrooms.

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
PREVENTION SOLUTIONS	
K-12 Lunch Improvements	Significant contributions of grants from both government and non-government sources are expected as the return on investment is mostly derived from societal good and lacks a direct financial return. Areas of investment for grants include waste audits and developing food rescue and recycling programs. Innovation is needed from external solution providers and tech-enabled services. There will likely be a role for private food service providers to play as well.
Portion Sizes	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit. Additionally, government grant funding may be necessary to incentivize changes particularly from a nutrition perspective. Implementation of this solution could work in tandem with Consumer Education Campaigns.
Small Plates	Corporate finance and spending is expected to cover the majority of investment as this activity could lead to increased profitability as lower consumption reduces cost of goods sold. Grants and impact-first investors can incentivize changes in small to medium sized restaurants and chains by covering the upfront cost of smaller plates. Government grants may also play a larger role In institutional settings that are run by the government (e.g., university campuses).
Trayless	Corporate finance and spending is expected to cover the majority of Trayless solution investment as this activity could lead to increased profitability as lower consumption reduces cost of goods sold. Grants and impact-first investors can incentivize changes in small to medium sized restaurants and chains by covering the upfront costs of trayless dining systems and training. Government grants may also play a larger role in institutional settings that are run by the government (e.g., university campuses).
Package Design	Corporate finance and spending-type funding is most appropriate for this solution as businesses themselves receive most of the financial benefit and are likely the decision makers. Different levels of government can also provide grants to trade associations, academia, or nonprofits for areas requiring further research. Additionally, innovative Package Design solutions are key targets for private equity due to their asset-heavy nature. Much of the innovation in this solution is occurring in established manufacturers, which would be appealing for private equity investors, as they can purchase existing, cash flow-generating businesses with the optionality of growth.
Standardized Date Labels	This requires capital from corporate finance and spending to implement the solution given it is a corporate decision. Grants from government and non-government sources can help spark pre-competitive action by; coordination of, and broad adoption among corporations given limited first-mover incentive for corporations.
Meal Kits	Meal Kit solutions are scaling rapidly in mid- to later- stages of venture capital or accessing public markets, therefore this solution will require a significant amount of corporate finance and spending in the form of consumer revenue. There is also a role for established retailers and food companies to provide food in this form to their customers. Meal Kits will also continue to be financed by a meaningful level of venture and private equity as more innovation is still needed in order to overcome business model and distribution challenges.

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
RESCUE SOLUTIONS	
Donation Coordination & Matching	Non-government grants and other concessionary capital sources are expected to fund Donation Coordination & Matching initiatives given much of this work is occurring within nonprofits. Technology-enabled solutions may also be funded by corporate finance and spending (where there is the potential for revenue) and venture capital. Impact-first investments can play a role in adoption of solutions requiring upfront cost. Legislators and government agencies have the potential to fund this initiative through grants.
Donation Education	Government and non-government grants will contribute vital funding for donation education campaigns. The government may also direct resources to inform stakeholders of incentives currently in place.
Donation Transportation	Non-government grants are expected to fund this solution given it has not historically resulted in market-rate returns. Funders can also help drive regional or coordinated efforts for asset sharing to improve overall logistics among various food recovery organizations. Government grants are expected to contribute a portion of capital through incentives and grants to largely nonprofit organizations. Raising awareness about the opportunity and positive impact that funding donation transportation can have is a critical element that can help solution providers receive more funding for these activities. New, innovative business models may be financed with impact-first investments and venture capital.
Donation Storage Handling & Capacity	Non-government grants are expected to fund Donation Storage Handling & Capacity given this solution has not historically resulted in market-rate returns that would attract traditional investors. Additionally, government grants are expected to supplement other philanthropic efforts. Impact-first investments will continue to act as catalytic, risk-taking capital complementing the aforementioned capital. Corporate finance and spending may bear the costs of donated cold storage and lending of other resources.
Donation Value-Added Processing	The expansion of grant and loan programs by federal agencies, such as the US Department of Agriculture, can help businesses expand processing capabilities, particularly on-farm where there are large opportunities for food rescue. Non-government grants are also expected to fund solution providers given these solution models have not historically resulted in market-rate returns. Additionally, impact-first investing will play a catalytic role for new innovative solutions, business models, and asset purchases.
RECYCLING SOLUTIONS	
Centralized Anaerobic Digestion	Centralized Anaerobic Digestion will be largely funded by commercial and government project finance given the type of investment required for infrastructure. Anaerobic digesters are able to generate revenue (from corporate finance and spending) via tip fees and energy sales. Government grants can be helpful in accelerating the adoption of organics recycling solutions, rather than landfill, by covering upfront costs or ongoing operating costs. This may make the adoption of this solution potentially more viable from an economic standpoint. Philanthropic capital and impact-first investments can help bridge gaps in financing (particularly for more regional operations) that may not currently have consistent feedstock.

SOLUTION NAME	RATIONALE FOR FUNDING ALLOCATION
RECYCLING SOLUTIONS	
Co-digestion at Wastewater Treatment Plants	Co-digestion at Wastewater Treatment Plants will be funded by government project finance given the type of investment required for infrastructure (e.g., digesters). Additionally, financing is expected from government grants to maintain the service as a public good given there are limited private solutions. The service will likely need to be subsidized to incentivize businesses to adopt this as a waste destination versus other possibilities.
Livestock Feed	Corporate finance and spending will provide a meaningful level of capital for this solution and these businesses will receive most of the financial benefit. The asset-heavy nature of livestock feed processing will require a fair amount of commercial project finance. The established nature of Livestock Feed businesses makes them ideal targets for private equity, which can focus on driving further sustainability in operations. Lastly, venture capital is expected to fund startups in the space as they scale.
Centralized Composting	Government and commercial project finance will play an equally important role given the infrastructure and equipment (e.g., depackagers) investment required. Corporate finance and spending will provide capital in the form of revenue for disposal of organic waste. There are business models at various stages of development (e.g., R&D to rapidly scaling startups) which will require venture capital and private equity. Government grants, non-government grants, and impact-first investments will continue to act as catalytic, risk-taking capital ahead of more traditional investors, to incentivize adoption by corporations and the public.
Community Composting	Government project finance, government grants, and non-government grants are expected to support site development, especially working to align community composting sites with other community assets to increase the non-financial benefits such as job creation and educational opportunities. Services provided to consumers through a government subsidized model will assist with adoption. Additionally, impact-first investing can play a role to increase adoption either locally or by government agencies.
Home Composting	Home Composting is largely expected to be supported by government grants to institute regular composting pick up, subsidize home composters, and cover the cost of education campaigns. Venture capital and impact-first investments can play a role to fund innovative business models focused on at-home composting.

Prevention Solutions

Table H5. Prevention Solution Modeling Assumptions

BUYER SPECIFICATION EXPANSION		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Optimize The Harvest	
Description	Adjustment of purchasing specifications that allow for a greater variety of product grades into sales and recipes, while still ensuring that specs do not lead to in-house waste.	
Diversion Rate	Average Rate	12.00%
	Source(s)	Abecasis, M. et al.[12]
	Additional Notes	
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Left behind after harvest (Not marketable)
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	Partial applicability (50%) for Dairy & Eggs and Fresh Meat & Seafood as this solution would not apply to all products in those categories.
Assumptions	Financial Costs	$100/ton upfront costs per ton for staff retraining, no recurring costs related as this is a procedural change only; any labor and storage changes are assumed to be marginal based on expert interviews. Cost estimates developed through expert interviews.
	Additional Notes on Costs	Producers assumed to carry upfront costs related to harvesting and processing larger harvest quantities.
	Financial benefits	$55.36/ton for tip fee savings; $4,932.64/ton wholesale food cost saving.
	Additional Notes on Benefits	Producers & Manufacturers assumed to get 75% total benefit as they sell a greater volume of product by expanding specifications. Retailers assumed to get 25% total benefit in price discounts.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

GLEANING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Optimize The Harvest	
Description	Collecting leftover product from fields after the initial commercial harvest that would be otherwise inefficient and uneconomical to harvest, often conducted by volunteers.	
Diversion Rate	Average Rate	20.00%
	Source(s)	Lee, D. et al.[13]
	Additional Notes	Diversion rate derived from approximate mean value of 5 crops studied.
Applicable Sectors & Causes	Farm	Fields never harvested (Market dynamics) | Fields never harvested (Other) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Consumers | Solution Providers
	Additional Notes	This solution was applied only to 8.1% of the total farm volume. It tends to be impractical on large farms, thus we applied it only to farms 250 acres and less which, per the 2017 USDA Ag Census, make up only 8.1% of farms[14].
Applicable Food Types	List	Produce
	Additional Notes	

GLEANING		
Assumptions	Financial Costs	$740/ton - Annual cost from a survey of 95 gleaning organizations in the US, 7 reported their annual budget and estimated fraction of their budget which is used to support gleaning (which may be partially or fully done by volunteers and are outside of this budget.)[15]. Figure represents their quoted total budget multiplied by this fraction for gleaning, divided by their pounds gleaned. Arithmetic mean of the 7 which reported their gleaning fraction is used. No upfront costs involved.
	Additional Notes on Costs	Solution providers (gleaning organizations) incur costs associated with operating and coordinating a gleaning program, including transportation, gloves or other protective equipment for volunteers.
	Financial benefits	$3,132.44/ton average retail produce costs.
	Additional Notes on Benefits	Consumers receive the full benefit as gleaned food is often available in food recovery and food donation locations. While farmers are eligible for tax deductions from food donation, we do not include them in our model as many farmers are not able to take advantage of this for accounting reasons.
	Jobs Created	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	NA	DATA QUALITY NOT YET EVALUATED

IMPERFECT & SURPLUS PRODUCE CHANNELS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Imperfect & Surplus Produce Channels	
Solution Type	Prevention	
Priority Action Area	Optimize The Harvest	
Description	Surplus, off-grade, near-expiration, or "imperfect" produce that is packaged and distributed via alternative sales channels or directly to consumers.	
Diversion Rate	Average Rate	35.00%
	Source(s)	Solution provider and expert input[16].
	Additional Notes	Rate reflects diversion potential only when applicable causes are considered.
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Fields never harvested (Market dynamics) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Retailers| Foodservice | Consumers
	Additional Notes	
Applicable Food Types	List	Produce
	Additional Notes	While a diversion rate of 35% is used, it is sure to vary by product, location, and other dynamics. This model is only applied to produce, but other product categories are finding their way into these sales channels as well.
Assumptions	Financial Costs	$244.44/ton for pick and pack out costs, developed from expert interviews; no upfront costs needed; operational changes not included.
	Additional Notes on Costs	Producers assume the ongoing implementation costs.
	Financial benefits	$55.36 on tip fee savings; $2,352.60/ton produce wholesale food cost.
	Additional Notes on Benefits	Producers receive 50% total benefit as they sell a greater volume of product by expanding specifications. Retailers and Foodservice assumed to get 25% total benefit each in discounted prices.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**NA**	**DATA QUALITY NOT YET EVALUATED**

PARTIAL ORDER ACCEPTANCE		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Optimize The Harvest	
Description	Processes to reject at a higher level of granularity and limit rejections of product that meet specs.	
Diversion Rate	Average Rate	3.80%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 2.5-5% depending on applicability within the sector, and food type.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the diversion potential will be less applicable to other sectors such as manufacturers and food service at 50% savings potential and 25% for producers.
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	Partial order acceptance creates the largest impact on products with high variation in quality, primarily due to perishability, with Produce and Fresh Meat & Seafood being the highest.
Assumptions	Financial Costs	$140/ton for upfront costs in process updates and staff training, and $2,280/ton in operating costs for labor; all costs determined through Deloitte interviews with SMEs.
	Additional Notes on Costs	Retailers and Foodservice hold the associated costs split between the two. In addition, they receive 25% of the financial benefit.
	Financial benefits	$55.36 on tip fee savings/ton and $4,301/ton of wholesale food cost saving.
	Additional Notes on Benefits	Producers and Manufacturers receive 50% of the financial benefit with no cost to them as they are able to reduce the number of rejections and wasted product. Retailers and foodservice receive 25% of the benefits each as they save in not having to source other product and reduced out-of-stocks.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

DECREASED TRANSIT TIME		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Enhance Product Distribution	
Description	Reducing time in transit by team driving to extend the distance product can move each day from farm to distribution.	
Diversion Rate	Average Rate	15.00%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 8-23% depending on applicability within the sector and perishability of food type.
Applicable Sectors & Causes	Farm	Buyer rejections
	Manufacturing	Buyer rejections
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the savings potential is fully applicable in retail settings. For foodservice, it's only applied to 50% of the volume because many foodservice institutions do not have the ability to affect distribution and product does not typically remain for as long.
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce
	Additional Notes	Diversion potential increases with the perishability of the product in transit, where Fresh Meat & Seafood and Produce have the greatest opportunity for diversion at 23% and Bread & Bakery the lowest at 8%.
Assumptions	Financial Costs	$20/ton upfront costs and $720/ton in annual costs, based on the Deloitte case study, which determined that fixed and variable operating costs could not be split and instead calculated costs per ton.
	Additional Notes on Costs	Each sector bears its own costs to decrease transit time. Costs include: Software licenses; Software integration; Staff training; Increased Transportation Costs.
	Financial benefits	$55.36/ton on tip fee savings; $4,932/ton of wholesale food cost saving.
	Additional Notes on Benefits	The financial benefit of decreased transit time will apply to each sector that adopts the solution, since the food cost savings would be within their operations.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

FIRST EXPIRED FIRST OUT		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Enhance Product Distribution	
Description	Designing processes to move product based on what will expire first, rather than when it was received.	
Diversion Rate	Average Rate	15.0%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 10-20% depending on applicability within the sector, perishability, and cold chain requirements.
Applicable Sectors & Causes	Farm	
	Manufacturing	Unshipped finished product
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the savings potential is fully applicable in retail settings and only minimally applicable to manufacturers and foodservice. It is applied to only 10% of foodservice volume to reflect that. The greatest effect would be in routing of fresh produce to restaurants, and FEFO is a more common practice already in kitchens
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	FEFO creates the largest impact on products with shorter shelf life, that can also have high variability in freshness. Fresh meat & Seafood and Produce can have high variability depending on catch / farm and cold chain compliance while en route. Prepared foods have moderate addressability based on shelf life and freshness, while ready-to-drink beverages, Breads & Bakery, and Dairy & Eggs have low addressability and diversion potential.

FIRST EXPIRED FIRST OUT			
Assumptions	Financial Costs		$100/ton upfront costs and $1,100/ton annual costs, based on the Deloitte case study, which determined that fixed and variable operating costs could not be split and instead calculated costs per ton.
	Additional Notes on Costs		Each sector bears its own costs. Costs include: Process updates; Staff training.
	Financial benefits		$55.36/ton on tip fee savings; $4,294/ton of wholesale food cost savings.
	Additional Notes on Benefits		The financial benefit of FEFO will apply to each business that adopts the solution, since the food cost savings would be within their operations.
	Jobs Created		0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE		3	SEE APPENDIX I FOR DATA QUALITY DETAIL

INTELLIGENT ROUTING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Enhance Product Distribution	
Description	Routing of product based on near time data on impacts to freshness, such as cold chain maintenance so that shorter-life product is routed to closer destinations.	
Diversion Rate	Average Rate	15.0%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 12.5-17.5% depending on applicability within the sector, perishability, and cold chain requirements.
Applicable Sectors & Causes	Farm	Buyer rejections
	Manufacturing	Buyer rejections
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice | Solution Providers
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the savings potential is fully applicable in retail settings, moderately applicable to foodservice, and minimally applicable to manufacturers. It was applied to only 45% of foodservice volume to reflect this.
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce
	Additional Notes	Produce has the highest potential for waste reduction impact as it has the shortest shelf life of items sold in retail. Dairy & Eggs and Fresh Meat & Seafood have moderate potential as perishable items because of the longer shelf life. Ready-to-drink beverages, Breads & Bakery, and Prepared Foods are either less constrained by these factors or are prepared closer to their final destination (such as in-store bakeries and commissaries).

INTELLIGENT ROUTING		
Assumptions	Financial Costs	$180.00/ton upfront cost as the initial investment to purchase new systems or upgrade existing systems to allow for intelligent routing. $960.00/ton for annual costs. Fixed and variable costs could not be split and are instead calculated as costs per pound of food, then scaled up per ton.
	Additional Notes on Costs	Each sector bears its own costs. Costs include: Software licenses; Software integration; Staff training; Miles driven.
	Financial benefits	$55.36/ton on tip fee savings; $4,294/ton of wholesale food cost savings.
	Additional Notes on Benefits	The financial benefit of intelligent routing will apply to each business that adopts the solution, since the food cost savings would be within their operations. In addition, solution providers selling the solution will benefit from its sales, equal to costs that businesses are paying.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	SEE APPENDIX I FOR DATA QUALITY DETAIL

TEMPERATURE MONITORING (PALLET TRANSPORT)		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Enhance Product Distribution	
Description	Use of measurement and alert technology and other systems for pallet- or truck-level temperature tracking to identify areas for improved cold chain compliance, third-party issue identification, and real-time detection and resolution.	
Diversion Rate	Average Rate	7.0%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 4-9% depending on applicability within the sector, perishability, and cold chain requirements.
Applicable Sectors & Causes	Farm	Buyer rejections
	Manufacturing	Buyer rejections
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Dairy & Eggs | Fresh Meat & Seafood | Produce | Frozen
	Additional Notes	Temperature monitoring creates the largest impact on products that require strict cold chain compliance and have fresh ingredients, with Meat and Seafood, Produce, and Frozen foods having the highest diversion potential of 9%.
Assumptions	Financial Costs	$140/ton upfront costs for the initial investment to purchase sensing technology for monitoring pallets or cases, new trucks and sensors, and other system requirements. $480/ton of annual costs that will support the maintenance and use of these systems.
	Additional Notes on Costs	Each sector bears its own costs, except retail, where costs are assumed to be split amongst the other actors earlier in the supply chain (producers and manufacturers). Costs include: Temp tracking hardware; Software licenses; Software integration; Staff training.
	Financial benefits	$55.36/ton on tip fee savings; $3,218/ton of wholesale food cost savings.
	Additional Notes on Benefits	The financial benefit of cold chain monitoring will apply to each business that adopts the solution, since the food cost savings would be within their operations.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

ASSISTED DISTRESSED SALES		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Assistance, through third-party companies or apps, in selling salvaged, off spec, overstocked, and out of date food at a discounted rate.	
Diversion Rate	Average Rate	31.8%
	Source(s)	Solution provider case studies and expert interviews[16].
	Additional Notes	Diversion rate ranged from 20% diversion for retail distribution of near expiration product to 43.5% diversion of unshipped finished goods at manufacturing.
Applicable Sectors & Causes	Farm	
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	Date label concerns
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	All food and drink types have the same diversion percentage.
Assumptions	Financial Costs	No upfront costs. $21/ton diverted of annual operating costs.
	Additional Notes on Costs	Each sector bears its own costs.
	Financial benefits	$1,240/ton diverted. $21/ton to solution provider, based on expert interviews.
	Additional Notes on Benefits	The financial benefit of assisted distressed sales will apply to each business that adopts the solution, since the food cost savings would be within their operations. Solution providers received the relative financial benefits associated with sales of assisted distressed services.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**NA**	**DATA QUALITY NOT YET EVALUATED**

DECREASED MINIMUM ORDER QUANTITY		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Reduce minimum order quantities to avoid over-purchasing.	
Diversion Rate	Average Rate	7.0%
	Source(s)	Deloitte case study[17].
	Additional Notes	Diversion rate ranges from 3-11% depending on applicability within the sector and perishability.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Retailers | Foodservice
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the savings potential is fully applicable in retail settings. Applied at 50% to foodservice volume to reflect that it's unlikely to apply to smaller operations.
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	The Deloitte case study was focused on produce waste and determined that produce has the greatest potential for waste diversion (11%), foods such as dairy & eggs would have moderate diversion potential (7%), and less perishable items such as breads would have low diversion potential (3%).
Assumptions	Financial Costs	$40.00/ton diverted upfront costs and $640/ton diverted of annual operating costs.
	Additional Notes on Costs	Each sector bears its own costs. Costs include: Software changes and staff training.
	Financial benefits	$55.36/ton on tip fee savings; $4,294/ton of wholesale food cost savings.
	Additional Notes on Benefits	The financial benefit of decreasing minimum order quantities will apply to each business that adopts the solution, since the food cost savings would be within their operations. No increase in revenue, only savings in food costs and reduced waste hauling costs.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

DYNAMIC PRICING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Systems and technologies that automatically and comprehensively discount pricing for items, with the purpose of re-appraising based on remaining shelf life, inventory on hand, and incoming orders.	
Diversion Rate	Average Rate	30.0%
	Source(s)	Solution provider case study (based in Italy) and expert interviews[16].
	Additional Notes	
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Retailers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	All perishable products are applicable but items are required to have a date label or barcode for the solution to work.

DYNAMIC PRICING		
Assumptions	Financial Costs	$2,293.65/ton diverted for upfront costs (derived from estimated $2000/store and $30,000.00 per chain costs). Variable costs estimated at $2,780.52/ton diverted (derived from facility estimate using rate of $5.80 per SKU/month and 2000 SKU's per location).
	Additional Notes on Costs	The cost to implement dynamic pricing will only be incurred by retailers implementing the solution.
	Financial benefits	$55.36/ton on tip fee savings; $2,840.50/ton of wholesale food cost savings.
	Additional Notes on Benefits	Retailers who implement dynamic pricing will incur the benefits of selling more product at a lower discount (estimated 20% higher price than typical discounts) and paying lower food waste disposal costs. Solution providers will receive the financial benefit associated with sales of the technologies and services of dynamic pricing systems to retail customers. Consumers are assumed to receive no financial benefit because although they might see a reduction in prices, dynamic pricing systems can also be used to reduce the size of the discount or markdown required to sell product, so the forces will more or less cancel each other out.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	SEE APPENDIX I FOR DATA QUALITY DETAIL

ENHANCED DEMAND PLANNING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Improved intelligence around demand planning through systems or incorporating historical data in future decisions, often using machine learning to aid in better forecasting and fulfillment.	
Diversion Rate	Average Rate	38.0%
	Source(s)	Solution provider input and expert interviews[16].
	Additional Notes	
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Retailers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	This technology currently used in produce only, but applied to all perishable food types in model as it should work more broadly.
Assumptions	Financial Costs	$1,576.97/ton diverted upfront costs (based on $100k/facility fixed upfront cost). $78.78/ton diverted annual operating cost estimate.
	Additional Notes on Costs	The cost to implement enhanced demand planning will be incurred by retailers themselves.
	Financial benefits	$55.36/ton on tip fee savings, $4,932.64/ton of wholesale food cost savings, and $177.11 in additional cost savings/ton associated with reduced labor hours diverted from additional orders.
	Additional Notes on Benefits	The financial benefit of enhanced demand planning will benefit retailers, as it will help them optimize ordering and reduce shrink. Solution providers will receive the financial benefit associated with sales of the technologies and services of dynamic pricing systems to retail customers.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

INCREASED DELIVERY FREQUENCY		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Increasing the frequency of delivery from suppliers to stores, restaurants, facilities, or other food destinations to reduce dwell time in distribution centers.	
Diversion Rate	Average Rate	6.5%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate ranges from 3-9.25% depending on applicability within the sector and perishability.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	Date label concerns | Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice
	Additional Notes	The Deloitte case study was developed for retail clients, therefore the savings potential is fully applicable in retail settings (100%), moderately applicable to manufacturers (50%), and minimally applicable to foodservice (25%).
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	Increased delivery frequency will have the highest diversion potential for fresh meat and seafood and produce (9.25%), moderate diversion potential for prepared foods and dairy and eggs(6.5%), and low diversion potential for ready-to-drink beverages and breads and bakery (3%).
Assumptions	Financial Costs	$20/ton diverted of upfront costs and $1,020/ton diverted annual raw costs; costs are modeled per pound by food type.
	Additional Notes on Costs	Each sector bears its own costs. Costs include: Process updates; Trucking deliveries; Miles driven
	Financial benefits	$55.36/ton on tip fee savings; $4,294.80/ton of wholesale food cost savings.
	Additional Notes on Benefits	The financial benefit of increased delivery frequency will apply to each industry that adopts the solution, since the food cost savings would be within their operations.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

MARKDOWN ALERT APPLICATIONS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Applications that alert consumers to markdowns or excess food at retailers or restaurants	
Diversion Rate	Average Rate	26.4%
	Source(s)	Solution provider case studies and expert interviews[16].
	Additional Notes	26.4% for manufacturing and retail; 50% for foodservice (applies only to overproduction cause).
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	Overproduction
	Residential	
	Financially Impacted Stakeholder(s)	Retailers | Foodservice | Consumers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	In foodservice, applies only to prepared foods. In retail, can apply to all categories but more common in perishables.
Assumptions	Financial Costs	Retail: No upfront costs. $1,196.80/ton diverted annual operating costs. Foodservice: $2425.67/ton diverted annual operating costs.
	Additional Notes on Costs	Each sector bears its own costs. Costs include: service provider fees.
	Financial benefits	Retail: $55.36/ton on tip fee savings; $4,184.62/ton of additional revenue. Foodservice: $55.36/ton on tip fee savings; $7500/ton of additional revenue.
	Additional Notes on Benefits	Retail and Foodservice will benefit from additional revenue of sales and reduced landfill hauling costs. Consumers will receive some benefit of reduced prices but may also experience decreased discounts and therefore higher prices and no assumed financial benefit.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

MINIMIZED ON HAND INVENTORY		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Reduce product dwell time in distribution centers by not holding safety stock and excess days on-hand.	
Diversion Rate	Average Rate	8.0%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate varies between 3.5 - 12% depending on perishability.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Retailers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	Minimizing retail inventory on hand creates the largest impact on products that need temperature controlled environments, and thus might be wasted due to space constraints if there is more product than storage space, or that could be easily damaged by overcrowding product into space. Produce and Meat & Seafood (12%); Breads & Bakery, Dairy & Eggs, Frozen and Prepared Foods (8%); Ready to Drink Beverages (3.5%)
Assumptions	Financial Costs	$20/ton diverted upfront costs and $340/ton diverted of annual operating costs.
	Additional Notes on Costs	Retail bears its own costs to minimize on hand inventory. Costs Include: Process updates; Staff training; Ongoing analysis of order quantities and inventory excess.
	Financial benefits	$55.36/ton on tipfee savings; $4,208.94/ton of wholesale food cost saving.
	Additional Notes on Benefits	Retail will benefit from minimizing retail inventory on hand since the food cost savings would be within their operations.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

REDUCED WAREHOUSE HANDLING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Enhance Product Distribution	
Description	Minimizing the number of touches on a product during distribution, preparation, and on display can prevent blemishes or bruising and reduce the potential for damages.	
Diversion Rate	Average Rate	1.5%
	Source(s)	Deloitte case study and expert interviews[17].
	Additional Notes	Diversion rate varies between .5 - 1.5% depending on handling sensitivity.
Applicable Sectors & Causes	Farm	Buyer rejections
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	Handling errors | Spoiled
	Foodservice	Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	Diversion rate may vary for different types of produce, but was not specified in current model. Any food type variation in diversion is based on packaging material, perishability, and susceptibility to damages. Produce (1.5%); Meat & Seafood, Breads & Bakery, Diary & Eggs (1%); Prepared Foods (.5%)
Assumptions	Financial Costs	$20/ton diverted upfront costs and $980/ton diverted of annual operating costs.
	Additional Notes on Costs	Each sector bears its own costs. Costs include: Staff training as the solution requires operational changes to existing procedures.
	Financial benefits	$55.36/ton on tip fee savings; $4,932.64/ton of wholesale food cost saving.
	Additional Notes on Benefits	The financial benefit of reduced handling will apply to each industry that adopts the solution, since the food cost savings would be within their operations. There could be positive downstream implications for reduced handling upstream, but this cannot be modeled currently, so we have conservatively assumed that reduced handling only impacts the sector in which it is practiced.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

TEMPERATURE MONITORING (FOODSERVICE)		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Implementation of measurement and alert systems within foodservice cold storage units to detect out of range temperatures and notify automatically.	
Diversion Rate	Average Rate	3.1%
	Source(s)	Solution provider case study[16].
	Additional Notes	
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Spoiled
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Dairy & Eggs | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	Diversion only applies to perishable food types with cold chain requirements.
Assumptions	Financial Costs	$60.61/ton diverted of annual operating costs. No upfront costs.
	Additional Notes on Costs	Each sector bears own costs (for now this solution only modeled for foodservice). Temperature monitoring model assumes $10 / month for sensor and 1 sensor per location. This solution models a new low-cost technology to monitor cooler temperatures. Other technologies exist at higher costs.
	Financial benefits	$55.36/ton on tip fee savings; $4,534/ton of wholesale food cost saving.
	Additional Notes on Benefits	All sectors that implement temperature monitoring will benefit since the food cost savings would be within their operations.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**NA**	**DATA QUALITY NOT YET EVALUATED**

WASTE TRACKING (FOODSERVICE)		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Refine Product Management	
Description	Technology-enabled tracking of food loss and waste to highlight opportunities for reduction.	
Diversion Rate	Average Rate	35.6%
	Source(s)	Solution provider case studies; Expert interviews[16].
	Additional Notes	
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Plate waste | Other | Spoiled | Trimmings & byproducts
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Solution Providers
	Additional Notes	Solution case studies for institutional food service. Lower applicability applied to full service restaurants (75%) and limited service restaurants (30%) to account for different models.
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$1,316.07/ton annual costs. No upfront costs. Costs include: Monthly hardware and software rental / license fees, influence tools, coaching and reporting fees based on package. Prices are tiered but this represents the most popular product package.
	Additional Notes on Costs	Each business that implements waste tracking at their locations will incur the costs associated with the technology and ongoing use.
	Financial benefits	$55.36/ton on tip fee savings; $4,534.00/ton of wholesale food cost saving.
	Additional Notes on Benefits	The financial benefits will accrue to each business that implements this solution since this helps decrease waste within businesses' operations
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

ACTIVE & INTELLIGENT PACKAGING		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Maximize Product Utilization	
Description	Barriers applied directly to products or individual storage containers used to extend shelf life and maintain quality (e.g., water vapor barriers, ethylene absorption, modified atmospheres, moisture absorption, and oxygen barriers).	
Diversion Rate	Average Rate	21.5%
	Source(s)	Solution provider input; ReFED 2016 model[18].
	Additional Notes	Diversion rate ranges between 10.75-21.5% with the greatest applicability in retail operations.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Spoiled
	Foodservice	
	Residential	Date label concerns | Spoiled
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice | Consumers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Dairy & Eggs | Fresh Meat & Seafood | Produce
	Additional Notes	Diversion potential varies by perishability of food type: Fresh meat & seafood and produce - 21.5% (however, applied to only 10% of produce as that's what is packaged); Dairy & eggs - 10.75%.
Assumptions	Financial Costs	$701.55/ton annual costs, assumed with unit cost of $.08/lb of fruit and $.04/lb of meat. No upfront costs are assumed.
	Additional Notes on Costs	Manufacturers incur the costs associated with active and intelligent packaging production on a per unit basis, dependent on food type.
	Financial benefits	$55.36/ton on tip fee savings; $3,763.53/ton of wholesale food cost saving.
	Additional Notes on Benefits	Solution providers benefit from additional sales of active & intelligent packaging across all industries. Active and intelligent packaging extends the shelf life of perishable products and financially benefits retailers, foodservice, and consumers from decreased food costs and landfill tipping fees.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

MANUFACTURING BYPRODUCT UTILIZATION (UPCYCLING)		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Maximize Product Utilization	
Description	Converting food by-products that would otherwise not go to human consumption (e.g. spent grains, fruit or vegetable pulps, and rinds) into a new ingredient or edible food product through value-added processing.	
Diversion Rate	Average Rate	21.5%
	Source(s)	Expert interviews[16]; solution provider case studies[16]; Upcycled Foods Association internal survey[19].
	Additional Notes	Average of diversion potential cited from UFA survey was 88.8%. This estimate was then applied to an estimate of the percentage of addressable byproduct materials for which upcycling could apply, estimated to be 24.2%.
Applicable Sectors & Causes	Farm	
	Manufacturing	Byproducts & production line waste
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$160.50/ton of upfront costs and $1,232.86/ton of annual costs, based on the mean of the per pound cost paid by solution provider to the source provider.
	Additional Notes on Costs	Solution providers incur all costs associated.
	Financial benefits	$55.36/ton on tip fee savings; $1,232.86/ton of income from sale of byproduct (based on mean of the per pound cost paid by solution provider to the source provider.).
	Additional Notes on Benefits	Producers and manufacturers receive the full benefit of landfill tipping fee and food cost savings (or sale of byproduct) with no costs incurred. Solution providers are assumed to have a 39% gross margin over their costs, resulting in $1,412.25/ton income.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**NA**	**DATA QUALITY NOT YET EVALUATED**

MANUFACTURING LINE OPTIMIZATION		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Maximize Product Utilization	
Description	Identifying opportunities to reduce food waste from manufacturing and processing operations, such as in product line changeovers.	
Diversion Rate	Average Rate	10.0%
	Source(s)	ReFED 2016 report[18] and 15 line improvement examples from 5 different Provision Coalition case studies[20].
	Additional Notes	Diversion rate derived from ReFED 2016 report[18] as other case studies did not give diversion from full waste stream.
Applicable Sectors & Causes	Farm	
	Manufacturing	Byproducts & production line waste
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Manufacturers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$348.60/ton annual costs and no upfront costs (Provision Coalition case studies).
	Additional Notes on Costs	Manufacturers assumed to bear annual costs.
	Financial benefits	$55.36/ton tip fee savings; $711.68/ton food cost savings (derived from case studies, not wholesale costs).
	Additional Notes on Benefits	Manufacturers assumed to benefit from reduced landfill tipping fee and food cost savings.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

MEAL KITS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Assemblies of pre-measured ingredients to cook specific meals, marketed as a way to save time and minimize waste of raw ingredients purchased individually. Can be sold via direct-to-consumer or in-store channels.	
Diversion Rate	Average Rate	22.0%
	Source(s)	Wuppertal Institute, Hello Fresh Food Waste Study, March 2020. Proprietary[21]. Heard, et al.[22]
	Additional Notes	Diversion rate derived from total waste comparison in Wuppertal study. Clear diversion rates not released in Heard et al. study, but GHG emissions found to be 33% higher for grocery store meals than meal kits.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Spoiled
	Financially Impacted Stakeholder(s)	Retailers | Consumers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce
	Additional Notes	
Assumptions	Financial Costs	$513.69/ton annual costs
	Additional Notes on Costs	A 10% premium retail cost for consumers is assumed for the ingredients in meal kits. The cost to retailers of providing meal kits is not modeled for lack of data.
	Financial benefits	$5,136.90/ton
	Additional Notes on Benefits	Retail food cost savings for consumers for less food discarded.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**NA**	**DATA QUALITY NOT YET EVALUATED**

BUFFET SIGNAGE		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	On-site signage to encourage choices and behaviors that reduce waste at point of consumption.	
Diversion Rate	Average Rate	8.9%
	Source(s)	Portland State University and ReFED[23]. Whitehair et al. 2013[24]
	Additional Notes	Diversion rate discounted 50% from studies to reflect that behavior change may not be maintained over time.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Solution Providers
	Additional Notes	Applies only in All You Can Eat settings, assumed for the following subsectors: Limited Service Family Casual (100%), University (60%), Healthcare (33%), Business & Industry (10%), Lodging (33%), Recreation (6%), and Catering (50%).
Applicable Food Types	List	Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$1.50/ton upfront costs and $1.50/ton annual costs.
	Additional Notes on Costs	Foodservice assumed to bear the upfront and annual costs of sign design and printing.
	Financial benefits	$55.36/ton tip fee savings; $4,534.00/ton wholesale food cost savings.
	Additional Notes on Benefits	Foodservice assumed to benefit from the reduced tipping fee and cost of food; solution providers assumed to benefit from the cost of implementation.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

CONSUMER EDUCATION CAMPAIGNS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Conducting large-scale advocacy campaigns to raise awareness and educate consumers about ways to prevent food waste in their homes.	
Diversion Rate	Average Rate	7.0%
	Source(s)	TriFOCAL 2020[25]
	Additional Notes	To be conservative and assuming that the changes don't always last, 7% is half of the rate from the above study.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Too little to save | Other | Spoiled | Considered inedible
	Financially Impacted Stakeholder(s)	Retailers | Consumers | Government | Solution Providers
	Additional Notes	Retail only impacted because they are assumed to participate in education campaigns.
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$51.41/ton annual cost to government for national campaign, based on an estimate of $70M national campaign which was extrapolated from costs to Alameda County for their local education campaign. In addition, a cost of $23.38/ton is assumed for retailers based on the experience of a large retailer's campaign. These are annual as messaging and campaign materials are refreshed regularly.
	Additional Notes on Costs	
	Financial benefits	$5,463/ton retail food cost savings.
	Additional Notes on Benefits	Consumers assumed to benefit from food cost savings.
	Jobs Created	0.379125 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

K-12 LUNCH IMPROVEMENTS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Implementing strategies, policies, or equipment changes in front of house and/or back of house foodservice facilities at K-12 schools to decrease school food waste.	
Diversion Rate	Average Rate	12.4%
	Source(s)	World Wildlife Fund[26]. Costs derived from Clackamas County initiative[27].
	Additional Notes	For this model run, the only change modeled is for milk dispensers, thus that diversion rate was used.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Government | Solution Providers
	Additional Notes	Applied only to K-12 subsector
Applicable Food Types	List	Prepared Foods
	Additional Notes	Addressed at 11.4%. Since this solution addresses plate waste of milk alone, we estimated based on Technomic menu data[38] for Applebees (which is the proxy menu for K-12 because it's a varied menu), that Dairy & eggs makes up 11.4% of the ingredients in K-12 Prepared Foods.
Assumptions	Financial Costs	$4,241 upfront costs per school. .6 ton/year annual savings per school.
	Additional Notes on Costs	Foodservice assumed to bear upfront costs. While the government may ultimately bear some of the costs and benefits, we've chosen to model this for foodservice only.
	Financial benefits	$55.36/ton tip fee savings; $2,005.00/ton wholesale food cost saving (dairy only)
	Additional Notes on Benefits	Foodservice assumed to benefit from avoided landfill tipping fee and food cost savings; solution providers assumed to benefit from upfront costs to foodservice. While the government may ultimately bear some of the costs and benefits, we've chosen to model this for foodservice only.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

PACKAGE DESIGN		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Optimizing food packaging size and design to ensure complete consumption by consumers and avoid residual container waste.	
Diversion Rate	Average Rate	7.5%
	Source(s)	ReFED 2016[18]
	Additional Notes	
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	Date label concerns | Spoiled
	Financially Impacted Stakeholder(s)	Manufacturers | Consumers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$933.33/ton annual costs and no upfront costs.
	Additional Notes on Costs	Manufacturers assumed to bear annual costs.
	Financial benefits	$5,463.95/ton retail food cost savings.
	Additional Notes on Benefits	Consumers assumed to benefit from food cost savings.
	Jobs Created	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

PORTION SIZES		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Creating smaller size options for menu items to reduce over-portioning and plate waste.	
Diversion Rate	Average Rate	35.6%
	Source(s)	Berkowitz et al. 2016[28]. Freedman & Brochado[29].
	Additional Notes	The case studies reported plate waste at the per person level, then measured reduction % with the solution. The cost for the solution is at the facility level. Per person waste streams are converted into facility-level estimates with Technomic data[38].
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Consumers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$500/ton upfront cost and no annual cost.
	Additional Notes on Costs	Foodservice assumed to bear upfront costs. Costs include: communications, staff re-training, and any asset purchases required (e.g. different sized plateware, new printed menus, etc.), recognizing that for the large restaurant chains this effort won't need to be duplicated for each location
	Financial benefits	$55.36/ton tip fee savings; $247.67/ton net revenue (foodservice); $3,474.71 retail food cost saving (consumers)
	Additional Notes on Benefits	Foodservice assumed to benefit from avoided landfill tipping fee and food cost savings. This assumes restaurant operators save wholesale costs of less ingredients, but lose 30% revenue in reduced prices for smaller portions (e.g., a "half order" is sold at 30% less than a full order). Consumers assumed to benefit from 30% in reduced prices. Solution providers benefit from the cost of new plates.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

SMALL PLATES		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Using plates with a smaller diameter in all-you-can-eat dining establishments to provide visual appeal of abundance while minimizing portion sizes to reduce plate waste.	
Diversion Rate	Average Rate	18.6%
	Source(s)	Kallbekken and Sælen[30]. Skov et al. 2013[31]. Cardwell et al. 2019[32].
	Additional Notes	The case studies reported plate waste variously on the per person or per facility level, then measured reduction % with the solution. The cost for the solution is at the facility level. For numbers given at the facility level, no conversion is needed. For numbers given at the per person level, the per person waste streams are converted into facility-level estimates with Technomic data[38]. All results are then averaged. In the event that a study found no reduction with the solution, its numbers for estimating the per facility waste stream may still be used to get a final per facility tonnage for those studies which did find a reduction. Reductions were averaged by their final percentages, including any which did not have a reduction.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Solution Providers
	Additional Notes	Applies only in All You Can Eat settings, assumed for the following subsectors: Limited Service Family Casual (100%), University (60%), Healthcare (33%), Business & Industry (10%), Lodging (33%), Recreation (6%), and Catering (50%).
Applicable Food Types	List	Prepared Foods
	Additional Notes	

SMALL PLATES		
Assumptions	Financial Costs	$7,500/ton upfront cost to replace plateware per facility and no annual cost. The upfront cost is the midpoint of $5k for restaurants and $10k for universities based on data from ReFED 2016[18].
	Additional Notes on Costs	Foodservice assumed to bear cost. Costs include: replacing plateware per facility. The upfront cost is the midpoint of $5k for restaurants and $10k for universities based on data from ReFED 2016[18].
	Financial benefits	$55.36/ton food cost savings; $4,534.00/ton wholesale food cost savings.
	Additional Notes on Benefits	Foodservice assumed to benefit from avoided landfill tipping fee and food cost savings; solution providers assumed to benefit from sale of plateware.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	2	SEE APPENDIX I FOR DATA QUALITY DETAIL

STANDARDIZED DATE LABELS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Standardizing the wording of food label dates to two phrases, one to indicate quality and another for dates which indicate safety risk, in order to reduce consumer misinterpretation. In doing so, also eliminating visible "sell by" dates.	
Diversion Rate	Average Rate	18.7%
	Source(s)	ReFED[33]
	Additional Notes	Diversion rate varies 2.47%-56.20% based on food type
Applicable Sectors & Causes	Farm	
	Manufacturing	Unshipped finished product
	Retail	Date label concerns
	Foodservice	Date label concerns
	Residential	Date label concerns
	Financially Impacted Stakeholder(s)	Manufacturers | Retailers| Foodservice | Consumers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	Fresh Meat & Seafood - 56.2% Dry Goods - 34.00% Breads & Bakery - 21.72% Dairy & Eggs - 15.77% Prepared Foods - 11.96% Produce - 4.93% (Applied to only 20% of produce) Frozen - 2.63a Ready to Drink Beverages - 2.47%
Assumptions	Financial Costs	$16.27/ton annual costs and no upfront costs based on estimate of $10M total/year across industry (ReFED 2016[18] and industry experts).
	Additional Notes on Costs	Manufacturers assumed to bear annual costs.
	Financial benefits	$55.36/ton tip fee savings; $4,301.00/ton wholesale food cost savings (for business sectors) and $5,463.95/ton retail food cost savings (for consumers).
	Additional Notes on Benefits	Manufacturers, retailers and foodservice assumed benefit is the wholesale / ton cost of food addressed. Consumers assumed benefit is the retail / ton cost of food addressed.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

K-12 EDUCATION CAMPAIGNS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Education programs aimed at students to increase awareness and educate future generations about the environmental and economic implications of food waste.	
Diversion Rate	Average Rate	3.0%
	Source(s)	World Wildlife Fund[26]
	Additional Notes	These case study reported plate waste at the person level, then measured reduction % with the solution. Per person waste streams converted to facility-level estimates with Technomic data[38].
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice | Government
	Additional Notes	Applied only to K-12 subsector
Applicable Food Types	List	Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$100/ton annual costs for supplies and staff time and no upfront costs based on an interview with the authors of the WWF report.
	Additional Notes on Costs	Government assume to bear annual costs.
	Financial benefits	$55.36/ton tip fee savings; $2,267/ton wholesale food cost saving.
	Additional Notes on Benefits	Government assumed to benefit from avoided landfill tipping fee and food cost savings.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**1**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

TRAYLESS		
SOLUTION TYPE	**PREVENTION**	
Priority Action Area	Reshape Consumer Environments	
Description	Eliminating trays in all-you-can-eat dining facilities to reduce over-portioning by consumers.	
Diversion Rate	Average Rate	18.6%
	Source(s)	Hackes et al. 1997[34] Mior et al. 2008[35] Freedman and Brochado 2010[29] Thiagarajah and Getty 2013[36]
	Additional Notes	These case studies reported plate waste at the person level, then measured reduction % with the solution. Per person waste streams converted to facility-level estimates with Technomic data[38].
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	Plate waste
	Residential	
	Financially Impacted Stakeholder(s)	Foodservice
	Additional Notes	Applies only in All You Can Eat settings. In addition, many facilities in university and healthcare have already made this change. Therefore, application rate was assumed as follows for the following subsectors: Limited Service Family Casual (100%), University (12%), Healthcare (6.6%), Lodging (33%), Recreation (6%), and Catering (50%).
Applicable Food Types	List	Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$15,000/ton upfront cost and no assumed annual costs, based on the ReFED 2016 model[18].
	Additional Notes on Costs	Foodservice assume to bear upfront cost. Costs include: retrofit tray return systems.
	Financial benefits	$55.36/ton tip fee savings; $4,534/ton wholesale food cost savings.
	Additional Notes on Benefits	Foodservice assumed to benefit from avoided disposal cost and food cost savings.
	Jobs Created	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

Rescue Solutions

Modeling Approach

There are several ways in which our food rescue systems can be strengthened. Doing so can help food donors increase food donations, and can help food rescue organizations receive and handle food more effectively. It's difficult, however, to isolate the impact of any single food rescue solution. For instance, educating potential food donors on liability protections and food safety capabilities in recovery systems might inspire them to donate more food, but if there's not enough storage capacity, they could be limited in what they are able to donate.

Because of the interconnected nature of food rescue solutions, our methodology accounted for them working collectively as a single system. They were modeled as follows:

- First, a total potential donation diversion rate estimate was developed. After several expert interviews, we assumed that a diversion rate of 30% of current surplus was a reasonable estimate of the remaining potential that could be donated.
- The impact of the different solutions were divided within that 30% total according to the breakdown of reasons given for not donating in the Food Waste Reduction Alliance 2016 Survey[37]. For each sector, a weighting factor for each solution was developed from the survey responses to "Barriers to Donation". That weighting factor was then applied to the 30% total to get the diversion rate for each food rescue solution.

Implication of Implementation Order

Note that because rescue solutions come after prevention solutions in the EPA Hierarchy[10], and thus in our Implementation Order, the total amount of food the diversion rates are applied to assume all prevention solutions have already occurred. As we know 100% adoption of prevention solutions is unlikely in the near future, totals for the rescue solutions are likely underestimates.

Tax Savings Approach

The model aims to estimate the "cash tax savings" to businesses of donating food--that is, the actual value saved, rather than the amount of deductions. As businesses' approach to taxes, losses, and charitable deductions is highly complex, the actual value of enhanced tax deductions will vary.

We estimated cash tax savings based off of average retail prices and gross margins. We then discounted the amount to account for some businesses not taking the deductions in cases where it's financially beneficial to take a standard loss deduction instead, as we know this to be prevalent. For farm level donations, we chose to assume no tax benefits. Many farmers have already maxed out their tax deductions and are not able to take advantage of the federal enhanced tax deduction. Additionally, tax credits vary in the handful of states where they're available.

Calculations to estimate Cash Tax Savings were as follows:

Table H6. Cash Tax Savings Assumptions

SECTOR	FARM	MANUFACTURING	RETAIL	FOODSERVICE
Food Sales Price (per Lb)	$0.27	$1.49	$1.88	$7.06
Sales Price Data Source	USDA 2019[7]	Calculated from retail prices	Nielsen IQ 2019[8]	Calculated from Technomic[38], LeanPath[39] data
Margin*	15.50%	39.00%	26.50%	22.00%
Margin Data Source	USDA[40,41]	Investopedia [42]	U.S. Census Bureau[11]	Restaurant 365[43]
Tax Rate	21%	21%	21%	21%
Have they already maxed out their tax deductions?	Yes	No	No	No
Tax Basis (per Lb)	$0.23	$1.07	$1.49	$5.79
Donation Enhancement Cash Tax Savings (per Lb)	$0.00	$0.27	$0.35	$1.35
$ Value of Food to Consumers (per Lb)	$0.27	$1.49	$1.88	$7.06
Traditional Loss Cash Tax Savings (per Lb)	$0.05	$0.22	$0.31	$1.22
Cash Tax Savings of Claiming Enhanced Deduction (per Lb)	$0.00	$0.04	$0.04	$0.13
Cash Tax Savings of Claiming Enhanced Deduction (per Ton)	$0.00	$87.58	$82.72	$267.35
25% Discount to account for companies that don't take benefit	$0.00	$65.68	$62.04	$200.52

Table H7. Rescue Solution Modeling Assumptions

DONATION COORDINATION & MATCHING		
SOLUTION TYPE	**RESCUE**	
Priority Action Area	Strengthen Food Rescue	
Description	Using technology platforms to connect food donors with recovery organizations, simplifying the communication and coordination needed to align surplus product with need and available space.	
Diversion Rate	Average Rate	5.5%
	Source(s)	See description in Rescue Solutions introduction.
	Additional Notes	Manufacturing: 5.4%, Retail: 6.0%, Foodservice: 5.1%
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	Date label concerns | Overproduction
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Cooking issues
	Residential	
	Financially Impacted Stakeholder(s)	Retailers | Foodservice | Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$6.40/ton upfront cost and $243.80/ton annual cost for tech maintenance and update. Upfront cost and tonnage based on data from Feeding America's MealConnect[17,44]. For food donors, $169.17/ton of labor to execute donations, based on assumption of 5 hours per store per week. Varied tax cost for government.
	Additional Notes on Costs	Retailers and foodservice assumed to bear labor costs to donate; government assumed to bear costs of tax incentives; solution providers assumed to bear the cost of software development and maintenance and staffing.
	Financial benefits	$55.36/ton tip fee savings and cash tax savings of $62.04/ton for retailers and $200.52/ton for foodservice. $4431.73/ton consumer savings for donated food;
	Additional Notes on Benefits	Retailers and foodservice assumed to benefit from tax benefits and reduced landfill tipping fee; consumers assumed to benefit from retail cost of food.
	Jobs Created	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

DONATION EDUCATION		
SOLUTION TYPE	**RESCUE**	
Priority Action Area	Strengthen Food Rescue	
Description	Continued education on food safety precautions taken by food rescue organizations, donation liability protections, and other information to increase the rate of donations by manufacturers, retailers, or restaurants.	
Diversion Rate	Average Rate	10.6%
	Source(s)	See description in Rescue Solutions introduction.
	Additional Notes	Farm: 14%, Manufacturing: 14%, Retail: 6.6%, Foodservice: 10.1%
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Fields never harvested (Market dynamics) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	Date label concerns | Overproduction
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Cooking issues
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	

DONATION EDUCATION		
Assumptions	Financial Costs	$87.72/ton annual fixed operating costs (derived from $5,000,000 annual estimate from ReFED 2016[18]), $241.80 annual staffing at organizations ($3.72 jobs per 1000 tons @ $65k per job). For food donors, $169.17/ton of labor to execute donations, based on assumption of 5 hours per store per week. Varied tax cost for government.
	Additional Notes on Costs	Producers, manufacturers, retailers and foodservice assumed to bear cost of labor; government assume to bear the cost of annual costs of education campaign and tax savings; solution providers assumed to bear the cost of annual staffing for outreach at organizations.
	Financial benefits	$55.36/ton tip fee savings and cash tax savings of $65.68 for manufacturers, $62.04/ton for retailers and $200.52/ton for foodservice. $4431.73/ton consumer savings for donated food. No farm tax benefits assumed because they are often not taken.
	Additional Notes on Benefits	Manufacturers, retailers and foodservice assumed to benefit from tax benefits and reduced landfill tipping fees; consumers assumed to benefit from retail cost of food.
	Jobs Created	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	2	SEE APPENDIX I FOR DATA QUALITY DETAIL

DONATION STORAGE HANDLING & CAPACITY		
SOLUTION TYPE	**RESCUE**	
Priority Action Area	Strengthen Food Rescue	
Description	Expanding temperature-controlled food distribution infrastructure (e.g. refrigeration, warehouses) and labor availability to handle (e.g. process, package) additional food donation volume.	
Diversion Rate	Average Rate	4.1%
	Source(s)	See description in Rescue Solutions introduction.
	Additional Notes	Farm, manufacturing, foodservice: 3.6%; Retail: 5.6%
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Fields never harvested (Market dynamics) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	Date label concerns | Overproduction
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Cooking issues
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$1,000/ton upfront cost (derived from $100M national estimate from ReFED 2016 report[18]) and $241.80/ton annual staffing at organizations ($3.72 jobs per 1000 tons @ $65k per job). For food donors, $169.17/ton of labor to execute donations, based on assumption of 5 hours per store per week. Varied tax cost for government.
	Additional Notes on Costs	Producers, manufacturers, retailers and foodservice assumed to bear cost of labor; government assume to bear the cost of tax savings; solution providers assumed to bear the cost of upfront investment.
	Financial benefits	$55.36/ton tip fee savings and cash tax savings of $65.68 for manufacturers, $62.04/ton for retailers and $200.52/ton for foodservice. $4431.73/ton consumer savings for donated food. No farm tax benefits assumed because they are often not taken.
	Additional Notes on Benefits	Manufacturers, retailers and foodservice assumed to benefit from tax savings.
	Jobs Created	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

DONATION TRANSPORTATION		
SOLUTION TYPE	**RESCUE**	
Priority Action Area	Strengthen Food Rescue	
Description	Improving transportation and distribution by increasing small-scale transportation infrastructure, long-haul transport capabilities, or other methods that allow donations to either travel further or allow donations from more businesses.	
Diversion Rate	Average Rate	9.5%
	Source(s)	Berkenkamp and Phillips[45] See description in Rescue Solutions introduction.
	Additional Notes	Farm: 7.0%, Manufacturing: 7.0%, Retail: 12.9%, Foodservice: 11.2%
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Fields never harvested (Market dynamics) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	Buyer rejections | Unshipped finished product
	Retail	Date label concerns | Overproduction
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Cooking issues
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	

DONATION TRANSPORTATION		
Assumptions	Financial Costs	$610/ton in annual transportation and donor location labor and no upfront costs. Costs derived from ReFED 2016 study and solution provider estimates[18]. Costs based on labor operating costs and assume use of existing physical transportation infrastructure. Additional costs to purchase physical capital, e.g. trucks, are not explicitly modeled here. For food donors, $169.17/ton of labor to execute donations, based on assumption of 5 hours per store per week. Varied tax cost for government.
	Additional Notes on Costs	Producer, manufacturers, retailers and foodservice assumed to bear cost of labor; government assumed to bear cost of tax incentives; solution providers assumed to bear upfront and annual transportation and donor location labor costs.
	Financial benefits	$55.36/ton tip fee savings and cash tax savings of $65.68 for manufacturers, $62.04/ton for retailers and $200.52/ton for foodservice. $4431.73/ton consumer savings for donated food. No farm tax benefits assumed because they are often not taken.
	Additional Notes on Benefits	Manufacturers, retailers and foodservice assumed benefit from tax benefits and avoided tipping fees; consumers assumed benefit from retail/ton cost of food received.
	Jobs Created	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	2	SEE APPENDIX I FOR DATA QUALITY DETAIL

DONATION VALUE-ADDED PROCESSING		
SOLUTION TYPE	**RESCUE**	
Priority Action Area	Strengthen Food Rescue	
Description	Building processing infrastructure equipment and facilities to freeze or convert donated or excess food into products such as soups, sauces, and jams, or prepared meals.	
Diversion Rate	Average Rate	10.0%
	Source(s)	ReFED 2016 Report[18]
	Additional Notes	In the 2016 model, value-added processing was modeled with a high diversion rate of 20% based on guidance from the 2016 Advisory Council. In this analysis, we used Deloitte's low estimate - half this rate - to be conservative.
Applicable Sectors & Causes	Farm	Packhouse losses (Not marketable) | Fields never harvested (Market dynamics) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable)
	Manufacturing	
	Retail	
	Foodservice	
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Consumers | Solution Providers
	Additional Notes	
Applicable Food Types	List	Produce
	Additional Notes	Assumes 50% because only applicable for certain types of produce.
Assumptions	Financial Costs	$720/ton upfront costs and $268.80/ton annual costs including labor. Upfront costs are based on an investment made by one food bank's investment in facilities and equipment. Annual costs are based on the 2016 model.
	Additional Notes on Costs	Solution providers expected to bear upfront and annual costs.
	Financial benefits	$3132.44/ton consumer savings for donated food. No tax savings assumed as this solution currently applied to farm only, and farms typically do not take advantage of the enhanced tax deduction.
	Additional Notes on Benefits	Consumers assumed to benefit from tax savings.
	Jobs	3.72 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**2**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

Recycling Solutions

In 2016, ReFED commissioned Resource Recycling Systems (RRS) to conduct the analysis of recycling solutions for the original 2016 ReFED Roadmap[18]. To do this, RRS analyzed the top 50 Metropolitan Statistical Areas (MSAs) considering tip fees, labor costs, energy costs, and other factors. From that, they modeled the cost, revenue, and diversion potential for different recycling solutions. Diversion rates were estimated for what would be a realistic potential given the various local factors of each MSA.

ReFED and Deloitte had several discussions while developing the solutions assumptions and it was their expert opinion that the base analysis still holds. Therefore, most of the diversion rate, cost, and benefit assumptions are the same.

The description of the RRS analysis can be found in Appendix J and on pages 43-48 of the 2016 ReFED Roadmap Technical Appendix[18].

Table H8. Recycling Solution Modeling Assumptions

CENTRALIZED ANAEROBIC DIGESTION		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	Industrial-scale collection of food waste that undergoes the anaerobic digestion process at a dedicated central location, typically operated by a dedicated energy generator.	
Diversion Rate	Average Rate	11.68%
	Source(s)	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs.
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Packhouse losses (Inedible)
	Manufacturing	Buyer rejections | Unshipped finished product | Byproducts & production line waste
	Retail	Date label concerns | Overproduction | Food safety recall | Cooking issues | Equipment issues | Handling errors | Other | Spoiled | Trimmings & byproducts
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Plate waste | Food safety recall | Cooking issues | Equipment issues | Handling errors | Other | Spoiled | Trimmings & byproducts
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Too little to save | Food safety recall | Left out too long | Cooking issues | Other | Spoiled | Considered inedible | Inedible parts
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Consumers | Government | Solution Providers
	Additional Notes	

CENTRALIZED ANAEROBIC DIGESTION		
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$493.98/ton upfront costs, $58.18/ton operating costs, and $77.29/ton collection costs. This estimate is based on an average size of an AD facility being 50,000 tons / year, weighted average of operating costs for the top producing MSAs, and RRS financing assumptions.
	Additional Notes on Costs	Government assumed to bear collection costs; solution providers assumed to bear upfront and operating costs.
	Financial benefits	$86.07/ton avoided disposal costs and $133.12/ton in revenue generated. This is based on a weighted average of top MSAs revenue. This revenue was calculated using base tip fees, natural gas costs, and compost value in the top producing MSAs as well as RRS proprietary data. Avoided disposal costs differ from landfill disposal fees in prevention models, since the RRS model assumed a collection cost reduction, and not just cost avoidance.
	Additional Notes on Benefits	Government benefits from avoided disposal costs, solution providers assumed to benefit from revenue generated.
	Jobs	1.026 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	SEE APPENDIX I FOR DATA QUALITY DETAIL

CENTRALIZED COMPOSTING		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	Large scale composting facilities that process commercial, residential, institutional, and industrial food waste, managed either by third party waste and compost companies or solid waste agencies.	
Diversion Rate	Average Rate	31.2%
	Sources	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs. This is based on a weighted average for Windrow and ASP composting.
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Packhouse losses (Inedible)
	Manufacturing	Buyer rejections | Unshipped finished product | Byproducts & production line waste
	Retail	Date label concerns | Overproduction | Cooking issues | Equipment issues | Handling errors | Other | Spoiled | Trimmings & byproducts
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Plate waste | Cooking issues | Equipment issues | Handling errors | Other | Spoiled | Trimmings & byproducts
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Too little to save | Food safety recall | Left out too long | Cooking issues | Other | Spoiled | Considered inedible | Inedible parts
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice | Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	

CENTRALIZED COMPOSTING		
Assumptions	Financial Costs	$222.50/ton in upfront costs, $20.34/ton in annual operating costs and $57.90/ton in collection costs. This is based on a weighted average of Windrow and ASP composting, assuming a processing capacity of up to 40,000 tons annually. The facility costs include maintenance and operating costs. The operating costs include labor costs.
	Additional Notes on Costs	Government assumed to bear collection costs; solution providers assumed to bear upfront and annual operating costs.
	Financial benefits	$68.71/ton in avoided disposal costs and $53.61/ton in revenue generated. The avoided disposal costs differs from landfill disposal fees in prevention models, since the RRS model assumed a collection cost reduction, and not just cost avoidance. The revenue generated is the weighted averaged of the revenue generated for the top MSAs for both Windrow and ASP composting.
	Additional Notes on Benefits	Government assumed to benefit from avoided disposal costs; solution providers assumed to benefit from revenue generated.
	Jobs	1.03 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	SEE APPENDIX I FOR DATA QUALITY DETAIL

CO-DIGESTION AT WASTEWATER TREATMENT PLANTS		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	A process whereby energy-rich organic waste materials (e.g. Fats, Oils, and Grease (FOG) and/or food scraps) are added to dairy or wastewater digesters with excess capacity.	
Diversion Rate	Average Rate	15.56%
	Sources	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs.
Applicable Sectors & Causes	Farm	
	Manufacturing	Buyer rejections | Unshipped finished product | Byproducts & production line waste
	Retail	Date label concerns | Handling errors | Spoiled | Trimmings & byproducts
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Plate waste | Food safety recall | Cooking issues | Handling errors | Spoiled | Trimmings & byproducts
	Residential	Date label concerns | Didn't want leftovers | Food safety recall | Left out too long | Cooking issues | Spoiled | Considered inedible
	Financially Impacted Stakeholder(s)	Government
	Additional Notes	
Applicable Food Types	List	Ready to drink beverages | Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Frozen | Prepared Foods
	Additional Notes	

CO-DIGESTION AT WASTEWATER TREATMENT PLANTS		
Assumptions	Financial Costs	$450.00/ton upfront costs and $52.76/ton annual costs. This is based on the weighted average of operating costs for the top producing MSAs and RRS financing assumptions.
	Additional Notes on Costs	Government assumed to bear upfront and annual costs. There are no collection costs for generators (food businesses and consumers) for this solution because it is assumed that waste is sent to the facility through existing sewage systems rather than via trucks
	Financial benefits	$104.37/ton in avoided disposal and collection costs and $32.59/ton in revenue generated. This is based on a weighted average of the base tip fees for the top MSAs, and RRS assumptions on the collection cost offsets. This differs from landfill disposal fees in prevention models, since the RRS model assumed a collection cost reduction, and not just cost avoidance.
	Additional Notes on Benefits	Government assumed to benefit from avoided disposal and collection costs and revenue generation of CNG, either direct electricity sales or conversion to CNG for use by onsite trucks.
	Jobs	1.026 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	3	SEE APPENDIX I FOR DATA QUALITY DETAIL

COMMUNITY COMPOSTING		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	Food waste from homes and small businesses diverted to small, community or neighborhood-level compost facilities.	
Diversion Rate	Average Rate	1.04%
	Sources	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Too little to save | Food safety recall | Left out too long | Cooking issues | Other | Spoiled | Considered inedible
	Financially Impacted Stakeholder(s)	Consumers | Government | Solution Providers
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dry Goods | Produce
	Additional Notes	
Assumptions	Financial Costs	$695.98/ton upfront costs and $51.57/ton annual costs. $40/ton in fees. This estimate is based on RRS proprietary data and assumptions.
	Additional Notes on Costs	Consumers assumed to bear some cost in fees; Solution providers assumed to bear upfront and annual costs.
	Financial benefits	$105.36/ton in tip fee savings; $40/ton in revenue generated. This is based on RRS proprietary data and assumptions.
	Additional Notes on Benefits	Government assumed to benefit from reduced residential collection costs; solution providers assumed to benefit from revenue generated.
	Jobs	1.03 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

HOME COMPOSTING		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	Maintaining a small compost pile or bin at the residence level (e.g. home, apartment).	
Diversion Rate	Average Rate	1.16%
	Sources	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs.
Applicable Sectors & Causes	Farm	
	Manufacturing	
	Retail	
	Foodservice	
	Residential	Date label concerns | Didn't taste good | Didn't want leftovers | Too little to save | Food safety recall | Left out too long | Cooking issues | Other | Spoiled | Considered inedible
	Financially Impacted Stakeholder(s)	Consumers | Government
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dry Goods | Produce
	Additional Notes	
Assumptions	Financial Costs	$44.32/ton for upfront costs and $36/ton for annual education and outreach. This estimate is based on RRS proprietary data and assumptions.
	Additional Notes on Costs	Consumers assumed to bear upfront equipment costs since this solution is implemented by households. The investment cost is low compared to other recycling solutions, because this solution requires little technology to implement (e.g. bucket or backyard space to create pile). Government assumed to bear annual costs for education and outreach.
	Financial benefits	$105.36/ton for annual benefits based off of landfill tipping fee. This is based on a weighted average of base tip fees plus residential collection costs for the top producing MSAs. The tip fee reflects the estimated $50 residential collection costs avoided. It is assumed that there will be $0 revenue generated.
	Additional Notes on Benefits	Government assumed to benefit from reduced residential collection costs and avoided tip fees.
	Jobs	0 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

LIVESTOCK FEED		
SOLUTION TYPE	**RECYCLING**	
Priority Action Area	Recycle Anything Remaining	
Description	Diverting material from the food supply chain (directly or after minimal processing) to use as feed for livestock.	
Diversion Rate	Average Rate	0.30%
	Sources	ReFED 2016 Report (based on analysis by RRS)[18]
	Additional Notes	Modeled from analysis of the top producing MSAs.
Applicable Sectors & Causes	Farm	Buyer rejections | Packhouse losses (Not marketable) | Left behind after harvest (Inedible) | Left behind after harvest (Marketable) | Left behind after harvest (Not marketable) | Packhouse losses (Inedible)
	Manufacturing	Buyer rejections | Unshipped finished product | Byproducts & production line waste
	Retail	Date label concerns | Overproduction | Cooking issues | Handling errors | Other | Spoiled | Trimmings & byproducts
	Foodservice	Date label concerns | Catering overproduction | Overproduction | Plate waste | Cooking issues | Handling errors | Other | Trimmings & byproducts
	Residential	
	Financially Impacted Stakeholder(s)	Producers | Manufacturers | Retailers| Foodservice
	Additional Notes	
Applicable Food Types	List	Breads & Bakery | Dairy & Eggs | Dry Goods | Fresh Meat & Seafood | Produce | Prepared Foods
	Additional Notes	
Assumptions	Financial Costs	$139.34/ton for upfront costs, $92.44/ton for annual cost. This is based on proprietary RRS data.
	Additional Notes on Costs	Producers, Manufacturers, Retail and Foodservice assumed to bear upfront and annual costs.
	Financial benefits	$55.36/ton for tip fee savings; $23.55/ton revenue generated. The revenue generated is based on proprietary RRS data.
	Additional Notes on Benefits	Producers, Manufacturers, Retail and Foodservice assumed to benefit from cost savings and revenue generated.
	Jobs	1.5165 jobs/ton were assumed for this solution.
DATA QUALITY SCORE	**3**	**SEE APPENDIX I FOR DATA QUALITY DETAIL**

Appendix I: Data Quality Rubric

Data in the field of food waste reduction is challenging. In many cases, only case studies or anecdotal evidence is available, while in others third-party, peer-reviewed academic studies have been performed or many proof points are available. In modeling our solutions, we aimed to get the best data we could, but recognize that significant assumptions and extrapolations are involved. We therefore developed a Data Quality Rubric to rank our sources and how we were using them.

To ensure full transparency in this analysis, we have included a confidence score of 1-5 for each solution's data. These confidence scores were obtained through a quantitative assessment that evaluated the relative quality of each solution's data. Each solution's data inputs were scored from 1-5 across four dimensions*:

- **Credibility of Sources:** This metric evaluates the validity of the data, measuring if the information is based on ReFED assumptions, published industry implementation data, or a combination thereof.
- **Number of Sources:** This metric evaluates the breadth and depth of the data used, only earning a 5 if the data represents a majority of the industry.
- **Geographic Coverage:** This metric evaluates if the data was obtained from entirely United States sources, and if so, if the data was provided from national US operations or regional case studies.
- **Timing:** This metric evaluates the relevance of the data, only earning a 5 if the data is less than a year old.

Once each dimension was individually scored, the scores were averaged, resulting in a final data quality score for each solution. This is intended to provide clarity and to ensure ReFED is providing a faithful representation of available data.

Table I1. Data Quality Rubric

CRITERIA	1	2	3	4	5
Credibility of Sources	All data sources are ReFED assumptions	All data sources are a combination of expert interviews, Advisory Council input, and ReFED assumptions without industry data to support	Data sources are a combination of industry data on implementation, expert interviews, and ReFED assumptions	All data sources are a combination of expert interviews and industry implementation data (data source may be undisclosed) with no assumptions	Data sources are a combination of published and verified data (either academic, government, or NGO report) and industry data
Number of Sources	Only 1 data source is used, or all sources are ReFED assumptions	2 data sources are combined	3 distinct data sources are combined	4 data sources are combined	5 or more data sources are combined and represent a majority of the industry

CRITERIA	1	2	3	4	5
Geographic Coverage	Data provided entirely from non-US operations, and operations vary significantly for this solution as compared to in the US, or all sources are ReFED assumptions	Data provided entirely from non-US operations, and there are similarities in operations between non-US and US operations	Data provided represents a mix of Us and non-US operations	Data provided is from US operations, but is limited to a few regions	Data provided is from national US operations
Timing	Data source is 10+ years old, or all sources are ReFED assumptions	Data source is 8-9 years old	Data source is 5-7 years old	Data source is 2-4 years old	Data source is no more than 1 year old and is the most recently available study

Table I2. Data Quality Scores

*Note that six of the solutions have not yet been scored, these are marked with an asterisk.

SOLUTION	FINAL DATA QUALITY SCORE (AVG OF SCORES)	CREDIBILITY OF SOURCES	NUMBER OF SOURCES	GEOGRAPHIC COVERAGE	TIMING
Active & Intelligent Packaging	**2.3**	2	1	4	3
Assisted Distressed Sales*					
Buffet Signage	**2.8**	2	2	3	4
Buyer Specification Expansion	**2.3**	2	1	4	3
Centralized Anaerobic Digestion	**3.8**	3	4	5	3
Centralized Composting	**3.8**	3	4	5	3
Co-digestion at Wastewater Treatment Plants	**3.8**	3	4	5	3
Community Composting	**3.5**	3	3	4	4
Consumer Education Campaigns	**2.8**	3	2	3	3
Decreased Minimum Order Quantity	**3.1**	3	1	5	4

SOLUTION	FINAL DATA QUALITY SCORE (AVG OF SCORES)	CREDIBILITY OF SOURCES	NUMBER OF SOURCES	GEOGRAPHIC COVERAGE	TIMING
Decreased Transit Time	3.1	3	1	5	4
Donation Coordination & Matching	3.1	2	1	5	5
Donation Education	2.4	2	1	3	3
Donation Storage Handling & Capacity	3	2	1	5	4
Donation Transportation	2.8	2	1	4	4
Donation Value-Added Processing	2.5	2	1	4	3
Dynamic Pricing	3.6	4	2	5	5
Enhanced Demand Planning	3.6	4	1	4	5
First Expired First Out	3.1	3	1	5	4
Gleaning*					
Home Composting	3.8	3	3	5	4
Imperfect & Surplus Produce Channels*					
Increased Delivery Frequency	3.1	3	1	5	4
Intelligent Routing	3.1	3	1	5	4
K-12 Education Campaigns*					
K-12 Lunch Improvements	3	3	1	4	4
Livestock Feed	3.8	3	4	5	3
Manufacturing Byproduct Utilization (Upcycling)*					
Manufacturing Line Optimization	2	2	1	3	2
Markdown Alert Applications	3	3	2	2	4
Meal Kits*					
Minimized On Hand Inventory	3.1	3	1	5	4
Package Design	2.1	2	1	3	2

SOLUTION	FINAL DATA QUALITY SCORE (AVG OF SCORES)	CREDIBILITY OF SOURCES	NUMBER OF SOURCES	GEOGRAPHIC COVERAGE	TIMING
Partial Order Acceptance	**3.1**	3	1	5	4
Portion Sizes	**2.8**	2	2	4	3
Reduced Warehouse Handling	**3.1**	3	1	5	4
Small Plates	**3.3**	3	3	3	4
Standardized Date Labels	**3.8**	3	2	5	5
Temperature Monitoring (Foodservice)*					
Temperature Monitoring (Pallet Transport)	**3.3**	3	1	5	4
Trayless	**3.1**	4	2	4	3
Waste Tracking (Foodservice)	**4**	4	2	5	5

Appendix J: 2016 ReFED Roadmap RRS Analysis

The following is an excerpt of pages 43-48 of the 2016 ReFED Roadmap Technical Appendix[18]:

Recycling Solutions Methodology
The economics of food waste recycling are complex and sensitive to local variation. ReFED modeled these variations for the 50 largest metropolitan areas (using Combined Statistical Area data), since they generate roughly of all food waste nationwide. Once tonnage was generated for each county, this data was imported into a GIS and summed at the CBSA level, and then combined with datasets for statewide policies, tip fees, labor rates, energy prices, relative land values, and the value of finished compost.

Economic modeling was done in three stages:

1. Determine baseline cost model structure for each solution.
2. Determine amounts of food waste able to be diverted to each solution.
3. Assign food waste to key solutions on an individual MSA basis based on favorable economics.

Recycling Cost Model Structure
Detailed operational models were constructed for windrow composting, aerated static pile composting, anaerobic digestion and WRRF with AD. Facilities were assumed to have an average processing capacity of 40k tons per year. While most operations are significantly smaller today, reaching these economies of scale is important to demonstrate cost effectiveness on a per-ton basis. The economic modeling accounted for all facility and equipment costs, operations and maintenance, labor expenses, expected revenues, and other avoided costs, using both public and proprietary datasets. Capital expenditures were fixed across all locations, but operational costs varied according to local prices. Properties were assumed to be leased, and leasing rates were varied by a cost of land index at the state level. A separate model was constructed for the capital and operational costs of collection for both residential and business generators.

For on-site solutions, community and home composting, and animal feed, a nation-wide approach was used to model the economic potential, costs, and benefits, as the local complexities are significantly fewer.

The figure below outlines the results of the Roadmap MSA-level estimate of food waste currently wasted by landfilling, and the amount of food waste diverted through recycling in those cities. This estimate was built by first estimating existing waste at the county level for each of the main stakeholder groups, and then aggregating to the MSA level. It is important to note that given that local environments vary drastically, the Roadmap did not attempt to analyze how individual cities adoption rates of different technologies would roll out and each technology was analyzed independently. A capture rate of 100% indicates that a city has multiple recycling technologies that could be very successful in the local environment. The capture rate v. baseline shows the amount of additional food waste diverted through the Roadmap versus the current waste levels sent to landfill.

Note: This analysis can be assumed to be illustrative of what may occur. However, it was completed at a macro level and uses national datasets (versus in-depth regional assessments), and as a result local roll-out realities are likely to differ.

Figure 19: Top 20 Metropolitan Regions by Existing Annual Food Waste Levels and Roadmap Diversion Potential

METRO AREA	ANNUAL FOOD SCRAPS SENT TO LANDFILL (TONS PER YEAR)	ROADMAP WASTE DIVERTED FROM LANDFILL (TONS PER YEAR)	ADDITIONAL CAPTURE V. BASELINE
New York-Newark-Jersey City, NY-NJ-PA	3,048,559	1,066,996	35%
Los Angeles-Long Beach-Anaheim, CA	2,104,863	947,188	45%
Chicago-Naperville-Elgin, IL-IN-WI	1,524,136	533,448	35%
Dallas-Fort Worth-Arlington, TX	1,011,780	20,236	2%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	979,703	538,837	55%
Houston-The Woodlands-Sugar Land, TX	932,624	18,652	2%
Washington-Arlington-Alexandria, DC-VA-MD-WV	910,779	273,231	30%
Miami-Fort Lauderdale-West Palm Beach, FL	905,243	18,105	2%
Boston-Cambridge-Newton, MA-NH	882,397	882,397	100%
Atlanta-Sandy Springs-Roswell, GA	830,888	16,618	2%
Phoenix-Mesa-Scottsdale, AZ	676,929	13,539	2%
Detroit-Warren-Dearborn, MI	649,130	12,983	2%
San Francisco-Oakland-Hayward, CA	625,799	312,899	50%
Riverside-San Bernardino-Ontario, CA	610,839	335,962	55%
Minneapolis-St. Paul-Bloomington, MN-WI	556,357	250,361	50%
Seattle-Tacoma-Bellevue, WA	541,367	541,367	100%
San Diego-Carlsbad, CA	509,917	254,958	50%
Baltimore-Columbia-Towson, MD	466,174	186,470	40%
Tampa-St. Petersburg-Clearwater, FL	442,807	8,856	2%
St. Louis, MO-IL	427,454	136,785	32%
Top 20 Cities TOTAL	**18,637,745**	**6,369,888**	**34% (wght avg)**

Determining Regional Recycling Diversion Potential

In order to calculate the diversion potential for each solution, a matrix was designed to assign portions of the waste stream to different technologies based on the presence of significant policy drivers and likelihood, feasibility, and cost effectiveness of adoption. A weighted average of the uptake rate was determined based on local categorization by general policy categories - for instance does the state have a landfill ban on yard waste or recycling mandates. An overall recycling rate projection was assigned to each MSA, providing an estimate of the total amount of waste expected to be captured.

For each solution, regional factors were considered including labor rates and operating cost drivers, variations in end market material value, collection costs, and avoided disposal costs. MS from lowest to highest total system cost per ton of waste diverted. There were five main variables that fed into the total system cost calculation: (i) avoided disposal costs, (ii) cost of collection/logistics, (iii) processing capital cost, (iv) processing operational costs, and (v) processing revenue streams. Figures 20 and 21 below

show the top 20 MSAs by projected system benefit/cost on a per-ton basis for composting systems and AD, respectively.

Each MSA was assigned a separate percentage of food waste diversion for each of the major solutions (Centralized Compost, AD, and WRRF) in a way that maximized total benefit and minimized cost. Then weighted averages of each cost and benefit stream were calculated from the chosen MSAs and applied to the captured tonnage. These values were then utilized in a 10-year financial model to calculate the net present value and the environmental impacts of each solution.

Figure 20: Top 20 Metropolitan Regions by Highest Total Benefit per Ton Waste Diverted for Centralized Composting

METRO AREA	TOTAL BENEFIT (COST) $ PER TON	
	ASP COMPOSTING	WINDROW COMPOSTING
Hartford-West Hartford-East Hartford, CT	$29	$49
Portland-Vancouver-Hillsboro, OR-WA	$25	$44
Providence-Warwick, RI-MA	$16	$36
Boston-Cambridge-Newton, MA-NH	$16	$35
Seattle-Tacoma-Bellevue, WA	$16	$35
New York-Newark-Jersey City, NY-NJ-PA	$12	$32
Minneapolis-St. Paul-Bloomington, MN-WI	-$4	$16
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	-$9	$11
Pittsburgh, PA	-$11	$9
Milwaukee-Waukesha-West Allis, WI	-$16	$3
Chicago-Naperville-Elgin, IL-IN-WI	-$17	$3
Buffalo-Cheektowaga-Niagara Falls, NY	-$19	$0
Indianapolis-Carmel-Anderson, IN	-$19	$0
Baltimore-Columbia-Towson, MD	-$24	-$5
San Francisco-Oakland-Hayward, CA	-$25	-$5
Rochester, NY	-$25	-$6
San Jose-Sunnyvale-Santa Clara, CA	-$26	-$7
Los Angeles-Long Beach-Anaheim, CA	-$28	-$9
Tampa-St. Petersburg-Clearwater, FL	-$29	-$10
Orlando-Kissimmee-Sanford, FL	-$30	-$11

Composting systems were modeled based on regional economics of windrow and ASP systems, and tonnage was attributed to each technology based on the metropolitan regions where system economics were either positive or very near breakeven. The overall split was 79% windrow and 21% ASP. On average, the modeling showed that windrow technologies have a $20 per ton higher system net economic benefit than ASP. This data was then aggregated in order to generate the overall Centralized Composting solution results.

Figure 21: Top 20 Metropolitan Regions by Highest Total Benefit per Ton Waste Diverted for AD

METRO AREA	TOTAL BENEFIT (COST) $ PER TON
	ANAEROBIC DIGESTION
New York-Newark-Jersey City, NY-NJ-PA	$44
Buffalo-Cheektowaga-Niagara Falls, NY	$40
Rochester, NY	$36
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$22
Portland-Vancouver-Hillsboro, OR-WA	$20
Hartford-West Hartford-East Hartford, CT	$19
Seattle-Tacoma-Bellevue, WA	$12
Providence-Warwick, RI-MA	$7
Boston-Cambridge-Newton, MA-NH	$7
Washington-Arlington-Alexandria, DC-VA-MD-WV	-$4
Minneapolis-St. Paul-Bloomington, MN-WI	-$19
Las Vegas-Henderson-Paradise, NV	-$22
Pittsburgh, PA	-$26
Tampa-St. Petersburg-Clearwater, FL	-$26
Louisville/Jefferson County, KY-IN	-$30
Milwaukee-Waukesha-West Allis, WI	-$31
Chicago-Naperville-Elgin, IL-IN-WI	-$32
Phoenix-Mesa-Scottsdale, AZ	-$33
Indianapolis-Carmel-Anderson, IN	-$34
Baltimore-Columbia-Towson, MD	-$37

For anaerobic digestion, the main driver of total system cost-benefit is the cost of disposal, or tipping fee. Other key drivers included natural gas prices, compost prices, and labor costs.

Figure 22 below shows the top 50 recycling-MSA pairings with the highest system benefit per ton is listed (out of window composting, ASP composting, anaerobic digestion, and WRRF with AD). The top 5 most cost effective solutions are all modeled to be an expansion of AD at WRRFs in the Northeast, due to high value of energy, high value of compost, high value of avoided disposal costs, and relatively low incremental capital and operating cost.

Figure 22: Top 50 Metropolitan Regions by Highest Total Benefit - Compost, AD, WRRF

TOP SOLUTION	MSA	SYSTEM BENEFIT (COST) PER TON
WRRF	Hartford-West Hartford-East Hartford, CT	$65.98
WRRF	Rochester, NY	$60.28
WRRF	Boston-Cambridge-Newton, MA-NH	$59.55
WRRF	Providence-Warwick, RI-MA	$59.46
WRRF	Buffalo-Cheektowaga-Niagara Falls, NY	$58.77
WRRF	Portland-Vancouver-Hillsboro, OR-WA	$55.26
Windrow	Hartford-West Hartford-East Hartford, CT	$48.98
WRRF	Seattle-Tacoma-Bellevue, WA	$45.01
Windrow	Portland-Vancouver-Hillsboro, OR-WA	$44.12
AD	New York-Newark-Jersey City, NY-NJ-PA	$43.52
WRRF	New York-Newark-Jersey City, NY-NJ-PA	$42.92
AD	Buffalo-Cheektowaga-Niagara Falls, NY	$39.59
AD	Rochester, NY	$36.49
Windrow	Providence-Warwick, RI-MA	$35.70
Windrow	Boston-Cambridge-Newton, MA-NH	$35.51
Windrow	Seattle-Tacoma-Bellevue, WA	$35.25
WRRF	Pittsburgh, PA	$35.21
WRRF	Minneapolis-St. Paul-Bloomington, MN-WI	$34.13
WRRF	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$33.85
Windrow	New York-Newark-Jersey City, NY-NJ-PA	$31.69
ASP	Hartford-West Hartford-East Hartford, CT	$29.39
WRRF	Sacramento--Roseville--Arden-Arcade, CA	$25.69
ASP	Portland-Vancouver-Hillsboro, OR-WA	$25.05
WRRF	San Jose-Sunnyvale-Santa Clara, CA	$23.46
WRRF	Riverside-San Bernardino-Ontario, CA	$22.40
AD	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$21.69
AD	Portland-Vancouver-Hillsboro, OR-WA	$19.89
AD	Hartford-West Hartford-East Hartford, CT	$18.98
WRRF	Richmond, VA	$18.96

TOP SOLUTION	MSA	SYSTEM BENEFIT (COST) PER TON
ASP	Seattle-Tacoma-Bellevue, WA	$16.18
ASP	Providence-Warwick, RI-MA	$16.08
ASP	Boston-Cambridge-Newton, MA-NH	$15.89
WRRF	Indianapolis-Carmel-Anderson, IN	$15.83
Windrow	Minneapolis-St. Paul-Bloomington, MN-WI	$15.72
WRRF	Orlando-Kissimmee-Sanford, FL	$14.72
WRRF	Washington-Arlington-Alexandria, DC-VA-MD-WV	$13.52
ASP	New York-Newark-Jersey City, NY-NJ-PA	$12.48
AD	Seattle-Tacoma-Bellevue, WA	$11.58
WRRF	Milwaukee-Waukesha-West Allis, WI	$11.47
Windrow	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$10.57
WRRF	San Francisco-Oakland-Hayward, CA	$8.85
WRRF	Baltimore-Columbia-Towson, MD	$8.61
Windrow	Pittsburgh, PA	$8.58
WRRF	San Diego-Carlsbad, CA	$8.54
WRRF	Los Angeles-Long Beach-Anaheim, CA	$7.23
AD	Providence-Warwick, RI-MA	$7.20
WRRF	Chicago-Naperville-Elgin, IL-IN-WI	$7.17
AD	Boston-Cambridge-Newton, MA-NH	$7.02
WRRF	Tampa-St. Petersburg-Clearwater, FL	$6.57
WRRF	Detroit-Warren-Dearborn, MI	$5.98