A ROADMAP TO REDUCE U.S. FOOD WASTE BY 20 PERCENT

2016

ReFED | Rethink Food Waste *Through Economics and Data*

CONTENTS

FOREWORD

The Journey Starts Now

By 2050, it is estimated that the Earth's population will top 9 billion. This growing population will undeniably stress our food systems, natural resources, and ecosystems. But consider this: Currently, we waste up to 40% of our food globally. In the United States, this equals roughly 400 pounds annually for every American. Meanwhile, one in seven Americans are food insecure.

These stunning facts — partnered with seeing waste occur firsthand through our work with our operating farm and the restaurants and grocery stores it services — really brought this issue home for us. This prompted us as philanthropists and a family concerned about healthy communities and ecological sustainability to ask our team to explore the topic of wasted food.

Through our family foundation, we have been focused on solving large-scale environmental issues with market-based solutions since 2001. We started by looking at how funding solutions to climate change, both through grants and impact investments, can play an important role in transitioning our society to a low-carbon economy.

Over the past 15 years, we've seen how climate change and resource utilization are closely linked, and food is one of the most important resources in that equation. This puts food waste squarely at the center of many global challenges. Reducing food waste would have a game-changing impact on natural resources depletion and degradation, food insecurity, national security, and climate change. As one of the largest economies and agricultural producers in the world, we believe the United States has a major role to play in setting an example and contributing to significant food waste reduction.

Last year, we approached like-minded philanthropists to join us in launching ReFED: "Rethinking Food Waste through Economics and Data: A Roadmap to Reduce Food Waste" to map a path for action and solutions. We knew from the start that a multi-stakeholder approach was needed so we invited leading food businesses, environmental and hunger organizations, investors, policymakers, and innovators to join the effort.

The economic analysis and research we undertook revealed exciting news: Food waste is a solvable problem. But four priority actions are needed to reach significant reductions. First, we must galvanize hundreds of millions of dollars of new catalytic funding. Second, policymakers must make pragmatic changes to tax incentives, safety regulations, and permitting procedures to support healthy market solutions. Third, America must unleash its spirit of innovation to develop new technology and business-model innovations. Finally, a sweeping education and awareness campaign is needed to change behavior both among consumers and employees of food businesses.

This Roadmap report is a guide and a call to action for us to work together to solve this problem. Businesses can save money for themselves and their customers. Policymakers can unleash a new wave of local job creation. Foundations can take a major step in addressing environmental issues and hunger. And innovators across all sectors can launch new products, services, and business models. There will be no losers, only winners, as food finds its way to its highest and best use.

The Roadmap is just the beginning. In order to succeed, we need to crowdsource even more information and solutions. ReFED has welcomed input at every stage and encourages input now. After reading the Roadmap, we encourage you to visit refed.com, dig deeper into our analysis, and send us your ideas and feedback.

This is a defining moment for us all. Let's start the journey now.

Thank you,

Betsy and Jesse Fink
Trustees
The Fink Family Foundation

We are grateful to everyone who contributed to the creation of ReFED and this Roadmap, especially our philanthropic co-funders and Advisory Council members. We would also like to strongly acknowledge the pioneers in food waste reduction who have dedicated time and great passion to this issue. Many have worked for years at the grassroots, national, and international levels to pave the way for this effort. And we'd like to thank you, the reader, for engaging in this issue. Together, with the steps laid out in this report, we can cut food waste by 20% with actions that are feasible today, which will set us on the path to meet the U.S. government's target of a 50% reduction in food waste by 2030.

The Roadmap was made possible with the generous support from the following foundations:

Agua Fund, Inc.

Ahearn Family Foundation

Atticus Trust

The Claneil Foundation

the David & Lucile Packard Foundation

The Fink Family Foundation

GRACE Communications Foundation

Henry P. Kendall Foundation

IMPACTASSETS

The John Merck Fund

Local Economies Project

The New World Foundation

The Lumpkin Family Foundation

The Overbrook Foundation

Walmart Foundation

ABOUT ReFED

ReFED is a collaboration of over 30 business, nonprofit, foundation, and government leaders committed to reducing food waste in the United States. ReFED seeks to unlock new philanthropic and investment capital, along with technology, business, and policy innovation, which is projected to catalyze tens of thousands of new jobs, recover billions of meals annually for the hungry, and reduce national water use and greenhouse gas emissions.

ReFED was formed in early 2015 to create a Roadmap to Reduce U.S. Food Waste, the first ever national economic study and action plan driven by a multi-stakeholder group committed to tackling food waste at scale. Recently, a number of initiatives have raised awareness of the magnitude of the problem. The Roadmap is designed to fill the gap between awareness and action by creating transparency in the waste flows, costs, and opportunities of a more e□cient food system achieved by preventing, recovering, and recycling food waste.

The Roadmap is the result of a collaborative stakeholder process, including input and support from ReFED members and over 80 additional industry experts.

THE ROADMAP WAS DEVELOPED IN PARTNERSHIP WITH

NRDC RRS Closed Loop Fund Deloitte. MissionPoint Partners

ReFED STEERING COMMITTEE AND ADVISORY COUNCIL

The ReFED Steering Committee and Advisory Council played a critical role in driving the overall strategic direction of the Roadmap, ensuring it accurately represented the current food waste landscape, analyzed relevant and practical solutions, and resulted in actionable insights for all stakeholders.

Each ReFED Advisory Council and Steering Committee member contributed unique perspectives and expertise to the Roadmap, providing a holistic view of the challenges and opportunities for food waste reduction.

ReFED STEERING COMMITTEE

Dana Gunders, Natural Resources Defense Council, Sta Scientist

Eliza Brown, Atticus Trust, Trustee

Jesse Fink, The Fink Family Foundation, Trustee

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Waste Management
Federal Public Affairs Director

ReFED TEAM

ReFED TEAM

ReFED is led by Sarah Vared, Interim Director of ReFED and Principal at MissionPoint Partners, and Eva Fowler.

ROADMAP TEAM

MissionPoint Partners served as the project lead, coordinating the resources needed to develop the Roadmap. MissionPoint Partners is an impact investment firm specializing in environmental sustainability.

Team contributors included Mark Cirilli, Joan Briggs, and Adam Rein.

Deloitte Consulting LLP and **Resource Recycling Systems (RRS)** led the economic analysis and core technical drafting of the Roadmap.

Deloitte Consulting LLP's Sustainability O□ering works with clients to find new opportunities and manage risks by bringing expertise in energy, waste, and materials to both operations and supply chains. By leveraging this technical knowledge along with industry expertise and leading analytics solutions, Deloitte's Sustainability O□ering has helped clients execute strategies that have led to more than $3 billion in value.

Team members included Kyle Tanger, Sarah Matheson, Blythe Chorn, Robert Bui, and Sierra Bayles.

RRS is a management and technical consulting firm with core strengths in sustainable materials management and recovery, materials and applied sustainable design, and public-private sector collaborative partnership projects. RRS contributed significant pro bono hours to this initiative.

Team members included JD Lindeberg, David Stead, Hunt Briggs, Nick Lange, and Monica Walker.

Ocupop and **the No. 29** directed communications and community engagement for the Roadmap.

Ocupop is a small, creative team focused on super-charging clients' e□orts to change the world. Ocupop has studios in Milwaukee, Honolulu, and Whistler.

Team members included Michael Nieling, Abby Lindstrom, Amy Leibrock, and Tom Beck.

No. 29 Communications is a New York City-based media relations firm that works with companies, people, and organizations that challenge the status quo and create true impact.

Team member included Melody Serafino.

KEY INSIGHTS

The Roadmap to Reduce U.S. Food Waste by 20 Percent *was developed to identify the most cost-effective solutions to cut food waste at scale, to define research priorities, and to spur multi-stakeholder action. To join this effort or learn more, go to* ***refed.com****.*

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THE PROBLEM

Today, the United States spends over $218 billion – 1.3% of GDP – growing, processing, transporting, and disposing of food that is never eaten.

- Each year, 52.4 million tons of food is sent to landfill, and an additional 10.1 million tons remains unharvested at farms, totaling roughly 63 million tons of annual waste.

THE ROADMAP

ReFED envisions a future where combating food waste is a core driver of business profits, job creation, hunger relief, and environmental protection.

- The Roadmap shows an achievable path to a 20% reduction of food waste within a decade through 27 cost-effective, feasible, and scalable solutions. These solutions would divert 13 million tons from landfills and on-farm losses.
- Implementing the Roadmap is projected to generate 15,000 new jobs, double recovered food donations to nonprofits (1.8 billion meals per year), reduce up to 1.5% of freshwater use (1.6 trillion gallons per year), and avoid nearly 18 million tons of greenhouse gas emissions annually.

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ECONOMIC VALUE

The Roadmap *will require an $18 billion investment, less than a tenth of a penny of investment per pound of food waste reduced, which will yield an expected $100 billion in societal Economic Value over a decade.*

- The estimated funding need is $8 billion of government support via mostly existing legislation, $7 billion of market-rate private investments, and $3 billion of philanthropic grants and impact investments.
- Consumers will reap the biggest economic benefit, saving $5.6 billion annually by cutting unnecessary spending on food that is never eaten.
- Restaurants and foodservice providers could gain the largest business profit improvement — over $1.6 billion annually — by adopting Waste Tracking & Analytics, Smaller Plates, and other solutions.
- Prevention, which avoids unnecessary fertilizer and fuel use on farms, has twice the lifecycle greenhouse gas benefit per ton compared to food recycling. The prevention of unnecessary meat production offers the largest marginal environmental benefit of any category. Recycling reduces landfill methane emissions, while also offering the opportunity to return nutrients to large amounts of degraded soils.

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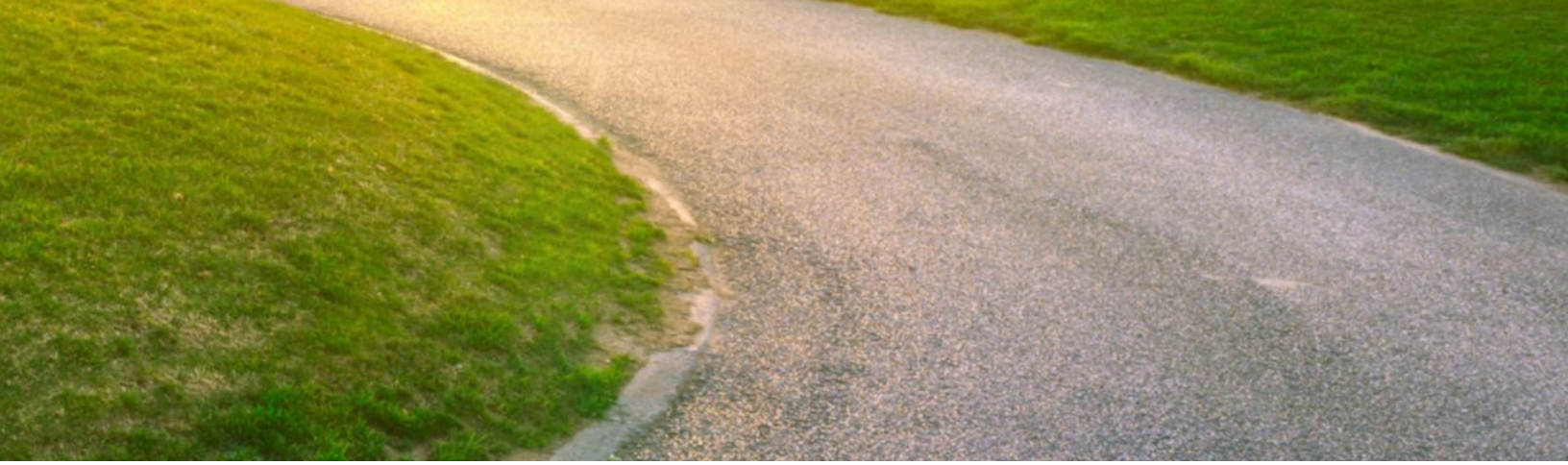
PREVENTION

Solutions that prevent waste in businesses and homes have the greatest Economic Value per ton and net environmental benefit, diverting 2.6 million tons of annual waste.

- The top three solutions with the greatest Economic Value per ton all utilize prevention: Standardized Date Labeling, Consumer Education Campaigns, and Packaging Adjustments.
- Prevention solutions are generally capital-light; they involve changing behaviors through packaging changes, software, and marketing.
- At retail, food is worth roughly $2.50 per pound, magnitudes higher than the value of food scraps for disposal, providing a large economic driver for prevention efforts.



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RECOVERY

Food recovery can increase by 1.8 billion meals annually, nearly doubling the amount of meals rescued today and diverting 1.1 million tons of waste.

- The food recovery ecosystem requires three pillars to scale: business education, enabling policy, and available and efficient transportation and cold storage.
- Over half of the opportunity requires legislation, including the maintenance and expansion of tax incentives for business donations and the standardization of food handling safety regulations.
- Nearly half of new recovery potential comes from produce surpluses on farms and at packinghouses, a sector with lower levels of donations today than food retailers.

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RECYCLING

Centralized Composting and Anaerobic Digestion (AD), as well as a smaller set of growing distributed solutions, will enable 9.5 million tons of waste diversion — nearly three-quarters of the total potential.

- Centralized Composting diverts the most waste, adding over 2 million tons of compost annually to fuel growth in the sustainable farming and environmental remediation markets.
- The Northeast, Northwest, and Midwest can generally realize the most Economic Value from recycling due to high landfill disposal fees and high compost and energy market prices.
- Nearly $3 billion of investment is needed for recycling infrastructure, mainly for compost and AD processing and collection.
- Municipalities can help build more large recycling projects by including non-financial job and environmental benefits into cost-benefit analyses.
- The top levers to scale recycling beyond the Roadmap targets are an increase in landfill disposal costs and efficiencies in hauling and collection through closer siting of organics processing to urban centers and optimized collection routes. Other key bottlenecks to overcome are the high cost of project capital, particularly for AD facilities, and low, unstable pricing for biogas and compost.

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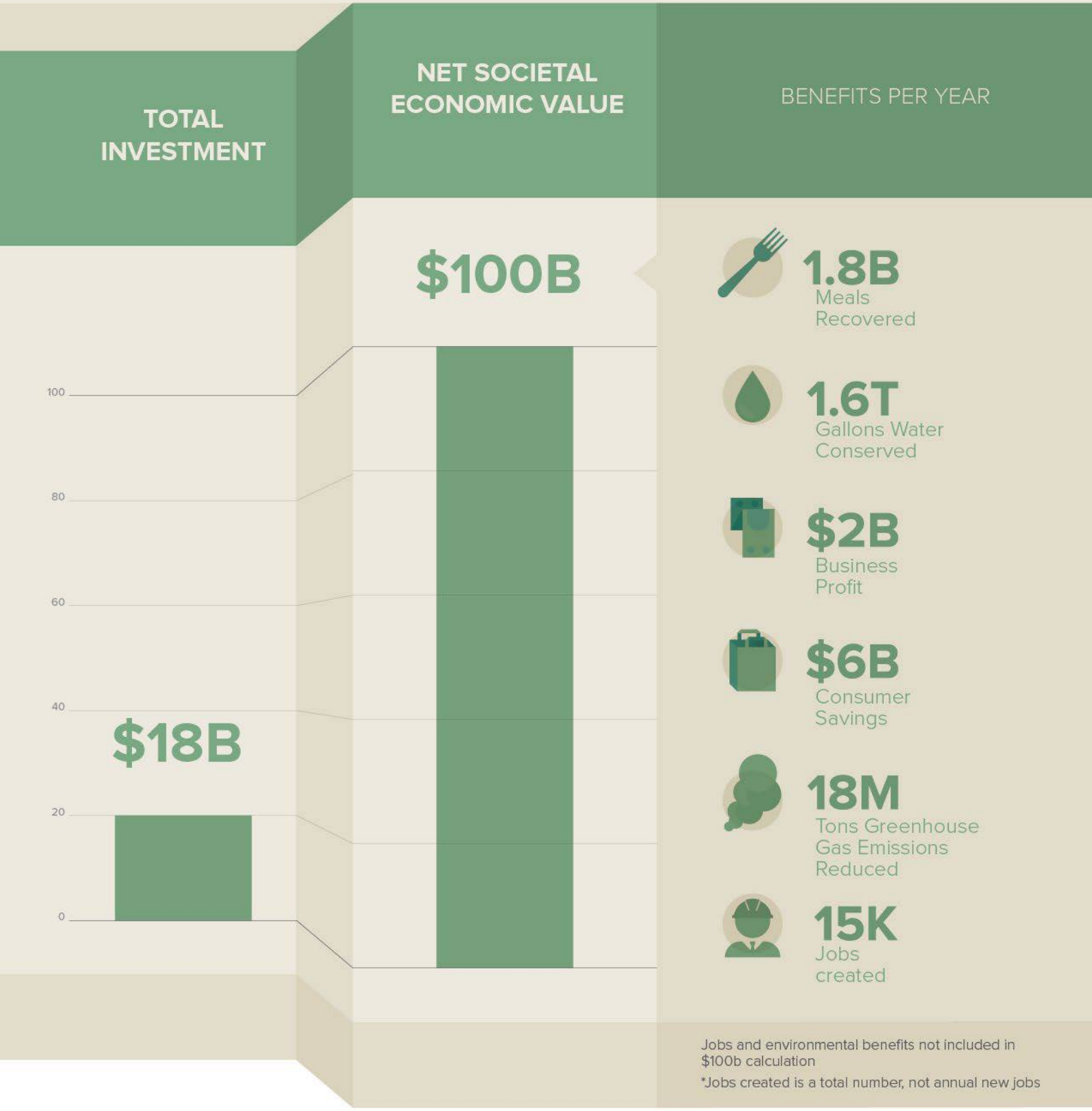
TOOLS FOR ACTION

Four crosscutting actions are needed to quickly cut 20% of waste and put the U.S. on track to achieve a broader 50% food waste reduction goal by 2030.

- **Financing** – To overcome the bottlenecks to unlocking $18 billion in financing, $100-$200 million annually is needed in catalytic grants, innovation investments, and low-cost project finance. Today, few investors or foundations focus explicitly on food waste.
- **Policy** – Commonsense policy adjustments are needed to scale federal food donation tax incentives, standardize safe handling regulations, and boost recycling infrastructure by expanding state and local incentives and reducing permitting barriers. The biggest lever to accelerate change is comprehensive federal legislation.
- **Innovation** – Key technology and business-model innovations are needed around packaging and labeling, IT-enabled transportation and storage, logistics software, value-added compost products, and distributed recycling. These could be accelerated through a national network of food waste innovation incubators.
- **Education** – Launching a widespread training effort to change the behavior of food business employees is critical. In addition, campaigns to raise food waste awareness among consumers need to attract additional funding and support to expand to the scale of anti-littering and anti-smoking efforts.

AN $18 BILLION INVESTMENT IN 27 SOLUTIONS TO REDUCE U.S. FOOD WASTE BY 20% WILL YIELD $100 BILLION IN SOCIETAL ECONOMIC VALUE OVER A DECADE



Jobs and environmental benefits not included in $100b calculation

*Jobs created is a total number, not annual new jobs

PRIORITY STAKEHOLDER ACTIONS AT A GLANCE

THESE ACTIONS o□er the largest opportunities for each stakeholder to contribute to food waste reduction, both through new initiatives and by expanding existing e□orts. They are described in more detail throughout the Roadmap.

FARMERS | Seek to reduce the ~10 million tons of cosmetically imperfect or unharvested food lost each year

- Collaborate with food businesses to further develop a secondary market for Imperfect Produce
- Leverage Value-Added Processing, both on farms and through partner organizations, to turn excess produce into soups or shelf-stable products for new profit- or donation-driven businesses

MANUFACTURERS | Expand existing leadership in repurposing excess food through multi-stakeholder collaborations

- Continue to increase efficiencies through Manufacturing Line Optimization to boost profits
- Collaborate with retailers on Packaging Adjustments, Spoilage Prevention Packaging, and Standardized Date Labeling

RESTAURANTS & FOODSERVICE | Save up to $1.6 billion in food purchasing costs

- Further adopt Waste Tracking & Analytics across all facilities and incorporate Imperfect Produce into menus to reduce costs
- Shift consumer behavior with Smaller Plates and Trayless Dining in all-you-can-eat facilities

GROCERY RETAILERS | Increase profits while empowering customers to reduce waste

- Boost revenues by marketing discounted Imperfect Produce, and continue to reduce costs by adopting Improved Inventory Management systems and Spoilage Prevention Packaging
- Collaborate with retailers and manufacturers to adopt Standardized Date Labeling to benefit consumers

FEDERAL GOVERNMENT | Cost-e□ectively create jobs and alleviate hunger through smart policies

- Retain and expand Donation Tax Incentives for businesses that donate food
- Introduce national Standardized Date Labeling legislation (if industry does not make voluntary progress)

STATE AND LOCAL GOVERNMENTS | Pursue holistic approaches to waste reduction — incentivizing prevention, recovery, and recycling to reduce the tax burden and address food insecurity

- Continue to support organics diversion through use of mandates or landfill or commercial food waste bans, reduce permitting barriers for compost and AD, and enforce programs through incentives or fines
- Implement Standardized Donation Regulations across states

FOUNDATIONS | Provide the ~$300 million needed annually to protect the environment, alleviate hunger, and develop local economies

- Provide grant funding for major Consumer Education Campaigns, and support multi-stakeholder efforts to enact Standardized Date Labeling and educate employees and others on best practices
- Make grants and impact investments to support food donation and recycling infrastructure, including trucks, cold storage, IT systems, and processing facilities

INVESTORS | Generate returns from an untapped $2 billion market opportunity

- Provide dedicated funds that offer flexible project finance for compost and AD facilities
- Provide early-stage and growth equity to scale existing business software solutions and innovative technologies that reduce the cost of prevention, recovery, and recycling

INTRODUCTION

The Problem

An Overview of Food Waste

THE MAGNITUDE OF THE FOOD WASTE PROBLEM IN THE UNITED STATES IS DIFFICULT TO COMPREHEND.

The country spends $218 billion a year, or 1.3% of GDP, growing, processing, and transporting food that is never eaten. That adds up to 52.4 million tons of food sent to landfill annually. Add to that another 101 million tons estimated to be discarded or left unharvested on farms and in packinghouses, and you have a 63-million-ton mountain of wasted calories, resources, and energy. This mountain of waste grows up to two times if you add in other food fit for people that ends up being composted, converted into animal feed, or discarded in other ways, leading to up to 40% of all food grown being wasted.*

Put another way, if all of our country's wasted food was grown in one place, this mega-farm would cover roughly 80 million acres, over three-quarters of the state of California. Growing the food on this wasteful farm would consume all the water used in California, Texas, and Ohio combined. The farm would harvest enough food to fill a 40-ton tractor every 20 seconds. Many of those trailers would travel thousands of miles, distributing food to be kept cold in refrigerators and grocery stores for weeks. But instead of being purchased, prepared, and eaten, this perfectly good food would be loaded onto another line of trucks and hauled to a landfill, where it would emit a harmful stream of greenhouse gases as it decomposes.⊕

Meanwhile, the biggest tragedy is that one in seven Americans, many of them children, are food insecure without reliable access to su□cient, a□ordable, nutritious food.

GOALS HAVE BEEN SET

Although the drivers of food waste di□er between developed and developing countries, food waste has recently emerged as an urgent global issue. In 2012, The European Parliament passed a resolution to halve food waste in the European Union by 2025. In 2015, the U.S. government declared a similar national 50% food waste reduction goal by 2030. Most recently, a gathering of world leaders at the United Nations agreed on the need to halve per capita food waste in the consumer and retail sectors and reduce food losses along production and supply chains by 2030 as part of the Global Sustainable Development Goals.

Research by the Natural Resources Defense Council (NRDC), the Food Waste Reduction Alliance (FWRA), BioCycle, and others has been critical to measuring the magnitude and building awareness of the issue. While some solutions are gaining ground, the United States still lacks a comprehensive action plan to unleash a wide-scale national reduction in food waste.

KEY INSIGHTS

Today, the United States spends over $218 billion – 1.3% of GDP – growing, processing, transporting, and disposing of food that is never eaten.

- Each year, 52.4 million tons of food is sent to landfill, and an additional 101 million tons remains unharvested at farms, totaling roughly 63 million tons of annual waste.
- The Roadmap shows an achievable path to a 20% reduction of food waste within a decade through 27 cost-effective, feasible, and scalable solutions. These solutions would divert 13 million tons from landfills and on-farm losses.
- Implementing the Roadmap is projected to generate 15,000 new jobs, double recovered food donations to nonprofits (1.8 billion meals per year), reduce up to 1.5% of freshwater use (1.6 trillion gallons per year), and avoid nearly 18 million tons of greenhouse gas emissions annually.

* The quantity of food waste regularly reported varies from 20% to 40% depending on what the baseline includes. ReFED's analysis focused on food waste currently sent to landfills and incenerators and left on farms, which is approximately 20% of food production. Including food that is currently being recycled, but not eaten, increases the total quantity of food waste to 30% to 40%.

⊕ Calculations and sources available in the Technical Appendix available at refed.com

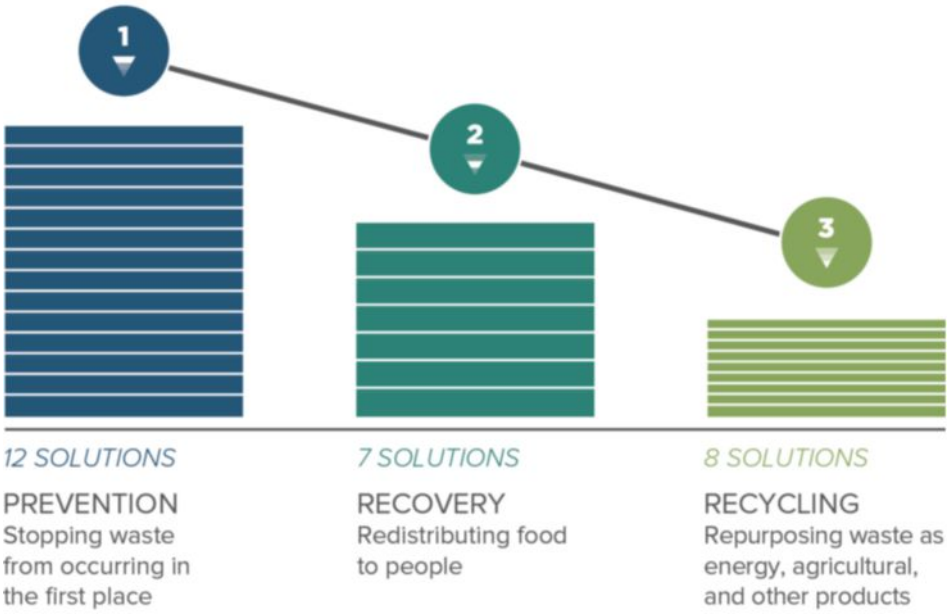
ReFED: THE ROADMAP FORWARD

ReFED was launched to build upon these e□orts by developing a data-driven, nationwide inventory of food waste and generating a roadmap to implement cost-e□ective solutions. More than just an academic research report, the Roadmap to Reduce U.S. Food Waste is a playbook to coordinate and guide key food sector stakeholders — corporations, nonprofits, foundations, policymakers, entrepreneurs, and investors — on a feasible path to cutting waste at scale.

The Roadmap adopted the Environmental Protection Agency (EPA) Food Recovery Hierarchy framework to categorize the solutions to reduce food waste, prioritizing prevention first, then recovery, and finally recycling, to maximize economic, social, and environmental benefits.

With the Roadmap's solutions in place, the United States will be on track to reduce food waste by 20% within a decade. It will also be on the path to achieve the broader national target of a 50% reduction in food waste by 2030.

FOOD RECOVERY HIERARCHY



Many of the solutions analyzed are ready to be implemented today. By acting quickly, businesses and other stakeholders can capture profits, create stronger brands, build customer engagement, and strengthen communities.

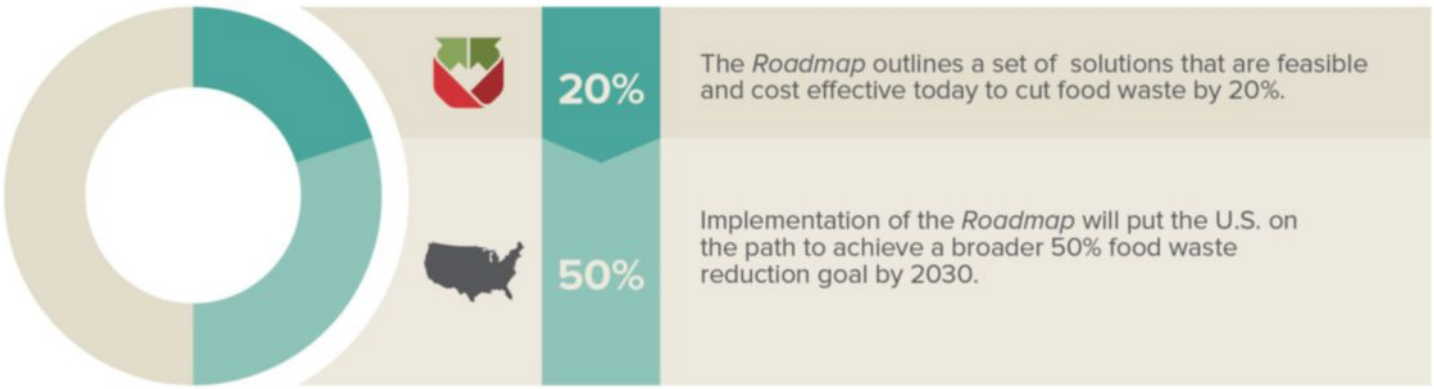
Additional solutions will require stakeholders to collaborate across the value chain. The expected payo□s from these e□orts will be game-changing, delivering multiple times more societal benefit than any single stakeholder can create alone.

THE CONTENTS OF THIS REPORT INCLUDE:

- A detailed overview of where and why food waste occurs
- Data analysis that includes a cost curve to compare the economic value per ton and total diversion potential of 27 food waste solutions, as well as an assessment of business profit potential and non-financial impacts
- Chapters providing more details on prevention, recovery, and recycling solutions
- A chapter describing the financing, innovation, policy, and education actions needed to catalyze the near-term Roadmap, with leverage points identified to achieve the broader 50% target

More information is available online at refed.com.

THE ROADMAP'S FOOD WASTE REDUCTION GOALS



OVERVIEW OF FOOD WASTE

WHAT IS FOOD WASTE?

Various organizations define food loss and food waste in di□erent ways. The UN Food and Agriculture Organization (FAO) refers to unintended loss of food during harvesting, post-harvest handling, processing, and distribution as “food loss,” and the food that gets lost at retail and consumption stages as “food waste.”[1] Similarly, the World Resources Institute defines “food loss” as food that spoils before reaching the consumer,[2] since it is considered an unintended loss due to mishandling. Meanwhile, the U.S. Department of Agriculture (USDA) uses the term “food waste” in general to refer to wasted food that happens anywhere along the supply chain.

ReFED has adopted the USDA definition of “food waste,” which includes all types of food loss and waste as defined by other leading institutions.

Food waste is a subset of organic waste, which includes anything biodegradable that comes from plants or animals, such as yard trimmings and manure. Food waste includes unavoidable scraps, such as bones and rinds that retain beneficial value for reuse. It does not include waste from crop varieties specifically grown for fuel, animal feed, or other commercial uses. ReFED’s focus is on food waste, but the Roadmap also references policies directed at organic waste more broadly.

KEY DEFINITION

FOOD WASTE Any food that is grown and produced for human consumption but ultimately is not eaten

WHERE DOES FOOD WASTE OCCUR AND WHAT EFFORTS EXIST TO REDUCE IT?

Addressable food waste can be found throughout the supply chain, which the Roadmap simplifies into four segments: farms, food manufacturers, consumer-facing businesses (including distributors, retail grocers, restaurants, foodservice providers, and institutions), and homes (including all dwellings).

Consumer-facing businesses and homes represent over 80% of all food waste. Furthermore, home waste represents roughly two-thirds of total lost Economic Value, due to high volumes of waste, the higher cost of food sold at retail, and the high value of meat — a popular consumer purchase item.

Existing e□orts already recover and recycle large amounts of food. They are not included in the Roadmap baseline, but they represent commendable progress made by stakeholders to date and an opportunity to increase value further through prevention.

If zero e□orts were made to recover or recycle food today, the potential waste generated would be over 89 million tons. Nearly 30% of this waste, or 26 million tons, is already recovered or recycled primarily by manufacturers, leading to the 63-million-ton baseline level of food waste within the Roadmap. ⊕

Of more than 10 million tons of produce that goes unsold each year from farms and on-farm packinghouses due to cosmetic imperfections, nearly all is composted on-site or left to be tilled into the soil where it enhances soil health similarly to compost. Very little food is sent from farms to landfill — mainly surplus and rejected product from packinghouses.* A small portion is recovered today through gleaning and farm-to-food-bank e□orts.

When food reaches manufacturers for industrial processing, waste is handled quite e□ciently. An estimated 95% of the 21 million tons of annual U.S. industrial food waste is

CONSUMER-FACING BUSINESSES AND HOMES REPRESENT OVER 80% OF ALL FOOD WASTE.

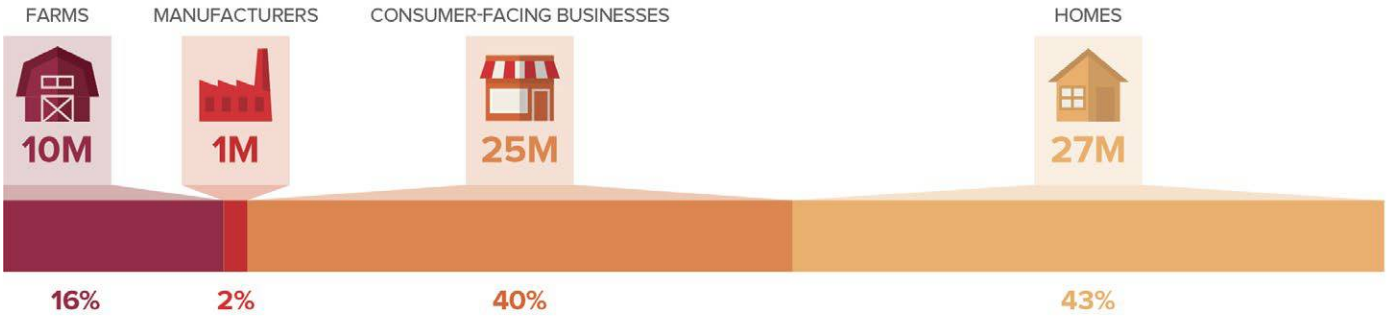
*There is limited data on the quantity of on-farm and packinghouse losses and what happens to that waste (tilled under, composted, or sent to landfill). Given the limited data, this analysis assumes none is landfilled.

⊕ More details available in the Technical Appendix on refed.com.

recycled,[3] primarily for animal feed. Large manufacturers have an advantage in diverting waste from landfill because the predictability of quantity and quality of the waste stream reduces risk for customers who use it for animal feed or energy generation.

In contrast, the 52 million tons of food waste derived from consumer-facing businesses and consumers reflects an estimated recovery and recycling rate of less than 10%.[4] Recycling of food scraps has lagged behind rates achieved for other materials. Food scraps are composed of 70% water, requiring transport costs without any corresponding revenues, while the market values for the energy and compost end products made from scraps are relatively low compared to plastics and metals. For these reasons, municipalities and businesses have prioritized recycling schemes for other materials.

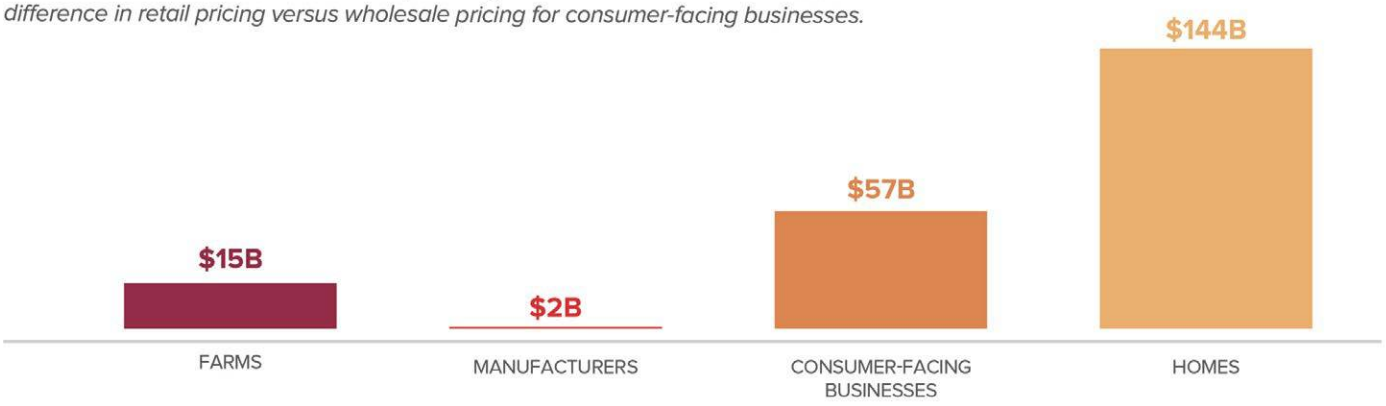
FOOD WASTED BY WEIGHT — 63 MILLION TONS



CONSUMER-FACING BUSINESSES INCLUDE

VALUE OF WASTE — $218 BILLION

The financial cost of food waste ends up costing consumers the most due to the difference in retail pricing versus wholesale pricing for consumer-facing businesses.



WHY DOES FOOD WASTE OCCUR?

The reasons for food waste are numerous and complex across the food value chain. Here are some examples of why it occurs:

FARMS Food loss starts at the production level. Low market prices and high labor costs often make it uneconomical for farmers to harvest all that they produce. Strict cosmetic standards result in insu□cient demand for imperfect-looking produce (i.e. oversized zucchinis or bent carrots). Despite gleaning and farm-to-food-bank e□orts to recover this unharvested food, the vast majority is left in the fields to be tilled under.

MANUFACTURERS While current recycling levels are highest among food processors and manufacturers, customer demand for a wide variety of products continues to cause ine□ciencies. Each time a production line is changed it must be emptied and cleaned. Products can require trimming for use in end products, leading to edible parts going unused (e.g. ends and skins).

CONSUMER-FACING BUSINESSES (Grocery Retailers, Restaurants, Institutions & Foodservice) Customers demand a variety and consistency of food availability that strains inventory management and food purchasing. Businesses are reluctant to change stocking practices or product sizes if those practices are intricately tied to their brand identities. Also, high customer standards for freshness lead businesses to dispose of safe, edible food when it is perceived to be past its prime.

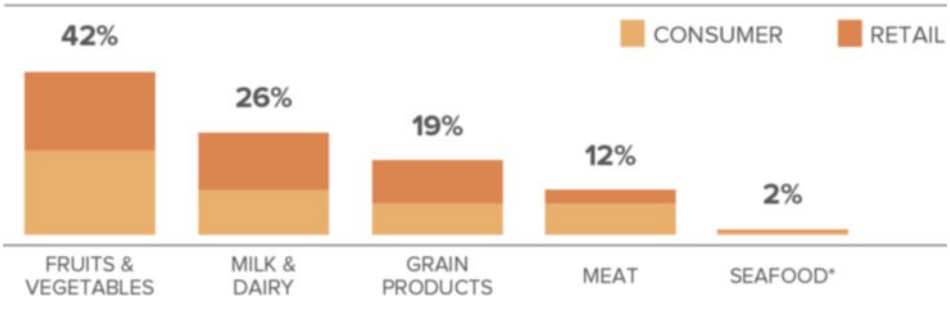
HOMES The demand for variety and abundance of food creates waste at home. For example, consumers may want a di□erent kind of cuisine each night but lack the knowledge of how to repurpose ingredients and store food properly. As much as 55% of food purchases are unplanned, which leads to over purchasing and food spoilage. Many families are tempted into bulk purchases of food that they will never consume to get a good deal on per-unit costs. A lack of standardization of date labels often leads consumers to throw away food before it's spoiled, causing an estimated 20% of at-home food waste.[5] Consumers also have limited access to municipal organics food waste recycling programs in most cities and perceive several barriers to composting at home.

WHICH FOODS GET WASTED?

Nearly 80% of food waste comes from perishable foods, which include prepared fresh deli items, meats, fruits and vegetables, seafood, milk and dairy, and some grain products such as bread and bakery items. In contrast, non-perishable foods — pastas, canned goods, and highly processed, shelf-stable products — are generally wasted less because they don't spoil as easily.

Perishables often get discarded because they are inexpensive and quickly go bad. Pound per pound, fruits and vegetables are among the least expensive and fastest spoiling foods, constituting over 40% of total food waste. Conversely, seafood and meats are the two least wasted and most expensive food types.*

FOOD WASTE BREAKDOWN (BY WEIGHT AND BY TYPE)



* While there is limited seafood wasted at the consumer level, large amounts of seafood are wasted during the production phase, with some estimates of up to 50% wasted as a result of seafood bycatch.

More examples of food loss throughout the supply chain can be found in NRDC's report "Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill" [6] and from the Food Waste Reduction Alliance.

ECONOMIC ANALYSIS

The Business and Societal Case for Reducing Food Waste

SCOPE

ReFED set out to understand the most cost-e□ective strategy to reduce food waste and to identify the resources needed for implementation at scale. The Roadmap was developed through a four-step process:

1. **BASELINE DEFINITION** — ReFED built one of the broadest data sets and literature reviews to date to establish a map by stakeholder and region of existing food waste sent to landfill and left on farms.
2. **SOLUTIONS EVALUATION** — A wide list of solutions was gathered from stakeholders and narrowed to a short list of 27 priority solutions for detailed analysis that met criteria around data availability, cost e□ectiveness, feasibility, and scalability.
3. **DATA ANALYSIS** — A robust cost-benefit analysis was conducted for the 27 solutions. A Marginal Food Waste Abatement Cost Curve ranked solutions by Economic Value per ton and landfill diversion potential. Additional calculations included Business Profit Potential and Non-Financial Impacts.
4. **DATA VALIDATION** — ReFED conducted over 80 expert interviews, including multiple reviews by a multi-stakeholder Advisory Board, to refine assumptions and methodology.⊕

BASELINE DEFINITION

Previous attempts to create a baseline for U.S. food waste have varied widely both in methodology and output. The FAO used global production data to estimate that 103 million tons of food intended for human consumption in the U.S. goes uneaten. The USDA estimated that 67 million tons go uneaten based on food businesses and home surveys, but excluding farms and food manufacturers. Meanwhile, a recent EPA study identified 35 million tons of waste landfilled annually, which excludes some categories such as food disposed within containers. These methodologies do not enable an analysis by geography or across the entire value chain, both of which were necessary to conduct a robust analysis of solutions.

Through a comprehensive e□ort, ReFED determined the baseline amount of food wasted in the United States today to be 62.5 million tons annually. This number is the sum of 52.4 million tons disposed annually (primarily in landfills, but also including incinerators) and 10.1 million tons of on-farm waste. Landfilled waste was calculated utilizing the most reliable research available at di□erent stages of the supply chain, including food manufacturing and processing facilities, food distribution centers, restaurants, grocers, institutional cafeterias (e.g. hospitals, schools, prisons, and military bases), and homes. On-farm losses were added to the baseline because they represent a substantial lost economic and resource opportunity that has often been excluded from past research.

⊕ More details about data validation, methodology, and potential sources of waste excluded from the baseline are available in the Technical Appendix on refed.com.

KEY INSIGHTS

The Roadmap *shows an achievable path to a 20% reduction of food waste within a decade.*

- Through 27 solutions that are cost-effective, feasible, and scalable, 13 million tons can be diverted from landfills and on-farm losses.
- Implementing the Roadmap is projected to generate 15,000 new jobs, double food donations to nonprofits (1.8 billion meals per year), reduce up to 1.5% of freshwater use (1.6 trillion gallons per year), and avoid nearly 18 million tons of greenhouse gas emissions annually.
- Consumers will reap the biggest economic benefit, saving $5.6 billion annually by cutting unnecessary spending on food that is never eaten.
- Restaurants and foodservice providers could gain the largest profit boost — over $1.6 billion annually — by adopting Waste Tracking & Analytics, Smaller Plates, and other solutions.
- The top three solutions with the greatest Economic Value per ton all utilize prevention: Standardized Date Labeling, Consumer Education Campaigns, and Packaging Adjustments.
- Centralized Composting and Anaerobic Digestion (AD), as well as a smaller set of growing distributed solutions, will enable 9.5 million tons of waste diversion — nearly three-quarters of the total potential.
- Prevention, which avoids unnecessary fertilizer and fuel use on farms, has twice the lifecycle greenhouse gas benefit per ton compared to food recycling. The prevention of unnecessary meat production offers the largest marginal environmental benefit of any category. Recycling reduces landfill methane emissions while also offering the opportunity to return nutrients to large amounts of degraded soils.

SOLUTIONS EVALUATION

ReFED identified a comprehensive list of over 50 possible food waste solutions. Solutions were prioritized for detailed analysis in the Roadmap if they met four core criteria:

1. **DATA AVAILABILITY** – Quantifiable data from one or more credible sources
2. **COST EFFECTIVENESS** – A positive or near-breakeven Economic Value to society
3. **SCALABILITY** – Potential to achieve significant waste diversion volume
4. **FEASIBILITY** – Identified stakeholders who can implement the solution without major changes to technology or policy

Using these criteria, ReFED narrowed the Roadmap analysis to focus on 27 solutions across eight categories outlined in the table below. These solutions primarily target consumer-facing food businesses, where market share is concentrated among a small set of companies that impact waste both upstream (through farms and manufacturers) and downstream (through consumers).

Other solutions were excluded from the economic analysis because they were out of scope, not economical, or limited in scale. It is recommended that additional research be conducted on these solutions to identify additional opportunities.[⊙]

FOOD WASTE PREVENTION SOLUTIONS

CATEGORY	SOLUTION NAME	DESCRIPTION	STAKEHOLDERS
Packaging, Product, & Portions	Standardized Date Labeling	Standardizing food label dates and instructions, including eliminating “sell by” dates, to reduce consumer confusion	Manufacturers, Retailers, Consumers
	Packaging Adjustments	Optimizing food packaging size and design to ensure complete consumption by consumers and avoid residual container waste	
	Spoilage Prevention Packaging	Using active intelligent packaging to prolong product freshness and slow down spoilage of perishable fruit and meat	
	Produce Specifications (Imperfect Produce)	Accepting and integrating the sale of o□-grade produce (short shelf life, di□erent size/ shape/ color), also known as “ugly” produce, for use in foodservice and restaurant preparation and for retail sale	Producers, Consumer-Facing Businesses
	Smaller Plates	Providing consumers with smaller plates in self-serve, all-you-can-eat dining settings to reduce consumer waste	Foodservice
	Trayless Dining	Eliminating tray dining in all-you-can-eat dining establishments to reduce consumer waste	
Operational & Supply Chain E□ciency	Waste Tracking & Analytics	Providing restaurants and prepared-food providers with data on wasteful practices to inform behavior and operational changes	Restaurants, Foodservice
	Cold Chain Management	Reducing product loss during shipment to retail distribution centers by using direct shipments and cold-chain-certified carriers	Retailers
	Improved Inventory Management	Improvements in the ability of retail inventory management systems to track an average product’s remaining shelf-life (time left to sell an item) and inform e□orts to reduce days on hand (how long an item has gone unsold)	
	Secondary Resellers	Businesses that purchase unwanted processed food and produce direct from manufacturers/distributors for discounted retail sale to consumers	
	Manufacturing Line Optimization	Identifying opportunities to reduce food waste from manufacturing/ processing operations and product line changeovers	Manufacturers
Consumer Education	Consumer Education Campaigns	Conducting large-scale consumer advocacy campaigns to raise awareness of food waste and educate consumers about ways to save money and reduce wasted food	Consumers, Consumer-Facing Businesses

[⊙] A list of excluded solutions can be found in the Technical Appendix on refed.com.

FOOD WASTE RECOVERY SOLUTIONS

CATEGORY	SOLUTION NAME	DESCRIPTION	STAKEHOLDERS
Donation Infrastructure	Donation Matching Software	Using a technology platform to connect individual food donors with recipient organizations to reach smaller-scale food donations	Farms, Consumer-Facing Businesses, Food Recovery Organizations
	Donation Storage & Handling	Expanding temperature-controlled food distribution infrastructure (e.g. refrigeration, warehouses) and labor availability to handle (e.g. process, package) additional donation volumes	
	Donation Transportation	Providing small-scale transportation infrastructure for local recovery as well as long-haul transport capabilities	
	Value-Added Processing	Extending the usable life of donated foods through processing methods such as making soups, sauces, or other value-added products	
Donation Policy	Donation Liability Education	Educating potential food donors on donation liability laws	
	Standardized Donation Regulation	Standardizing local and state health department regulations for safe handling and donation of food through federal policy	
	Donation Tax Incentives	Expanding federal tax benefits for food donations to all businesses and simplifying donation reporting for tax deductions	

FOOD WASTE RECYCLING SOLUTIONS

CATEGORY	SOLUTION NAME	DESCRIPTION	STAKEHOLDERS
Energy & Digestate	Centralized Anaerobic Digestion (AD)	A series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen resulting in two end products: biogas and digestate. There are many di□erent AD technologies, including wet and dry versions, the latter being generally better suited for food waste mixed with yard waste.	Municipalities, Manufacturers, Retailers
	Water Resource Recovery Facility (WRRF) with AD	Delivering waste by truck or through existing sink disposal pipes to a municipal WRRF, where it is treated with anaerobic digestion; the biosolids can be applied to land for beneficial reuse	WRRF, Retailers, Municipalities, Restaurants, Consumers
On-Site Business Processing Solutions	In-Vessel Composting	Composting at small scale at institutions or businesses with heat and mechanical power to compost relatively quickly (less than one month versus more than two months for windrow composting)	Restaurants, Foodservice
	Commercial Greywater	An on-site treatment technology, greywater aerobic digesters use combinations of nutrients or enzymes and bacteria to break food organics down until soluble, where it is flushed into the sewage system.	
Agricultural Products	Community Composting	Transporting food from homes by truck, car, or bicycle to small, community, or neighborhood-level compost facilities that process 2,500 tons per year on average	Restaurants, Consumers
	Centralized Composting	Transporting waste to a centralized facility where it decomposes into compost	Municipalities, Retailers, Restaurants, Foodservice, Consumers
	Animal Feed	Feeding food waste to animals after it is heat-treated and dehydrated and either mixed with dry feed or directly fed	Manufacturers, Consumer-Facing Businesses
	Home Composting	Keeping a small bin or pile for on-site waste at residential buildings to be managed locally; also known as “backyard composting”	Consumers

DATA ANALYSIS

Once the solutions were defined, ReFED conducted an economic analysis to explore what could be achieved for each solution given real-world constraints over a 10-year period. The economic model was built on the following variables:

CALCULATIONS	OUTPUT VARIABLES
• Potential to reduce waste by food product category and stakeholder • Upfront and ongoing implementation costs • Cost savings • New revenue opportunities	• Economic Value • Annual waste diversion • Business Profit Potential • Jobs created • Greenhouse gas reductions • Water savings • Meals recovered

Prevention and recovery solutions were assessed at the national level since the economics tend to be similar across geographies. Recycling solutions were assessed for the top 50 municipal statistical areas, capturing differences in existing policies as well as variances in labor, property, energy, disposal, and compost pricing.

The core economic model was used for three analyses:

MARGINAL FOOD WASTE ABATEMENT COST CURVE ("Cost Curve")

BUSINESS PROFIT POTENTIAL

NON-FINANCIAL IMPACTS

MARGINAL FOOD WASTE ABATEMENT COST CURVE

What is the Cost Curve? The Cost Curve ranks all 27 solutions based on their cost-effectiveness, or societal Economic Value generated per ton of waste reduced, while also visualizing the total diversion potential of each solution.

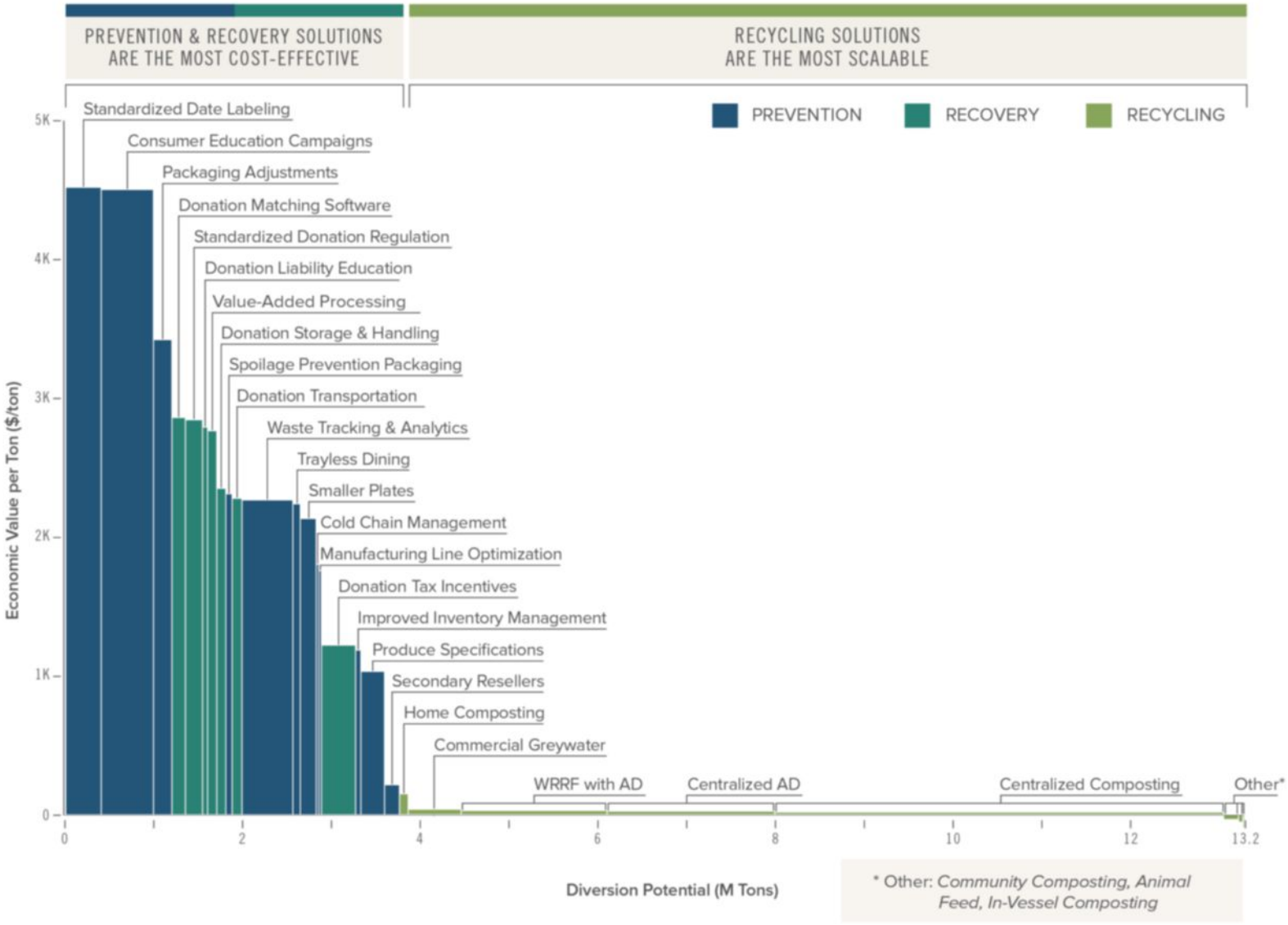
Why Build a Cost Curve? The Cost Curve ranks solutions based on cost-effectiveness, assuming that the key constraint is financial capital and that society should invest to solve food waste in the most efficient way possible. This cost-benefit approach is similar to how businesses and government agencies justify other capital investments. An alternate approach could have focused purely on scalability and ranked solutions by the total food waste diverted, regardless of net economic benefit, which would have put a larger emphasis on recycling solutions. This volume-based approach is more relevant when the core constraint is time or attention, with capacity to only pursue a handful of solutions at a time.

The full data set for the Cost Curve is available in the Appendix, and an interactive data visualization can be found at refed.com.

KEY DEFINITION

ECONOMIC VALUE is defined as the aggregate financial benefit to society (consumers, businesses, governments, and other stakeholders) minus all investment and costs. Economic Value is calculated as an annualized Net Present Value (NPV) that sums all costs and benefits for each solution over 10 years. It uses a social discount rate of 4% to reflect the long-term cost of borrowing to government as a representative discount rate for programs that benefit society. [7]

MARGINAL FOOD WASTE ABATEMENT COST CURVE



How do I read the Cost Curve?

The Cost Curve displays each solution in order of greatest to lowest Economic Value in dollars per ton of food waste diverted. A negative number indicates that the costs outweigh the benefits. The width of each bar reflects the feasible near-term diversion potential for each solution by weight measured in tons of waste reduced per year. The total area of each bar represents the Economic Value, and the bar's color represents the prevention, recovery, or recycling categories.

GREATEST ECONOMIC VALUE PER TON

- Standardized Date Labeling
- Consumer Education Campaigns
- Packaging Adjustments

MOST DIVERSION POTENTIAL

- Centralized Composting
- Centralized AD
- WRRF with AD

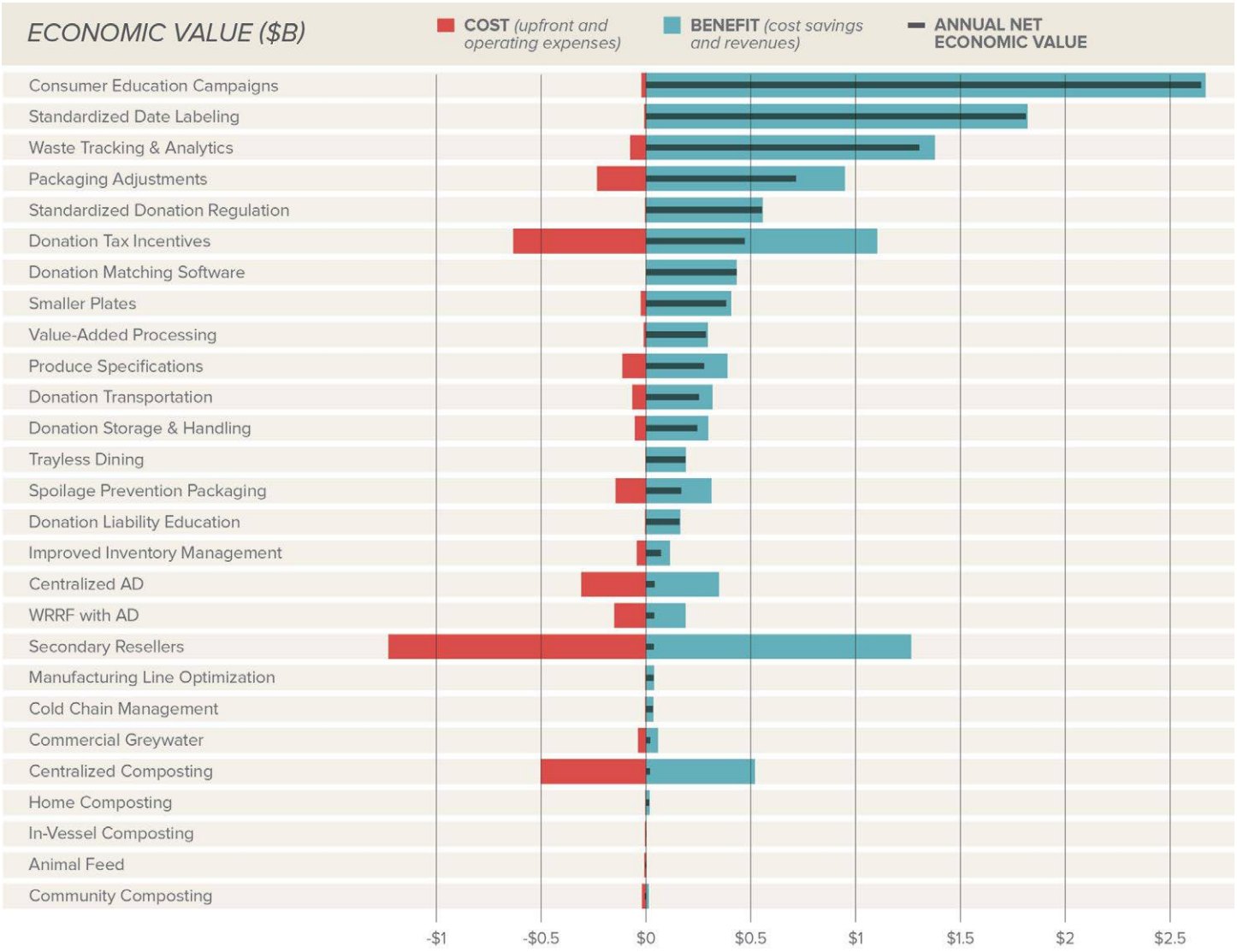
ECONOMIC VALUE ANALYSIS

The core conclusion of the Cost Curve is that prevention and recovery solutions generally result in greater Economic Value per ton, while recycling solutions have significantly larger diversion potential. What drives these results?

Over $10 billion of net annual Economic Value was identified from implementing the 27 solutions. Over 75% of the Economic Value is from prevention solutions, with 23% from recovery and the remaining potential from recycling. The chart below illustrates the benefit-cost ratio of each solutions.

The Economic Value created is driven by the investment required and ongoing financial benefits. Prevention and recovery solutions typically require relatively low upfront investment, such as capital-light software, packaging tweaks, or process changes. There are exceptions to this rule. Significant investment is needed for Secondary Resellers, Donation Tax Incentives, and Spoilage Prevention Packaging. On the other hand, most centralized recycling solutions require heavy investment for large processing and trucking infrastructure. Some recycling solutions can be implemented with low investment levels, such as Home Composting and distributed solutions, but their potential to scale is more limited.

$10 BILLION
OF NET ANNUAL ECONOMIC VALUE WAS IDENTIFIED FROM IMPLEMENTING THE 27 SOLUTIONS



Furthermore, the benefits of prevention and recovery, which capture the value of edible food, are many times higher than those gained from recycling food scraps. On average, edible food purchased at retail is valued at approximately $2.50 per pound, or $5,000 per ton. Meanwhile, when food is ready to be thrown away as scraps, its value has generally dropped by 10 to 50 times to under $100 per ton. This value is captured by processing facilities in the form of avoided disposal fees and the sale of energy and compost.

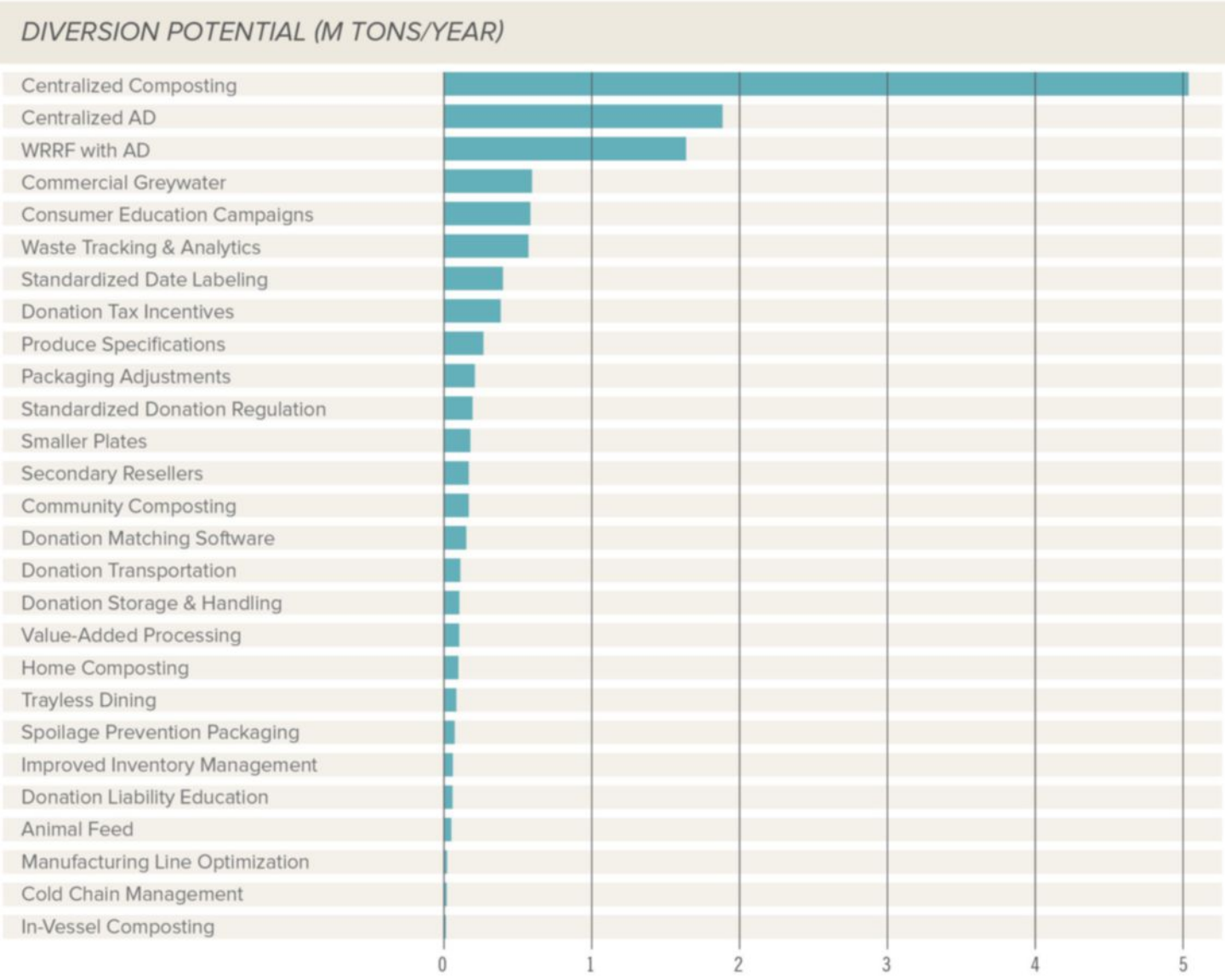
DIVERSION POTENTIAL ANALYSIS

Nearly 13 million tons of annual waste was identified that can feasibly be diverted from landfills and on-farm losses.

The top three solutions by diversion potential — Centralized Composting, Centralized AD, and WRRF with AD — can collectively reduce 9.5 million tons of waste annually, nearly three-quarters of the total potential across all solutions. These recycling solutions achieve scale through large municipal programs that coordinate policy, collection infrastructure, and centralized processing facilities.

Conversely, prevention and recovery solutions, representing 2.6 million and 1.1 million tons respectively, face three major barriers to scale:

- Some food scraps from consumers or food businesses — such as orange peels, egg shells, and chicken bones – are generally unavoidable and cannot be prevented or recovered.
- Prevention and recovery solutions generally require significant customization. For example, Waste Tracking & Analytics will require different software, hardware, and training based on the size and type of the food business where it is implemented.
- Prevention and recovery often require collaboration and spread costs and benefits across a greater number of stakeholders. For prevention solutions, organizational silos between sourcing and procurement, in-store operations, and waste management make it challenging to organize and communicate the return on investment of waste reduction initiatives across a business. Recovery solutions generally require either philanthropic or government support and coordination between local businesses and nonprofits.



BUSINESS PROFIT POTENTIAL

In calculating the Business Profit Potential, solutions fell into three categories depending on which stakeholder benefits. The simplest case is when a company invests in a project to increase its own profit, creating pure business benefits. For example, foodservice providers can achieve a positive return on investment — with a payback as short as one to two months — by retrofitting dining facilities to switch to Trayless Dining, which reduces their food purchase costs. On the opposite end, some solutions create only consumer and public benefits, with no (or limited) profit opportunity for businesses. For example, Donation Tax Incentives are needed to support economic incentives for businesses to donate food, which benefits consumers. Finally, some solutions have mixed benefits among business and other stakeholders. For example, Spoilage Prevention Packaging o□ers value to both retailers and consumers from longer-lasting food.⊙

The Roadmap estimates that there is $1.9 billion of annual Business Profit Potential from the revenue and cost savings of implementing nine prevention and two recycling solutions.

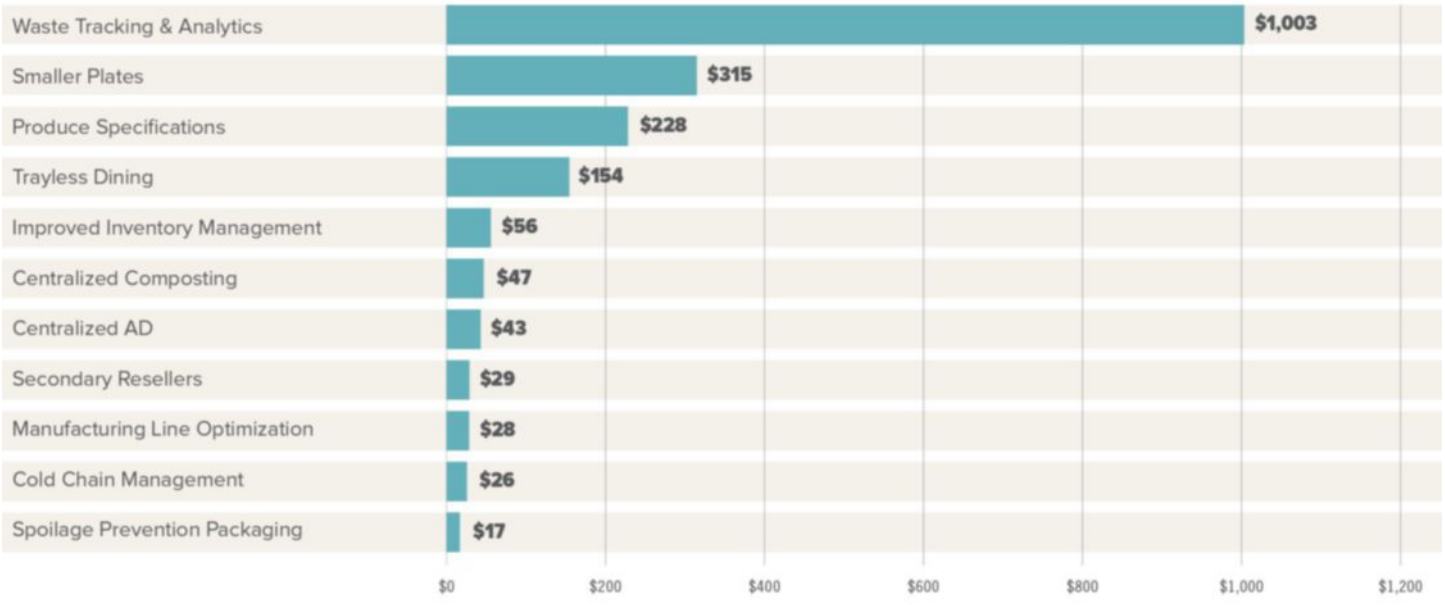
The stakeholders with the largest profit opportunity, $1.6 billion annually, are restaurants and foodservice facilities. Why has this profit not been captured already? Restaurants and foodservice facilities are highly fragmented and change their menus frequently. Stakeholder interviews identified a gap in employee training — caused by high turnover rates and competing priorities such as food safety and food quality — as a key challenge to achieving higher waste reduction.

The majority of this profit opportunity comes from improved Waste Tracking & Analytics, reflecting the operational ine□ciencies that exist today in food purchasing

KEY DEFINITION

BUSINESS PROFIT POTENTIAL is defined as the expected annual profits that the private sector can earn by investing in solutions after adjusting for initial investment required, di□erentiated costs of capital, and benefits that accrue to non-business stakeholders.

ANNUAL BUSINESS PROFIT POTENTIAL ($M)



⊙ More information on the Business Profit Potential and cost of capital methodology is available in the Technical Appendix on refed.com.

and kitchen prep. Smaller Plates and Trayless Dining o□er additional cost savings by nudging customers to waste less in all-you-can-eat settings. Imperfect Produce allows for lower input costs since it can be used as a lower cost substitute for retail-grade, cosmetically perfect food.

There is also profit potential for other stakeholders. Retailers can achieve additional revenue by marketing Imperfect Produce or near-expired food as a new product line and realizing cost savings through Spoilage Prevention Packaging and Improved Inventory Management.

Recycling processing facilities o□er meaningful profit potential, but lower than most prevention solutions. This is driven by the need to use cash flow to service project finance and relatively slim profit margins. Finally, for recovery, any additional tax incentives or brand benefits businesses receive are expected to be mostly o□set by their additional labor, storage, and transportation costs.

The Business Profit Potential analysis likely underestimates the true potential by focusing only on consumer-facing food business and recycling processing facilities. Additional profits can be generated from new product and service providers, such as spoilage prevention packaging companies, inventory software providers, and innovative value-add processors. Additional solutions not analyzed may also generate new profit opportunities.

RESTAURANTS AND FOODSERVICE FACILITIES HAVE THE LARGEST PROFIT OPPORTUNITY — $1.6 BILLION ANNUALLY.

NON-FINANCIAL IMPACTS: SOCIAL AND ENVIRONMENTAL

In addition to economic impacts, food waste reduction stimulates a wide range of social and environmental benefits. The Roadmap specifically focused on two social benefits: meals recovered and jobs created; and two environmental benefits: greenhouse gas reductions and water conserved. With the exception of meals recovered, the Cost Curve utilized a conservative methodology that excluded the net financial benefits from these Non-Financial Impacts, which therefore underestimates the Economic Value of food waste reduction. ⊕

ReFED strongly recommends future research into the Non-Financial Impacts of a large national reduction in food waste to help government and philanthropic decision-makers allocate the appropriate level of support.

MEALS RECOVERED

Details on meals recovered are included in the Recovery chapter on page 39.

JOB CREATION

Food waste solutions are a strong engine for job creation. The Roadmap includes a preliminary estimate of over 15,000 permanent jobs created or sustained by implementing the recovery and recycling solutions. (Prevention solutions were excluded due to a lack of data.)

Jobs within the recycling sector are created through two primary avenues. First, each processing facility generates an average of five to 10 permanent employees from construction, management, collection, and processing. The much larger driver is that every million tons of processed compost has been estimated to create 1,600 or more additional ancillary service jobs from compost utilization in green infrastructure or agriculture. As a result, nearly 80% of estimated job growth is projected to come from the growth of the Centralized Compost sector, creating up to 9,000 new jobs.

⊕ A list of solutions not analyzed and more details about Non-Financial Impacts are available in the Technical Appendix on refed.com.

The second largest job creator is Donation Storage and Handling, which is expected to generate over 2,000 new jobs both in food businesses and within food recovery organizations.

The third largest job opportunity is Centralized AD, which is estimated to produce four to six jobs for every 10,000 tons of processing capacity, as well as jobs in the post-processing of digestate. The remaining job potential is spread among the rest of the solutions, with the largest opportunity around Donation Transportation.

GREENHOUSE GAS (GHG) REDUCTIONS

A first look at GHG impacts shows that they are significant. For example, a recent EPA study concluded that the social benefit of a 1-ton reduction in CO2-equivalent emissions ranges from $11 to $56 per ton.[8] Using this estimate, the Roadmap's projected 18-million-ton emissions reduction would generate an additional societal value of $200 million to $1 billion per year.

The top three solutions with the largest potential to reduce GHG emissions are Centralized Composting, Consumer Education Campaigns, and Waste Tracking & Analytics.

Recycling solutions, led by Centralized Composting, achieve large environmental benefits primarily by diverting large volumes of waste from landfill and avoiding the associated methane emissions. Additionally, putting nutrients back into the soils of degraded lands through compost or digestate can have several benefits. First, it can be used as an alternative to traditional fertilizer use, which lowers the associated GHG impacts. Second, compost has water retention benefits, which are particularly useful in drought-prone agricultural areas. And finally, recent research shows that widespread application of compost may have significant carbon sequestration benefits.

In addition to avoiding landfill methane emissions, prevention and recovery o□er additional environmental benefits from avoided agricultural and livestock impacts, including all of the resources that go into producing, processing, and transporting food. Prevention and recovery both ultimately impact the demand at the farm level. When a consumer reduces spending on unnecessary food or when a donated meal replaces the need to purchase that meal from another source, there is a net demand reduction for all of the resources that go into the wasted food. Even if the farmer still produces the same amount of food as they were previously, there is a net increased e□ciency in the food system due to the associated reduction in waste. Avoiding the agricultural inputs and transportation of 1 ton of food through prevention or recovery has on average a two to 10 times larger GHG reduction compared to recycling 1 ton of food.

SYSTEM INTERDEPENDENCIES

Food systems are complex, consisting of a web of businesses, nonprofits, regulators, and consumers that make decisions every day on what to buy and what to throw away. Given these complexities, the Roadmap analysis could not include all system dynamics, unintended consequences, and secondary impacts.

ReFED has identified a number of possible interdependencies that should be analyzed more deeply in future research.

VALUE CHAIN LINKAGES

Each Roadmap solution was analyzed discretely. However, many solutions will require an increase in capacity in another part of the value chain to be implemented. This is most evident in recovery, which requires a simultaneous increase in donations from businesses, transportation capacity, and storage and distribution capacity among food recovery organizations. Similarly, the growth of recycling processing infrastructure will need to occur in balance with an increase in food scrap feedstock availability, transportation capacity, and market demand for compost products.

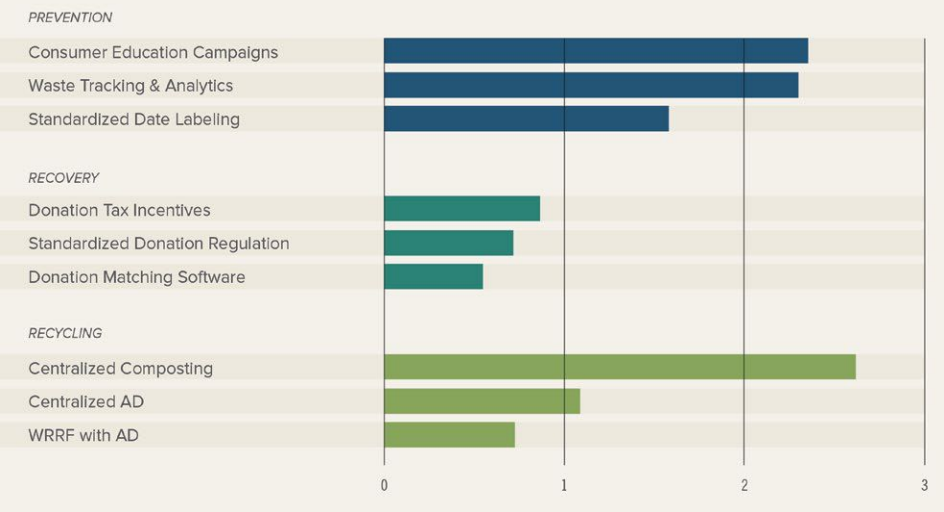
MULTIPLIER EFFECTS

When implemented together, some solutions may have additional benefits that are not captured in the Roadmap. For example, Consumer Education Campaigns may also improve waste practices at businesses, since employees at food businesses who participate in the campaigns may also change their behavior.

SUBSTITUTION EFFECTS

The Roadmap included substitution e□ects in modeling some solutions, such as the impacts of substituting cosmetically imperfect produce for higher cost items by restaurants and food service. However, the Roadmap did not factor in all potential e□ects that could reduce revenues for food businesses, such as the potential for secondary resellers to cannibalize revenues from

THE TOP SOLUTIONS TO REDUCE GREENHOUSE GAS EMISSIONS (M TONS PER YEAR)



WATER CONSERVATION

Solutions analyzed by ReFED could potentially conserve 1.6 trillion gallons of water annually, or 1.5% of annual U.S. freshwater withdrawals.

Water conservation occurs when a solution helps avoid agricultural water use to produce food that's ultimately wasted. Seventy-three percent of water conservation comes from prevention, with the remaining from recovery. It was assumed that recycling does not have impact on water use, although further research may refine this viewpoint by assessing the water footprint embedded in the energy, compost, and transportation systems, including the potential for increased use of compost to improve water retention in soils.

The top three solutions with the potential to conserve water are Waste Tracking & Analytics, Consumer Education Campaigns, and Standardized Date Labeling. Water conservation advocates should emphasize these and other solutions that reduce meat waste, which has a water footprint tied to livestock production that is eight to 10 times larger per pound compared to grain products, fruits, and vegetables.

In addition to water conservation, reducing seafood losses can provide substantial benefits. Seafood bycatch, the unintentional catch of fish by commercial ships, results in huge losses of fish in the ocean that can reduce the quality of marine ecosystems. This was not analyzed in the Roadmap, and additional research is recommended.

higher-priced retail products. The modeling also did not integrate the potential for system-wide food demand reduction if consumers or downstream food businesses waste and purchase less food at scale, which could impact revenues and profits of all upstream businesses. Based on recommendations from the ReFED Advisory Council, the Roadmap assumed that consumers and businesses will reinvest the vast majority of savings from waste reduction into a basket shift to buy a higher portion of premium food items that they could not previously afford.

DECREASED FARM PRODUCTION

The Roadmap assumes that when downstream businesses or consumers achieve savings from waste reduction, farmers do not experience significant net decreases in demand. The analysis uses the assumption that any lost revenue is made up by shifting to higher value or less resource-intensive products or by changing export behavior. One scenario excluded from the Roadmap is that prevention and recovery efforts at scale could reduce the total value of food produced in the United States.

AVAILABILITY FOR RECOVERY AND RECYCLING

Some interviewees raised a concern that a widespread successful campaign for waste prevention will decrease the food available for recovery or recycling, which could threaten the success of these programs. The Roadmap did not evaluate detailed systems dynamics of these impacts. At the macro level, prevention solutions are constrained by consumer demand for variety, food perishability, and supply and demand imbalances. Unless there are radical breakthroughs in all of these areas, it is a safe assumption that nationally there will continue to be a supply of food to significantly scale up recovery and recycling programs. This may not be true for a small number of localities with unusual waste supply dynamics, which points to the need for waste characterization studies in each municipality.

PREVENTION SOLUTIONS

ANNUAL DIVERSION POTENTIAL

2.6M TONS

ANNUAL ECONOMIC VALUE

$7.7B

INVESTMENT NEEDED OVER 10 YEARS

$6.2B

ANNUAL BUSINESS PROFIT POTENTIAL

$1.9B

ANNUAL GHGS REDUCED

9.7M TONS CO_2e

ANNUAL WATER CONSERVED

1.2T GALLONS

TOP SOLUTIONS BY DIVERSION POTENTIAL

CONSUMER EDUCATION CAMPAIGNS

WASTE TRACKING & ANALYTICS

STANDARDIZED DATE LABELING

MAIN BENEFICIARIES

CONSUMERS

BUSINESSES

ENVIRONMENT

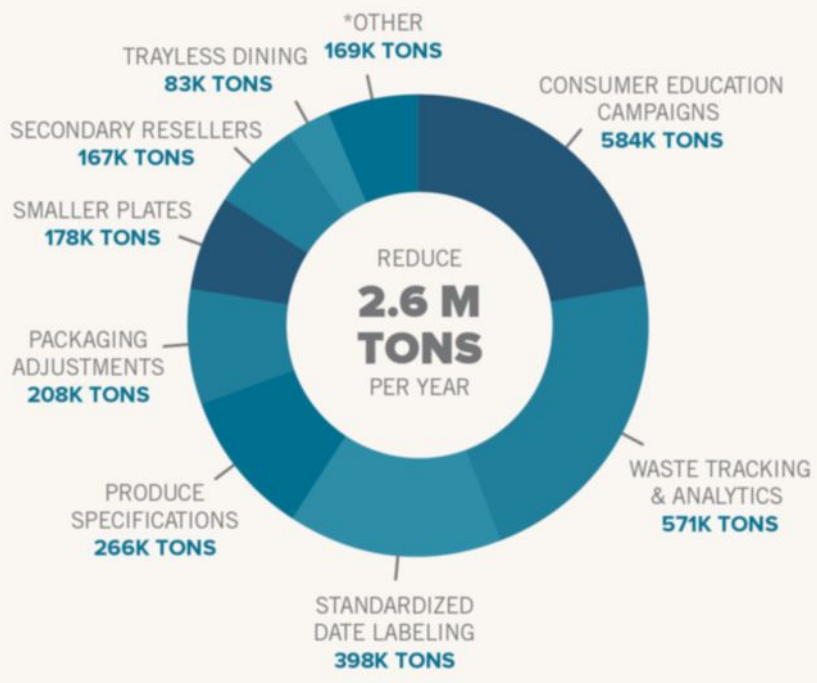
“AN OUNCE of prevention is worth a pound of cure.” Whether in health care, energy, or criminal justice, the most e□cient way to solve a critical social problem is often to invest in prevention. The same holds true with tackling food waste, where solutions that avoid waste o□er the largest social, environmental, and economic benefits. Therefore, prevention should be the first priority for e□ective management of food waste.

PREVENTION: THE OPPORTUNITY

Prevention is applicable across the value chain — from farms to homes. The Roadmap shows that prevention creates three times the societal net Economic Value of recovery and recycling combined. The two most cost-e□ective solutions, Consumer Education Campaigns and Standardized Date Labeling, both require relatively low investment to provide new information to consumers to shift wasteful behavior. Meanwhile, they avoid large volumes of food from being wasted that is valued at expensive retail prices, leading to high relative savings for consumers.

Prevention solutions also provide nearly $1.9 billion of annual Business Profit Potential for consumer-facing businesses. For example, Waste Tracking & Analytics can help restaurants and foodservice providers generate over $1 billion dollars in additional profit through reduced food purchase costs.

PREVENTION SOLUTIONS DIVERSION POTENTIAL



***OTHER:** SPOILAGE PREVENTION PACKAGING **72K TONS/YR**; IMPROVED INVENTORY MANAGEMENT **59K TONS/YR**; MANUFACTURING LINE OPTIMIZATION **20K TONS/YR**; COLD CHAIN MANAGEMENT **18K TONS/YR**

KEY INSIGHTS

Solutions that prevent waste in businesses and homes have the greatest Economic Value per ton and net environmental benefit, diverting 2.6 million tons of annual waste.

- The top three solutions with the greatest Economic Value per ton all utilize prevention: Standardized Date Labeling, Consumer Education Campaigns, and Packaging Adjustments.
- Prevention solutions are generally capital-light; they involve changing behavior through packaging changes, software, and marketing.
- At retail, food is worth roughly $2.50 per pound, magnitudes higher than the value of food scraps for disposal, providing a large economic driver for prevention efforts.

THE CURRENT LANDSCAPE

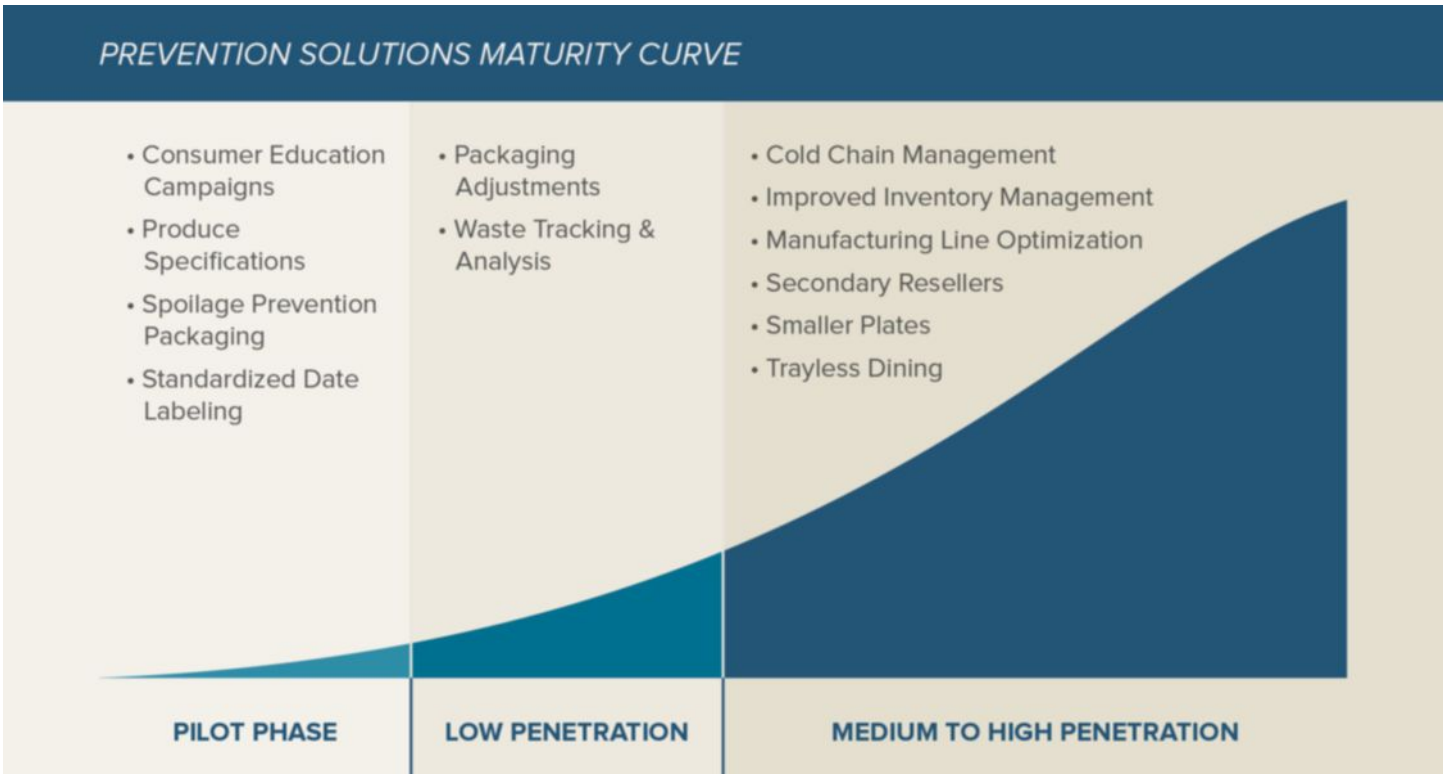
Prevention is largely nascent across the food value chain. For example, of the 12 prevention solutions ReFED analyzed, four are estimated to have less than 5% market penetration or to still be in the pilot phase. Two have an estimated 5% to 25% market penetration, and an additional six have a 25% or greater penetration. With the exception of manufacturers, most food businesses have accepted food waste as an unavoidable hit to their income statements.

Because food waste has often been viewed as a missed opportunity to alleviate hunger rather than as an environmental concern, many companies have not prioritized prevention. For instance, of the dozen retailers and restaurants that ReFED interviewed, all had food recovery programs, but only half were aggressively pursuing prevention. Additionally, when balancing concerns for food safety against waste, most consumers and food businesses choose to err on the side of wasting food rather than taking any health risks — real or perceived.[9]

New prevention technologies are emerging, including waste-tracking tools and packaging innovations. Interviews with ReFED Advisory Council members indicated that these technologies have reduced waste by 5% to 35% in initial pilots.[10] With retailer margins shrinking and consumer awareness growing, investment in prevention technologies is expected to grow.

At present, there is little in the policy landscape helping or hindering food waste prevention. Some solutions such as Standardized Date Labeling would benefit from a stronger policy environment, but the lack of policy in this space has not deterred stakeholders from proactively implementing change.

The maturity curve below shows the range of penetration of prevention solutions analyzed, highlighting a major opportunity to scale.



BARRIERS TO FOOD WASTE PREVENTION

Some overarching barriers to food waste prevention include:

MISALIGNMENT OF COSTS AND BENEFITS: There is limited reason for businesses to implement a new technology or process if another part of the supply chain receives the benefit. For example, businesses may find it hard to build a business case to invest in Packaging Adjustments, Spoilage Prevention Packaging, or

Standardized Date Labeling when consumers get most of the cost savings and the e□ect on enhanced brand equity is unclear.

LACK OF SOCIAL LICENSE: Consumer expectations for variety and cosmetic perfection constrain businesses from streamlining product selection, o□ering cosmetically imperfect food, reducing portion sizes, or even investing in proven approaches such as cold chain and inventory management. Food waste and its consequences are largely invisible to the public.

INFORMATION GAPS: There is uncertainty about where food waste occurs, how much is being wasted, and its associated value. During distribution, crates and packaging mask sight and smell so rapidly ripening produce cannot be separated out and moved to customers faster.

ORGANIZATIONAL SILOS: Implementing prevention solutions requires collaboration between di□erent departments within participating businesses, including buyers, merchants, store managers, chefs, waste managers, and financial analysts. Employees in di□erent parts of an organization may not be aware of the fully loaded cost implications of waste.

More information on the barriers to food waste prevention are available in NRDC's report "Wasted" [11] and from the Food Waste Reduction Alliance.

CASE STUDY: BON APPETIT MANAGEMENT COMPANY www.bamco.com

Bon Appetit Management Company (BAMCO), an on-site restaurant company that serves universities, corporations, and other institutional venues in 33 states, has embraced food waste as a key part of its sustainability e□orts.

BAMCO has explored a number of solutions to address food waste in its supply chain, prevent waste in its cafes, and recover food for donation. For example, by removing trays in its all-you-can-eat facilities, BAMCO enabled diners to improve self-portioning and reduce post-consumer plate waste, which contributes 50% to 75% of overall foodservice waste volumes. BAMCO also successfully reduced pre-consumer food waste in its cafes by deploying waste analytics software to track, monitor, and analyze kitchen waste.

In 2013, BAMCO created a Waste Specialist position dedicated to addressing its toughest food waste challenges. A year later, it launched the Imperfectly Delicious Produce program to tackle the opportunity of "ugly food" on farms — blemished, misshapen, or visually imperfect produce that fails strict retail market standards, but is otherwise perfectly safe to eat. By engaging directly with farmers and distributors to procure imperfect produce and working with chefs to incorporate this supply into menu o□erings, BAMCO pioneered a novel approach to waste reduction that it continues to expand today.

By taking a comprehensive approach, BAMCO has found improvement opportunities across its supply chain, from farms to kitchens to consumer behaviors. This sweeping approach has maximized the cost savings that BAMCO can achieve from food waste diversion, as well as enhanced its brand with customers.

PREVENTION SOLUTION DESCRIPTIONS

The top three solutions represent 60% of the total prevention diversion potential: Consumer Education Campaigns, Waste Tracking & Analytics, and Standardized Date Labeling. The solution descriptions on the following pages are sorted by diversion potential.

TOP THREE PREVENTION SOLUTIONS BY DIVERSION POTENTIAL

1. CONSUMER EDUCATION CAMPAIGNS

DEFINITION

Conducting large-scale advocacy campaigns to raise awareness of food waste and educate consumers about ways to save money and reduce wasted food

DIVERSION POTENTIAL

584K TONS

ECONOMIC VALUE

$2.65B

TIMEFRAME

MEDIUM TERM

PENETRATION

PILOT

WHO BENEFITS

CONSUMERS

WHO CAN TAKE ACTION

CONSUMER-FACING BUSINESSES

MUNICIPALITIES

NONPROFITS

OVERVIEW

According to the UN Food and Agriculture Organization (FAO), North American consumers lead the world in per-capita food waste. From making better use of leftovers to learning how to minimize spoilage by properly storing perishable foods, consumers have a direct hand in reducing waste in and outside the home. Increased awareness may also inspire consumers to demand that businesses operate more responsibly.

CHALLENGES

- Households throw away food for any number of reasons, including poor planning, inability to consume food in a timely manner, and a lack of awareness.
- Overcoming apathy or indi erence is the most significant hurdle to overcome. Surveys show that while consumers understand the importance of food waste reduction, they don't recognize their own role in solving the problem.[12]
- Consumer behavior change for any issue requires a long time horizon, which can inhibit investment and the ability to track impact.

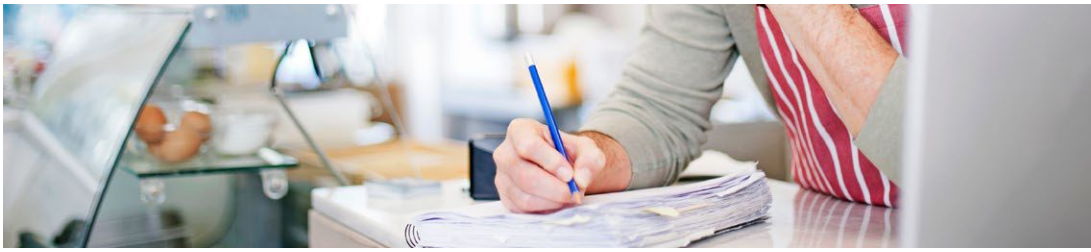
STAKEHOLDER ACTIONS

- Private and public stakeholders, supported by foundations, can collectively invest in consumer education e orts that increase awareness, o er tips for extending food shelf life and storing perishables properly, and promote a culture of active waste avoidance. Messaging should appeal to a wide variety of values, including reducing food bills.
- Nonprofits and local governments can extend the reach of a national advertising campaign to additional consumer segments. They can develop regionally relevant recipes and suggestions for repurposing leftovers, as well as simple toolkits for consumers to calculate the costs of throwing out food.
- Businesses can inform customers at the point-of-selection about ways to save money by wasting less. Retailer in-store media campaigns can provide information about products and packaging that have waste prevention attributes. Foodservice providers and restaurants may display waste-related messaging to customers. Consumer waste education is a branding opportunity for businesses to demonstrate their commitment to resource conservation.
- Campaigns can partner with nonprofits to track impact metrics to inform further targeted messaging. While studies have been conducted in the United Kingdom and elsewhere to measure the impact of consumer education, there has been minimal tracking in the U.S. to ensure that campaigns are e ective.

EXAMPLES

- In 2015, Walmart ran a video campaign in checkout lanes across the country explaining ways shoppers could save money by reducing food waste at home.
- In 2016, NRDC, in partnership with the Ad Council, will launch a major three-year public service campaign targeted at "moms and millennials" to communicate the benefits of food waste reduction, including the cost savings opportunities. The media campaign can be expanded to other consumer segments, deepened in priority regions, and extended beyond three years.
- In the U.K., the Waste and Resources Action Programme (WRAP) launched "Love Food Hate Waste," a national consumer awareness campaign that included print and web materials. It successfully reduced consumer food waste by 21% in five years.[13]

2. WASTE TRACKING & ANALYTICS



DEFINITION

Providing restaurants and prepared-food providers with data on wasteful practices to inform behavior and operational changes

DIVERSION POTENTIAL

571K TONS

ECONOMIC VALUE

$1.3B

TIMEFRAME

NEAR TERM

PENETRATION

LOW

WHO BENEFITS

RESTAURANTS

FOODSERVICE AND INSTITUTIONS

WHO CAN TAKE ACTION

RESTAURANTS

FOODSERVICE AND INSTITUTIONS

NONPROFITS

ENTREPRENEURS

MUNICIPALITIES

OVERVIEW

Every business has heard the adage “what is measured gets managed,” and this is true for food waste as well. Waste tracking and analytics tools include the publicly available Conserve program o□ered by the National Restaurant Association, private solutions such as LeanPath, and internally built business tools. Waste tracking varies in sophistication from using scales, cameras, and phone apps to basic paper and pen to collect and analyze data.

This data helps businesses identify the volumes and types of food that are tossed out during food preparation, informing operational changes and building the business case for investment in other solutions. There is a recent uptick in interest in waste tracking because it achieves two corporate priorities: increased profit margins and data reporting to show external stakeholders a path to lower overall waste levels.

CHALLENGES

- Many food facilities have no existing data to analyze waste.
- Restaurants and foodservice providers have not invested in this solution primarily because they are not aware of the potential cost savings at their facilities.
- Existing waste tracking tools may have the reputation for being either extremely expensive or cumbersome to use, although the cost and ease of use of tools is improving across the market.
- Tracking and analytics tools require an upfront investment of time and resources to realize a positive bottom-line impact.

STAKEHOLDER ACTIONS

- Restaurants and foodservice providers can deploy pilots in select facilities to demonstrate the positive return on investment. Waste tracking tools can improve employee engagement with sta□ who care about hunger and environmental issues.
- Strong corporate leadership is needed to overcome organizational silos because managers, chefs, and kitchen sta□ all need to buy into the benefits in order to coordinate implementation.
- Investors can fund entrepreneurs working to reduce operational costs and labor requirements for these technologies. This includes new camera or sensor technology to reduce the need for sta□ to manually input data.
- Nonprofits and municipalities can partner with technology providers to o□er discounted rates and employee training. Nonprofits that purchase a lot of food, such as nursing homes, colleges, and food banks, can increase their impact by freeing up operational dollars that previously were spent on discarded food.

EXAMPLES

- The National Foundation to End Senior Hunger’s “What a Waste” program partnered with LeanPath to implement waste tracking for senior nutrition programs.
- Stony Brook University adopted a food waste reduction program called Trim Trax, developed by foodservice contractor Compass Group to help businesses track and measure food waste costs.[14,15]
- StopWaste, a public agency in Alameda, Calif., launched the “Smart Kitchen Initiative” with LeanPath to subsidize the adoption of waste tracking and analytics tools among businesses that perceive too much risk to implement on their own.[16]

3. STANDARDIZED DATE LABELING

DEFINITION

Standardizing food label dates and instructions, including eliminating “sell by” dates, to reduce consumer confusion

DIVERSION POTENTIAL

398K TONS

ECONOMIC VALUE

$1.8B

TIMEFRAME

MEDIUM TERM

PENETRATION

PILOT

WHO BENEFITS

CONSUMERS

WHO CAN TAKE ACTION

CONSUMER-FACING BUSINESSES

MUNICIPALITIES

NONPROFITS

OVERVIEW

Current date labeling practices on food packaging cause confusion with “sell by,” “best by,” “use by,” and “best before” dates, leading up to 90% of Americans to occasionally throw out still-fresh food. Confusion over the meaning of date labels is estimated to account for 20% of consumer waste of safe, edible food.[17] This equates to approximately $29 billion of wasted consumer spending each year — 5% to 10% of this is expected to be impacted by Standardized Date Labeling.

CHALLENGES

- There is no comprehensive national regulation or government agency with the direct mandate to regulate food date labeling for safety and perishability.[18]
- Consumers face a confusing array of labels and phrasing that di□er widely based on varied state laws and manufacturer preferences.
- The cost of changing the date labels is negligible, but manufacturers have little incentive to change their practices because date label standardization would do little to lower costs, increase revenues, or reduce liability.
- Retailers could push for standardization from manufacturers but would need to collaborate with others to represent enough market share to drive manufacturers to change. There may be an opportunity for retailers to reduce operational and food costs associated with pulling near-expired product from shelves. Additional research is needed to quantify this potential benefit.
- Retailers and manufacturers consistently cite uncertainty regarding the design of standardized labels and wording as well as skepticism of its widespread impact on consumer behavior, as two reasons for not moving forward on a voluntary approach.
- Nineteen states restrict sale of products after the date on the label has passed even though the majority have no safety risk associated with the date. In addition to wasted food, this leads to fines when retailers have past-date products in their stores.

STAKEHOLDER ACTIONS

- Changes to date labels require little upfront investment from businesses and can be enacted unilaterally by large food companies to reduce consumer confusion. The best path forward is for a voluntary agreement of manufacturers to implement consistent language.
- If a voluntary agreement is not forthcoming, a multi-stakeholder approach is recommended to overcome inertia and achieve true standardization. This multi-stakeholder approach should aim to de-risk any industry concerns by working with consumer behavior experts to determine the best language for labels, develop a process for measuring if the implemented change is leading to the desired results, and fund consumer education to go alongside the change.
- In the absence of a voluntary commitment from industry, ReFED recommends that the federal government update existing FDA regulations to standardize date label wording. The federal government could also fund consumer education about these new date labeling practices in partnership with other private and public sector organizations.
- In addition, states should revoke restrictions on sale or donation after the date on the label. This could also be achieved through federal legislation.

EXAMPLES

- The Food Recovery Act, currently proposed and pending (as of February 2016) by Rep. Chellie Pingree, recommends standardizing labels with the phrase “best if used by," followed by “manufacturers suggestion only” and a standard “expires on” date required for the small number of items determined by the FDA to have food safety risks.[19]
- Some manufacturers have experimented with adding “freeze by” language onto packaging to encourage customers to take active steps to preserve food in the freezer instead of throwing it in the trash.

4. PRODUCE SPECIFICATIONS (IMPERFECT PRODUCE)

PENETRATION: **PILOT**
TIMEFRAME: **MEDIUM TERM**

DIVERSION POTENTIAL: 266K TONS | ECONOMIC VALUE: $277M

Who Benefits:

CONSUMER-FACING BUSINESSES, CONSUMERS

Who Can Take Action:

FARMERS, CONSUMER-FACING BUSINESSES, ENTREPRENEURS, STATE & FEDERAL GOVERNMENTS

DEFINITION

Accepting and integrating the sale of o□-grade produce (short shelf life, di□erent size/shape/color), also known as “ugly” produce, for use in foodservice and restaurant preparation and for retail sale

CHALLENGES

- Consumer-facing businesses are often unfamiliar with cost-saving opportunities from buying imperfect produce and are not o□ered it by their suppliers. Education is needed on how products could replace (foodservice) or supplement (retail) existing purchasing.
- Some retailers have concerns about the impact of imperfect produce on their brands; creativity is needed in menu planning for foodservice and institutions.
- Economics for farmers are unclear since cosmetically imperfect produce may partially cannibalize sales for top-tier, cosmetically perfect products.

STAKEHOLDER ACTIONS

- Businesses can set up pilots to partner with individual farmers and distributors to assess the economics and culinary dynamics of utilizing imperfect produce.
- Entrepreneurs and existing produce suppliers can support sourcing, di□erentiated marketing and branding, and innovative processing for imperfect produce.
- Foundations and USDA grants can support marketing and educational e□orts to farmers and consumers to stimulate adequate supply and demand for imperfect produce.
- State and federal governments can include stipulations in purchasing contracts to support the purchase of cosmetically imperfect products.

EXAMPLES

- See Bon Appetit Management Case Study, page 30.

CASE STUDY: WALMART www.walmart.com

As the largest U.S. food retailer, Walmart captures roughly 25% of all grocery market share — more than twice that of the next largest competitor. True to its mission to save money for its customers, Walmart is trying to find savings in food waste. With its size and buying power, Walmart has already piloted a number of waste prevention solutions.

In its perishables supply chain, Walmart recently experimented with smart labeling technology — electronic devices attached to produce shipping containers and crates to monitor spoilage. Despite significant implementation costs, ranging from RFID tags to handheld reader devices, Walmart developed the business case for this technology investment based on long-term expectations of reduced inventory loss.

To help its customers, Walmart also began a campaign to work directly with its suppliers to standardize date labels on the packaging of all of its privately branded products to provide clear and consistent information to customers. As an early adopter of date label standardization, Walmart has set a precedent for other retailers and manufacturers to follow.

With several pilots in progress, Walmart provides a signal to the broader retail industry that food waste prevention is a critical step to managing costs and staying competitive in the sector.

5. PACKAGING ADJUSTMENTS

PENETRATION: **LOW**
TIMEFRAME: **MEDIUM TERM**

DIVERSION POTENTIAL: 208K TONS	ECONOMIC VALUE: $715M
Who Benefits: **CONSUMERS (PRIMARILY) AND RETAILERS**	Who Can Take Action: **RESEARCHERS, MANUFACTURERS, CONSUMER-FACING BUSINESSES, ENTREPRENEURS**

DEFINITION
Optimizing food packaging size and design to ensure complete consumption by consumers and avoid residual container waste

CHALLENGES
- A large range of packaging sizes and configurations exists, requiring many individual solutions.
- Although easy grab-n-go snack packs are widely available, most other standard packaging has not been changed to minimize waste.
- Large bulk packaging can market lower net unit costs, often encouraging consumers to over purchase in the hopes of achieving net savings.
- Packaging that reduces food waste may have other environmental trade-o□s, such as higher net packaging volume or use of materials that are more challenging to recycle.
- Smaller packaging sizes can have unintended consequences by increasing SKUs and inventory needs.

STAKEHOLDER ACTIONS
- Nonprofits, academia, manufacturers, and trade associations can conduct research on packaging configurations and their impact on waste levels.
- Universities and accelerators can launch competitions to identify packaging innovations.
- Manufacturers and other food businesses can support entrepreneurs as pilot customers.

EXAMPLES
- In the U.K., bread was identified as one of the most thrown away items. In response, manufacturer Kingsmill recently introduced the "Little Big Loaf" to decrease the amount of bread wasted.[20]
- MIT engineers developed LiquiGlide, a nontoxic food packaging coating that increases the consumer's ability to get all of the food out of containers like ketchup bottles.[21]

6. SMALLER PLATES

PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 178K TONS	ECONOMIC VALUE: $382M
Who Benefits: **FOODSERVICE, INSTITUTIONS, RESTAURANTS**	Who Can Take Action: **FOODSERVICE, INSTITUTIONS, RESTAURANTS**

DEFINITION
Providing consumers with smaller plates in self-serve, all-you-can-eat dining settings to reduce consumer waste

CHALLENGES
- There are upfront switching costs needed to purchase new plates.
- It is uncertain whether smaller plates impact customer satisfaction by requiring more frequent trips for refills.

STAKEHOLDER ACTIONS
- Nonprofits and academia can study the brand impact of smaller plates to address concerns about negative impacts on customer loyalty.
- Businesses can experiment with alternative plate sizes to gauge consumer reaction and measure business impacts.
- Corporate financing is needed to implement across entire organizations.

EXAMPLES
- Cornell Professor Brian Wansink's research on food psychology found that consumers given larger bowls took (and consumed) 16% more cereal than those with smaller bowls. Consumers generally find a 70% fill rate to be "visually pleasing," so smaller plates reduce the amount of food consumers serve themselves.[22]

7. SECONDARY RESELLERS

PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **MEDIUM TERM**

DIVERSION POTENTIAL: 167K TONS	ECONOMIC VALUE: $37M
Who Benefits: **RETAILERS, CONSUMERS**	Who Can Take Action: **RETAILERS, NONPROFITS**

DEFINITION

Businesses that purchase unwanted processed food and produce direct from manufacturers/ distributors for discounted retail sale to consumers

CHALLENGES

- Businesses benefit from reliable product procurement and must understand trends in manufacturing and distribution to anticipate changes in market supply.
- Discount grocery stores have low margins and require e□cient operations to achieve a profit.
- The buildout of a retail store and initial losses during the first year of launch typically require a multi-million dollar investment per store.

STAKEHOLDER ACTIONS

- Stores can scale slowly to improve their understanding of consumer demand and local needs to identify how to e□ciently grow.
- Government and foundation loans can help secondary resellers expand to lower-income neighborhoods with less access to fresh foods thus helping to address higher food insecurity; nonprofits can lend expertise in analyzing these regions.

EXAMPLES

- Grocery Outlet's 225 retail stores, based primarily on the West Coast, work with manufacturers to understand their particular waste issues (the top reason is short-coded products near expiration) and come up with a custom distribution path.[23]
- Daily Table, located in Dorchester, Mass., is a not-for-profit retail store o□ering fresh, healthy "grab-n-go" meals and other grocery items at a bargain prices. These deals are available because Daily Table works closely with a large network of growers, supermarkets, manufacturers, and other suppliers who donate their excess healthy food and provide special buying opportunities.

8. TRAYLESS DINING

PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 83K TONS	ECONOMIC VALUE: $187M
Who Benefits: **FOODSERVICE, RESTAURANTS**	Who Can Take Action: **FOODSERVICE AND INSTITUTIONS, RESTAURANTS, STUDENTS, NONPROFITS**

DEFINITION

Eliminating tray dining in all-you-can-eat dining establishments to reduce consumer waste

CHALLENGES

- Retrofits to tray and plate returns are often needed if consumers are required to walk far distances or climb stairs while balancing plates. These can cost $10,000 to $25,000 per facility, but many institutions lack upfront capital to pay for them.
- Because trayless dining has been widely adopted by larger facilities, the remaining opportunity requires change within smaller facilities or those more resistant to change, including 10% of self-serve bu□et restaurants and 40% of cafeterias and dining halls.

STAKEHOLDER ACTIONS

- Education to consumers must be paired with any switch to trayless dining to reduce consumer complaints about the switch.
- Foodservice companies can develop a loan fund, similar to revolving energy e□ciency loan funds, to help pay for the upfront costs from institutions; loans will be repaid through cost savings.
- Student campaigns at universities can ask foodservice managers to remove trays from dining halls to promote the benefits of food waste reduction.

EXAMPLES

- University of Massachusetts Amherst dining halls removed trays from all dining halls in 2009 and reduced post-consumer food waste by 30%.[24]

9. SPOILAGE PREVENTION PACKAGING

PENETRATION: **PILOT**
TIMEFRAME: **MEDIUM TERM**

DIVERSION POTENTIAL: 72K TONS	ECONOMIC VALUE: $167M
Who Benefits: **CONSUMERS (PRIMARILY) AND RETAILERS**	Who Can Take Action: **CONSUMER-FACING BUSINESSES, ENTREPRENEURS, RESEARCHERS**

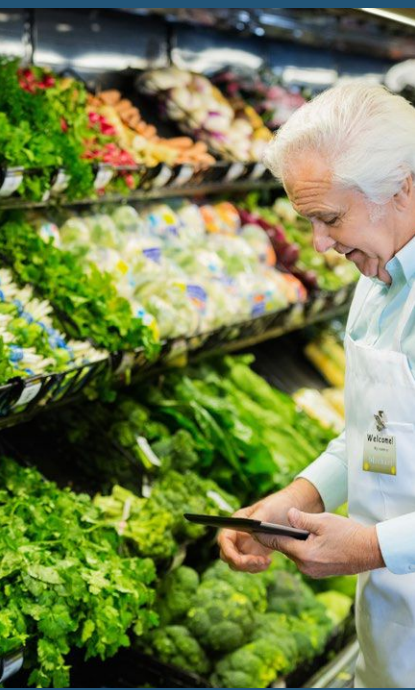
DEFINITION
Using active intelligent packaging to prolong product freshness and slow down spoilage of perishable fruit and meat

CHALLENGES
- Enhanced shelf life and the associated reduction in food waste from spoilage prevention packaging is highly variable for each food type. To prove that the impact is broad, pilots need to be conducted across many product categories.
- Businesses must pay for the product enhancement, but they may not see the direct savings if shelf life is only extended for consumers.
- The extent to which consumers will pay more for products with longer shelf life is untested, which may require the extra cost to be borne by the retailer.

STAKEHOLDER ACTIONS
- Retailers and manufacturers can use pilots to test consumer willingness to pay higher prices for this packaging along with the cost benefits from extended shelf life.
- Investors can fund technology innovators to bring down costs and invest in consumer marketing to spur demand.

EXAMPLES
- It's Fresh! uses an ethylene-removal technology that can be inserted during packaging of produce to help extend the shelf life. [25]
- BluWrap uses a controlled atmosphere technology solution to reduce oxygen in protein packages during transit to extend shelf life.[26]

10. IMPROVED INVENTORY MANAGEMENT



PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 59K TONS	ECONOMIC VALUE: $71M
Who Benefits: **RETAILERS**	Who Can Take Action: **RETAILERS, ENTREPRENEURS**

DEFINITION
Improvements in the ability of retail inventory management systems to track an average product's remaining shelf-life (time left to sell an item) and inform e□orts to reduce days on hand (how long an item has gone unsold)

CHALLENGES
- Current systems are optimized for minimizing stock-outs, not measuring and managing food waste. Therefore, managers optimize to ensure food is left over on the shelf.
- Although larger retailers and national chains typically use inventory management systems, it has not been seen as cost-e□ective among smaller retailers.

STAKEHOLDER ACTIONS
- Retailers can increase the e□ectiveness of inventory management systems by adding data on food donation levels as well as the quantity of any food waste and reasons for being disposed.
- Retailers can use inventory systems to help set corporate and individual buyer and store manager goals to reduce waste levels.
- Retailers can develop better forecasting and share the data transparently throughout the supply chain to better match supply and demand.

EXAMPLES
- Applied Data Corporation uses enhanced analytics to manage the stages of fresh food items for grocery and supermarkets throughout their life cycle, from ingredients ordering to display management and decision-making.[27]

11. MANUFACTURING LINE OPTIMIZATION

PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 20K TONS	ECONOMIC VALUE: $35M
Who Benefits: **MANUFACTURERS**	Who Can Take Action: **MANUFACTURERS**

DEFINITION
Targeting systemic and sporadic waste generation by optimizing equipment operating conditions (e.g. determining the most e□cient run settings), addressing production line design flaws, modifying production schedules to minimize changeovers, and identifying novel ways to repurpose discarded food for sale

CHALLENGES
- Each plant and product line is unique with di□erent opportunities for waste reduction, leading to di□culties identifying widespread solutions.
- Many of the most obvious waste prevention opportunities have already been implemented as cost-savings initiatives.

STAKEHOLDER ACTIONS
- Internal action teams can identify waste reduction opportunities, including holding competitions among facilities that incentivize workers to reduce waste.
- Employers can enhance existing worker training programs to include a food waste identification component and develop programs to reward proactive employee behavior.

EXAMPLES
- ConAgra changed the way it transitioned between pudding flavors to create blended flavors that could be sold at a lower value.[28]

12. COLD CHAIN MANAGEMENT

PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **MEDIUM TERM**

DIVERSION POTENTIAL: 18K TONS	ECONOMIC VALUE: $32M
Who Benefits: **RETAILERS**	Who Can Take Action: **DISTRIBUTORS, RETAILERS, NONPROFITS**

DEFINITION
Reducing product loss during shipment to retail distribution centers by using direct shipments and cold-chain-certified carriers

CHALLENGES
- The food logistics industry is highly fragmented.
- Retailers lack a financial incentive to act since they typically can pass the cost of rejected food as a loss back to the shipper or supplier.
- Smaller suppliers and distributors are motivated to reduce losses but lack the scale, financial capacity, and time to implement new practices.

STAKEHOLDER ACTIONS
- Retailers and manufacturers can develop performance standards.
- Large retailers can create demand for better cold chain practices among the fragmented logistics industry by using their buying power to encourage suppliers to change practices.
- Academic studies can analyze the business case for how point-to-point food shipments minimize temperature-related losses during transit.
- Nonprofits or industry players can develop a cold chain certification system that outlines best practices and holds businesses accountable for avoiding preventable waste.

EXAMPLES
- Tesco increased the shelf life of several fruits and vegetables by two days by cutting their time in transit through direct shipments from suppliers to stores.[29]
- The Global Food Safety Initiative is a new certification system example that includes cold chain management practices.

RECOVERY SOLUTIONS

ANNUAL DIVERSION POTENTIAL

1.1M TONS

ANNUAL ECONOMIC VALUE

$2.4B

INVESTMENT NEEDED OVER 10 YEARS

$8.7B

ANNUAL MEALS RECOVERED

1.8B

ANNUAL JOBS CREATED

4,000

GHGS REDUCED

3.4M TONS CO_2e

TOP SOLUTIONS BY DIVERSION POTENTIAL

DONATION TAX INCENTIVES

STANDARDIZED DONATION REGULATION

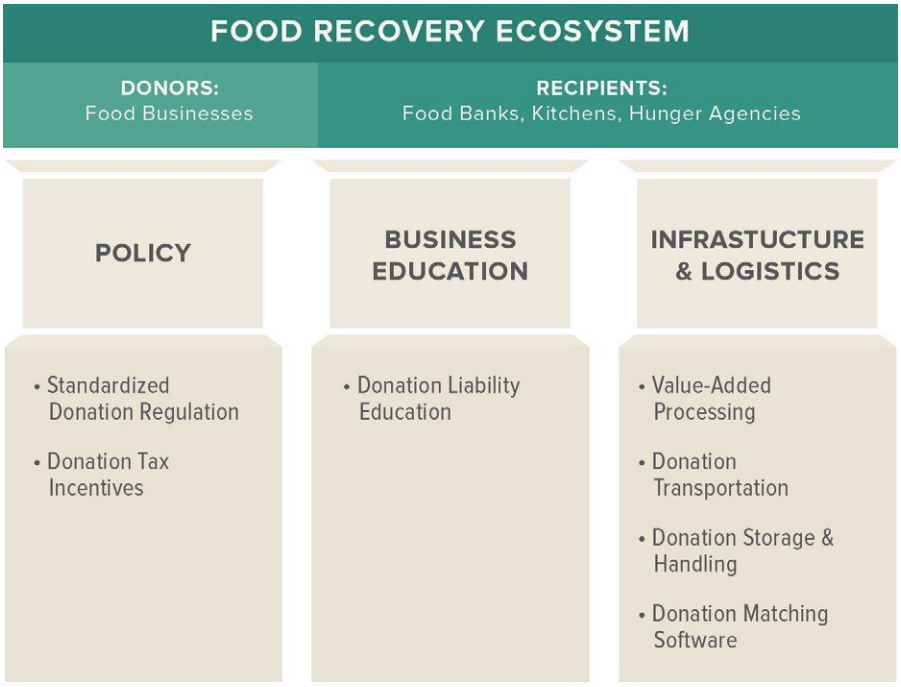
DONATION MATCHING SOFTWARE

MOST PEOPLE have seen perfectly good food thrown away at a restaurant, bakery, or dinner party and wished there was a way to get it to people in need. Food recovery captures that food and transports it while it is still edible to help address the issue of food insecurity.

FOOD RECOVERY: THE OPPORTUNITY

Although food recovery initiatives already exist throughout the country, there is significant opportunity to increase donations. Food recovery networks in the U.S. — spanning food banks, pantries, soup kitchens, shelters, and other agencies — already receive and distribute nearly 1.7 million tons of rescued food each year. Based on ReFED's analysis, over three times this amount — up to 5.8 million additional tons — could be feasibly recovered from food businesses one day.* The Roadmap shows how approximately 20% of this additional recovery potential, or 1.1 million tons (1.8 billion meals), can cost-effectively be recovered over the next decade.

While prevention strategies can be implemented as one-off solutions, recovery requires an ecosystem approach supported by three pillars: 1) education for food businesses on donor liability protections and safe food handling practices, 2) enabling policy to financially incentivize donations from businesses while providing standardized and science-based food safety regulations, and 3) efficient logistics and infrastructure to transport, process, and distribute excess food. Of these pillars, two types of enabling policy, Standardized Donation Regulation and Donation Tax Incentives, would drive over half of the overall recovery opportunity analyzed in the Roadmap.



* Baseline data based on Feeding America reported recovery data and market share. Additional recovery potential is based on calculations of total waste available for recovery and does not account for increasing marginal costs of recovery or the volume of actual meals needed to end hunger.

KEY INSIGHTS

Food recovery can increase by 1.8 billion meals annually, nearly doubling the amount of meals rescued today and diverting 1.1 million tons of waste.

- The food recovery ecosystem requires three pillars to scale: education for businesses, enabling policy, and efficient use of transportation and cold storage.
- Over half of the opportunity requires legislation, including the maintenance and expansion of tax incentives for business donations and the standardization of food handling safety regulations.
- Nearly half of new recovery potential comes from produce surpluses on farms and at packinghouses, a sector with lower levels of donations today than food retailers.

The Roadmap projects that nearly half of new recovery potential comes from farms, over a third from restaurants, and the remainder from grocery retailers. ⊕

The large potential for on-farm food recovery is a novel finding from the Roadmap. While many reports have highlighted the over 50 million tons of waste heading to landfills annually, up to 10 million tons of edible food tilled into farm soils or culled in on-farm packing houses is often ignored. ReFED estimates that less than 5% of this loss is being recovered today, primarily through farm-to-food-bank programs that have emerged over the past five to 10 years in several states.

Beyond farms, restaurants and foodservice have large volumes of food available but in smaller batches, so handling and transportation costs become a limiting factor. There is more limited incremental recovery opportunity from retailers and manufacturers given that these programs have been established for many years.

FOOD RECOVERY: THE CURRENT LANDSCAPE

The existing food recovery system is vast. Hundreds of regional and statewide food banks supply over 60,000 food recovery and hunger agencies, which in turn collect, handle, and distribute food to the hungry.[30] Currently, this industry relies on donations from all types of food businesses, including retailers and manufacturers and, to a lesser extent, farmers, restaurants, and foodservice providers.

Food banks and hunger agencies have traditionally relied on canned and processed food to serve their clients. New approaches to food recovery incorporate fresh produce and other nutritious foods. Rather than rebuilding the current food recovery system, the Roadmap envisions leveraging existing infrastructure and resources to incorporate more perishable sources of food.

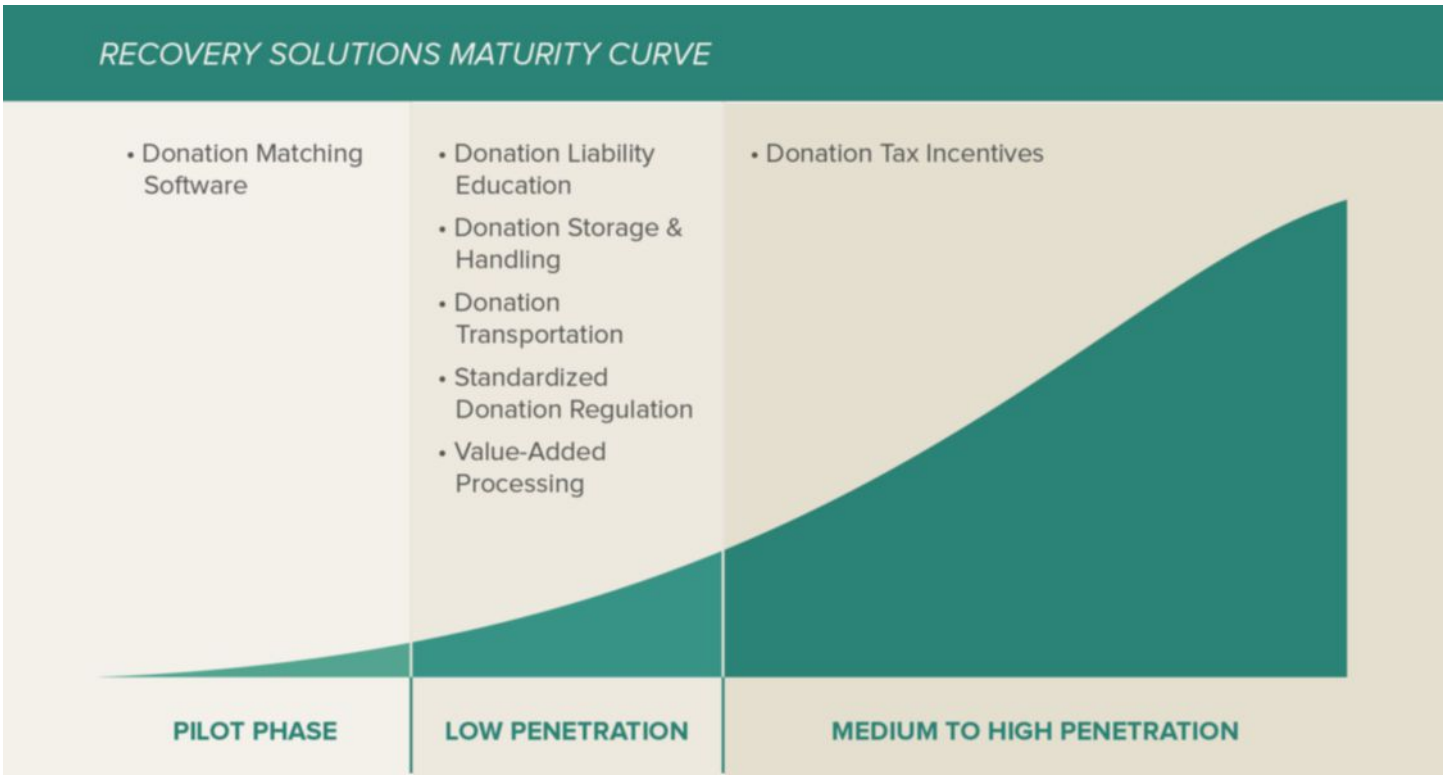
In this complex web of overlapping local networks, scale and transaction costs matter immensely. Large batches of food, such as a few dozen tons of potatoes, need significant transport, storage, and nonprofit labor and processing resources to be e□ectively utilized before spoiling. Conversely, if one bakery wants to donate a bag of 50 bagels, it is often hard to justify the labor and infrastructure costs needed to transport it to a donor recipient. The sector relies heavily on volunteer and philanthropic support.

LESS THAN 5% OF ON-FARM FOOD LOSS IS BEING RECOVERED TODAY.

⊕ More information available in the Technical Appendix on refed.com.

Given the highly local nature of most recovery e□orts, it is not surprising that most innovations have not spread widely. Donation Matching Software is the only recovery solution in the pilot stage. The majority of solutions have low penetration. There are examples of the solutions across the country, but they have not scaled widely. Donation Tax Incentives is the only solution with relatively high penetration.

The maturity curve below shows the range of penetration of recovery solutions analyzed.



REGIONAL CHALLENGES

Geographic variance in where unrecovered food is available versus where hunger is concentrated makes overarching national solution implementation impractical. While rural households are typically close to farms with excess food, families facing hunger are typically spread out making delivery of food more di□cult. There are also fewer nonprofit agencies operating with resources to support these communities. On the other hand, urban solutions benefit from population density and resource e□ciencies but may lack food sourcing and procurement channels if farms and manufacturers are located further away.

Food recovery is also complicated by the di□erent types of food available for donation. California, where almost half of all fruits, nuts, and vegetables are grown in the U.S., yields di□erent food surpluses than Midwest states that focus more on grain and livestock.[31] In regions such as the Northeast that have smaller agriculture sectors, food banks have not prioritized relationships with local farms, although this is starting to shift.[32] At retail and foodservice facilities, perishability introduces yet another layer of considerations; produce grown in California and sold in New York has significantly less remaining shelf life than locally grown produce.

Produce terminals and port cities, such as Los Angeles and New York City, also o□er large recovery opportunities, and certain border towns generate truckloads of blemished or otherwise unmarketable produce that could be recovered to a much greater extent than current practice.[33] For example, over half of the produce that is imported from Mexico comes through a single border crossing in Nogales, Ariz.[34]

BARRIERS TO FOOD RECOVERY

LIABILITY CONCERNS: The federal Good Samaritan Food Donation Act protects donors and recipients from civil or criminal liability short of gross negligence and misconduct. However, this legislation remains unproven and untested in court leaving corporate legal departments without a precedent to follow that would allow them to fully support food donation. Brand protection is another concern. As one retailer explained, “It doesn’t matter if I can’t be sued; it’d almost be worse to have the company’s name on the front page of the Wall Street Journal in conjunction with someone dying from eating our food.”[35]

FRAGMENTED REGULATION: Health regulations vary by city and state, arising from “home rule” authority in some localities and di□ering interpretations of the FDA Food Code, which only loosely defines basic requirements for food safety. This hampers national and global companies from developing uniform food donation policies across their organizations.

HANDLING, TRANSPORTATION, AND STORAGE: Many consumer-facing businesses lack su□cient facilities to store food for donation.[36] Food banks and pantries may similarly not have su□cient infrastructure or labor capacity to accept large donation volumes, especially of perishable foods requiring refrigeration or freezing.

FINANCIAL VIABILITY: Donating food for recovery often involves additional handling costs beyond regular disposal. For instance, state and federal tax benefits for recovered food rarely cover the farm labor costs involved. Without a way to recoup these costs, businesses are more likely to default to the path of least resistance: disposal.

RECOVERY SOLUTION DESCRIPTIONS

The top three solutions represent 66% of the total recovery diversion potential: Donation Tax Incentives, Standardized Donation Regulation, Donation Matching Software.

TOP THREE RECOVERY SOLUTIONS BY DIVERSION POTENTIAL

SPOTLIGHT ON FOOD DONATION TAX INCENTIVES

In December 2015, Congress signed into law a tax break package with provisions making permanent the charitable giving tax incentives for donating food. Supported by a coalition of nonprofit organizations including Feeding America, the Protecting Americans from Tax Hikes (PATH) Act made various new business entities eligible for food inventory enhanced deductions that had previously only been accessible to large C corporations.

Under the previous standard food donation deduction, a business could only claim the cost basis of donated inventory. An enhanced deduction passed in this legislation allows businesses to claim both the cost basis and half of potential profits if the inventory could be sold at fair market value. This new legislation is expected to spur increased donations from farms and smaller retailers and restaurants.

1. DONATION TAX INCENTIVES

DEFINITION

Expanding federal tax benefits for food donations to all businesses and simplifying donation reporting for tax deductions

DIVERSION POTENTIAL

383K TONS

ECONOMIC VALUE

$470M

MEALS RECOVERED

638M

TIMEFRAME

NEAR TERM

PENETRATION

MEDIUM - HIGH

WHO CAN TAKE ACTION

STATE AND FEDERAL GOVERNMENT

RESEARCH AND ADVOCACY ORGANIZATIONS

BUSINESSES

FOUNDATIONS

OVERVIEW

Tax incentives, whether in the form of credits or deductions, induce farms, retailers, restaurants, and foodservice providers to undertake the behavioral and operational changes needed to donate additional food instead of sending it to disposal. It is expected that the tax benefits will roughly equal the incremental costs of donation, leading to a net breakeven financial impact for businesses.

In total, up to $750 million of additional annual federal tax deductions should be funded to achieve 380,000 tons of additional donations: $620 million in incentives to farms would yield an additional 525 million donated meals, while $130 million provided to restaurants and retailers would generate 115 million meals annually. There is a lack of data regarding the portion of food donors that receive tax incentives today. Anecdotal evidence from ReFED interviews suggests that a large portion of businesses may not go through the effort of claiming small tax benefits after donating, which could significantly reduce the net cost of this solution.

While enhanced deductions were passed in December 2015 as part of the Protecting Americans from Tax Hikes (PATH) Act, food donation tax incentives will require ongoing support from food recovery organizations, foundations, and businesses to make them a priority in the face of future tax reforms.

CHALLENGES

- Successful food donation reform at the federal level requires a clear demonstration of expected societal benefits.
- Businesses may have practical difficulty claiming the tax benefits. For example, a recently passed food donation state tax credit in California requires an inventory-based method of valuation that is only accessible to large farming operations with well-established record-keeping practices.[37]

STAKEHOLDER ACTIONS

- Businesses should actively educate themselves on how their eligibility for tax incentives has changed to spur an increase in food donation efforts.
- Foundations and nonprofits can identify and promote additional donation policy opportunities — such as state-level tax credit programs — while helping measure the impact and success of existing food donation legislation.
- Nonprofits can lead efforts to analyze the cost-effectiveness of tax deductions to ensure ongoing and additional funding at the state and federal levels.
- Various types of food business need to collectively identify deficiencies in existing food donation laws and help draft new legislation that will meet the needs of donor and recipient organizations and fully incentivize businesses to engage in food recovery.

EXAMPLES

- The Protecting Americans from Tax Hikes (PATH) Act of 2015 made permanent an enhanced tax deduction for donating food, increasing business incentives to participate in food recovery. See “Spotlight on Food Donation Tax Incentives” on page 43.

2. STANDARDIZED DONATION REGULATION

DEFINITION

Standardizing local and state health department regulations for safe handling and donation of food through federal policy

DIVERSION POTENTIAL

193K TONS

ECONOMIC VALUE

$553M

MEALS RECOVERED

322M

TIMEFRAME

NEAR TERM

PENETRATION

LOW

WHO CAN TAKE ACTION

FOOD RECOVERY ORGANIZATIONS

FEDERAL GOVERNMENT

LOCAL AND STATE HEALTH DEPARTMENTS

FOUNDATIONS

BUSINESSES

OVERVIEW

State and local health departments across the country have food safety laws that may prohibit or hamper the donation of food that is still safe to eat. These regulations generally add an additional burden on donors and recipients to navigate the differences between states and cities.

The FDA Food Code is not law but a model code, allowing states and local governments to adopt all or just portions of it. Once states determine which portions to adopt, it becomes part of state law and is open to interpretation by the state health agents who are responsible for enforcement.

"Home rule" states may also allow county and local units of government to establish different regulations. For example, Massachusetts state law requires that past-date food be separated and labeled, with no additional stipulations barring these items from being sold or donated. However, Boston health department regulations strictly prohibit the donation of past-dated foods despite the lack of evidence that this poses an additional risk to food safety.[38]

Standardizing local and state health department laws through federal legislation to create a common policy will enable businesses nationwide to more easily track food regulations and understand their donation options with fewer liability concerns. Alternatively, ensuring any voluntary guidelines are up to date and disseminated widely may be a faster path than regulation. The Conference for Food Protection is voting on updated guidelines for food safety handling in spring 2016.

CHALLENGES

- Political bureaucracy may delay any efforts to enact sweeping legislative changes that would define a national standard for safe food handling and donation practices.
- Successful advocacy for regulation reform requires balancing a clear demonstration of societal benefits with an assurance of food safety. For example, language could be recommended that allows for canned or other nonperishable items to be donated past code date but only for a defined length of time.

STAKEHOLDER ACTIONS

- Businesses and food recovery organizations should map jurisdictional local and state health regulations to identify overly strict regulations that are not science-based and inhibit donations, as well as commonalities that should form the basis of national policy.
- Foundations can provide funding to develop research for new health policies and support effective advocacy strategy. Since many regulations are set at the state level, this fits well with interests of regionally focused foundations.
- Nonprofits can educate businesses and food recovery organizations once new regulations are enacted, particularly staff who will be directly handling and processing food donations. Additionally, local governments should provide updated training for health inspectors.
- Nonprofits can contribute to furthering science-based food safety research to bolster the case that food donation regulations align with strong safety protections.

EXAMPLES

- In Massachusetts, RecyclingWorks worked with a multi-stakeholder group of state and local health officials, food rescue organizations, and businesses with food donation programs to develop Food Donation Guidance documents to help clarify local policies for food donation.[39]

3. DONATION MATCHING SOFTWARE

DEFINITION

Using technology platforms to connect individual food donors with recipient organizations to reach smaller-scale food donations

DIVERSION POTENTIAL

150K TONS

ECONOMIC VALUE

$432M

MEALS RECOVERED

250M

TIMEFRAME

NEAR TERM

PENETRATION

PILOT

WHO CAN TAKE ACTION

ENTREPRENEURS

FOOD RECOVERY ORGANIZATIONS

IMPACT INVESTORS

OVERVIEW

Donation matching software provides dynamic, real-time information about food available for donation to enhance the operational e□ciency of food recovery partnerships between nonprofits and businesses with smaller-volume batches of edible food, such as cafes, restaurants, hotels, and other foodservice settings.

Smaller donations (under 50 pounds) are expensive for food recovery organizations to pick up, leading many to set minimum amounts for donation. Online donation matching software enables local food recovery agencies to identify multiple small pickups at once and design e□cient routes to recover food that otherwise would go to waste.

These apps are most e□ective when they include mechanisms for arranging and covering transportation, which removes a major cost barrier. Some smartphone apps coordinate volunteers for real-time food pickups and distribution.

It is assumed, like other real-time software platforms, that many apps and software systems will be developed and piloted and a handful of the best ones will scale nationwide. Several food recovery organizations that are in the early development of apps are assessing opportunities to share a white-labeled version of their products with other food recovery organizations.

CHALLENGES

- Food recovery organizations that have traditionally worked with donors that provide relatively reliable and consistent donations may need to adjust operations to accommodate unpredictable food donation types and volumes from new donors.
- Business employees must be trained to use a new technology platform to notify recovery agencies of available food donations. Likewise, food recovery organization sta□ must be familiar with the tool to identify food donation matches and plan pick-up routes.
- Businesses and recovery agencies must ensure proper cold chain management to safely store, handle, and transport perishable foods
- The cost of transportation is often a significant barrier to donation, particularly for smaller and more geographically dispersed donations.

STAKEHOLDER ACTIONS

- Nonprofit support is needed to train and educate all organizations to begin adopting a new technology.
- Impact investors are needed to fund the upfront cost of technology platforms and mentor startups and social entrepreneurs to develop sustainable software business models.[40]
- Businesses can collaborate with IT product developers to address specific food recovery obstacles. For example, small-volume foodservice donations are plagued by limited labor to handle food and transportation constraints. Small donations also create logistical hurdles for food recovery networks that must track, inventory, and distribute this food on relatively short notice.
- Food recovery organizations can also collectively engage with funders, developers, and businesses to understand where a donation technology platform could interface with other infrastructural resources needed to physically collect, store, and distribute food.

EXAMPLES

- Feeding America secured a $1.6 million grant from Google's nonprofit arm to create its Online Marketplace program and support development and training e□orts among Feeding America-a□liated entities.[41] The Online Marketplace overcomes logistical constraints by allowing businesses to quickly and e□ciently document food donations.
- Several nonprofit and for-profit companies that have launched donation matching software platforms over the past few years include Spoiler Alert, Zero Percent, Copia (formerly Feeding Forward), Community Plates, and Food Cowboy.

4. DONATION TRANSPORTATION

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 110K TONS	ECONOMIC VALUE: $252M
Meals Recovered: **183M MEALS**	Who Can Take Action: **FOOD RECOVERY ORGANIZATIONS, FOUNDATIONS, GOVERNMENT, BUSINESSES**

DEFINITION

Providing small-scale transportation infrastructure for local recovery as well as long-haul transport capabilities

CHALLENGES

- The cost of short-distance, small-load transportation is expensive per pound compared to long-haul transportation of larger loads.
- Perishables need to be distributed quickly and e□ciently to maintain freshness.
- Transportation costs are typically covered by food recovery organizations with small budgets.

STAKEHOLDER ACTIONS

- Retailers and foodservice distributors can share excess transportation capacity with recovery organizations.
- Foundations and government can provide grants or low-cost loans for physical assets such as trucks and the cost of trucking services.
- Rural recovery groups can build connections with other rural support services, including health care and education services to distribute food through existing channels.
- Recovery organizations should improve coordination to find a home for donated food that one organization cannot use due to capacity or budgetary constraints.

EXAMPLES

- The Borderlands Food Bank annually recovers 35 to 40 million pounds of rejected but safe-to-eat produce from Nogales, Ariz.,[42] which could be replicated at produce terminals nationally. Borderlands redistributes this food throughout the U.S., with hunger-relief organizations paying two cents per pound for transportation – which can equate to less than $1,000 per truckload for $70,000 worth of product.[43]

5. DONATION STORAGE & HANDLING

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 103K TONS	ECONOMIC VALUE: $244M
Meals Recovered: **172M MEALS**	Who Can Take Action: **FOOD RECOVERY ORGANIZATIONS, SOCIAL ENTERPRISES, FARMERS, IMPACT INVESTORS, FOUNDATIONS**

DEFINITION

Expanding temperature-controlled food distribution infrastructure (e.g. refrigeration, warehouses) and labor availability to handle (e.g. process, package) additional donation volumes

CHALLENGES

- Each warehouse serves a unique local need, which requires a regionalized understanding of food distribution capabilities and gaps.
- It can be di□cult to finance warehouses that are capital-intense but lack significant collateral.

STAKEHOLDER ACTIONS

- Food banks can expand existing infrastructure to increase handling capacity for perishables.
- The network of over 200 U.S. food hubs can use excess capacity to store and handle donated food.
- Foundations can provide low-cost infrastructure funding in addition to existing grants for food recovery operational expenses. Funding can also be directed toward mapping where underutilized assets exist, such as surplus refrigerator space within existing businesses.
- Nontraditional transportation and storage is needed. Ride-sharing services can provide near real-time transportation for donated food that must be picked up quickly. Similarly, since donated food often becomes available at night when many food banks are closed, other late-night businesses with refrigerated capacity may be available to hold food.

EXAMPLES

- The Second Harvest Food Bank of Middle Tennessee provided a Feeding America Produce Capacity Grant to Hughes Farm and Produce to cover the cost of installing a new processing line to sort green beans that were the incorrect size for retail standards. The upgrade cost less than $50,000, and Second Harvest expects to recover 1 million lbs. of green beans per year.[44]

6. VALUE-ADDED PROCESSING

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 102K TONS	ECONOMIC VALUE: $285M
Meals Recovered: **171M MEALS**	Who Can Take Action: **FOOD RECOVERY ORGANIZATIONS, SOCIAL ENTERPRISES, FARMERS, IMPACT INVESTORS**

DEFINITION

Extending the usable life of donated foods through processing methods such as making soups, sauces, or other value-added products

CHALLENGES

- Processing requires capital-intensive commercial kitchens and other infrastructure.
- New infrastructure may need to be built or identified in the community to use during prime harvesting season when existing infrastructure capacity is often not available.

STAKEHOLDER ACTIONS

- Nonprofits and social entrepreneurs can collaborate with businesses to process donated food and work with farmers and manufacturers in food-producing regions to find excess processing capacity to handle crop surpluses during prime harvesting months.
- Foundations and impact investors can provide low-cost capital for investment in additional processing line capacity.
- The USDA could expand its grant and loan programs to help farmers and entrepreneurs invest in their own processing capabilities.

EXAMPLES

- The Alameda Kitchen in Alameda, Calif., uses a shared kitchen to transform fruits and vegetables that would otherwise be wasted into a□ordable food products and meals for low-income populations.[45]
- Several social enterprises have emerged recently to sell value-added products from food waste at a profit. These include Barnana (banana snack bites from rejected products), Misfit Juicery (repurposing wasted food into juice), and MM Local Foods (value-added products from seconds from farmers).

7. DONATION LIABILITY EDUCATION

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 57K TONS	ECONOMIC VALUE: $159M
Meals Recovered: **95M MEALS**	Who Can Take Action: **NONPROFITS, RESEARCHERS, BUSINESSES**

DEFINITION

Educating potential food donors on donation liability laws

CHALLENGES

- The federal Good Samaritan Food Donation Act protects donors and recipients from civil or criminal liability short of gross negligence and misconduct. However, this legislation remains unproven and untested in court leaving corporate legal departments without a precedent to follow that would allow them to fully support food donation.
- In an industry with a wide variety of businesses, it is challenging to create scalable awareness campaigns and educational materials necessary to change mindsets.
- Because of high sta□ turnover, ongoing training is required for programs to be e□ective.

STAKEHOLDER ACTIONS

- Federal government can provide additional guidance on the Good Samaritan Act to increase clarity for businesses.
- Nonprofits can develop training guides for businesses and publicly recognize leading businesses.
- Businesses can include information on donation as a standard set of employee on-boarding trainings.
- Nonprofits and researchers can provide research to develop a simple data-driven framework for businesses to evaluate food-safety risks.

EXAMPLES

- Leading businesses such as Ahold and Bon Appetit Management Company have instituted donation protocols that have enabled them to adopt aggressive donation goals.

RECYCLING SOLUTIONS

ANNUAL DIVERSION POTENTIAL

9.5M TONS

ANNUAL ECONOMIC VALUE

$121M

INVESTMENT NEEDED OVER 10 YEARS

$2.9B

ANNUAL GHGS REDUCED

4.8M TONS CO_2e

ANNUAL JOBS CREATED

11,OOO

TOP SOLUTIONS BY DIVERSION POTENTIAL

CENTRALIZED COMPOST
CENTRALIZED AD
WRRF WITH AD

MAIN BENEFICIARIES

MUNICIPALITIES
ENVIRONMENT
BUSINESSES

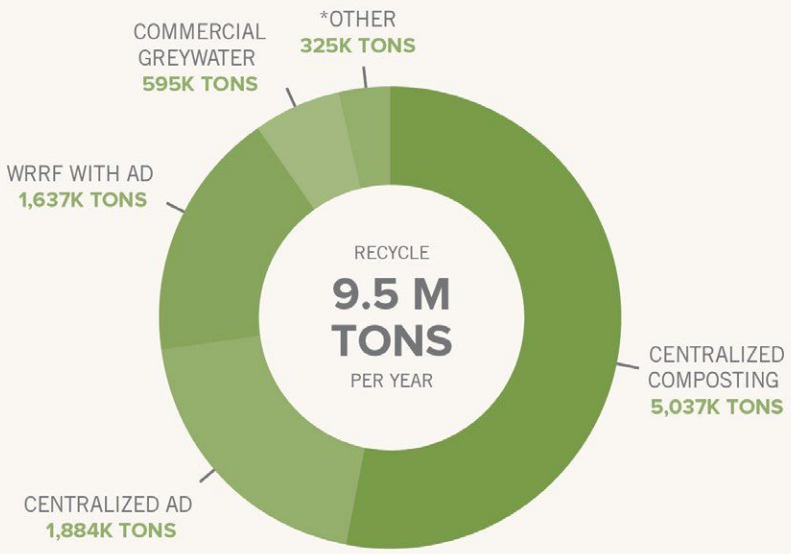
RECYCLING OFFERS the most scalable path to reducing food waste nationally. Action taken by a handful of large cities alone can prevent millions of tons of food scraps from being landfilled. In almost any scenario to reduce food waste nationwide by 50%, recycling will represent the majority of the volume.

RECYCLING: THE OPPORTUNITY

After pursuing as much prevention and recovery as possible, food scraps inevitably remain. Today, the vast majority of wasted food ends up in landfills where it costs cities millions of dollars per year in disposal fees and rapidly releases methane, a potent greenhouse gas. Yet food scraps are actually a resource that can be harvested to create a closed-loop system that supports a vibrant agricultural sector, energy independence, and greener cities.

Recycling technologies for organic, biodegradable materials have existed for decades. Historically, this organics recycling sector has focused on the composting of lawn clippings and manure, driven by bans or mandates to collect yard debris and lawn clippings in half of U.S. states. Existing e□orts to recycle food waste are usually combined with this larger organics recycling sector.

RECYCLING SOLUTIONS DIVERSION POTENTIAL



*OTHER: COMMUNITY COMPOSTING **167 TONS/YR**; HOME COMPOSTING **97K TONS/YR**; ANIMAL FEED **49K TONS/YR**; IN-VESSEL COMPOSTING **12K TONS/YR**

NOTE: Given the relative maturity of recycling solutions compared to prevention and recovery, regionally specific inputs were used in the economic analysis of recycling, resulting in a deeper set of sector-wide insights than found in other chapters.

KEY INSIGHTS

Centralized Composting and Anaerobic Digestion (AD), as well as a smaller set of growing distributed solutions, will enable 9.5 million tons of waste diversion — nearly three-quarters of the total potential.

- Centralized Composting diverts the most waste, adding over 2 million tons of compost annually to fuel growth in the sustainable farming and environmental remediation markets.
- The Northeast, Northwest, and Midwest can generally realize the most Economic Value from recycling due to high landfill disposal fees and high compost and energy market prices.
- Nearly $3 billion of investment is needed for recycling infrastructure, mainly for compost and AD processing and collection.
- Municipalities can help build more large recycling projects by including non-financial job and environmental benefits into cost-benefit analyses.
- The top levers to scale recycling beyond the Roadmap targets are an increase in landfill disposal costs and efficiencies in hauling and collection through closer siting of organics processing to urban centers and optimized collection routes. Other key bottlenecks to overcome are the high cost of project capital, particularly for AD facilities, and low, unstable pricing for biogas and compost.

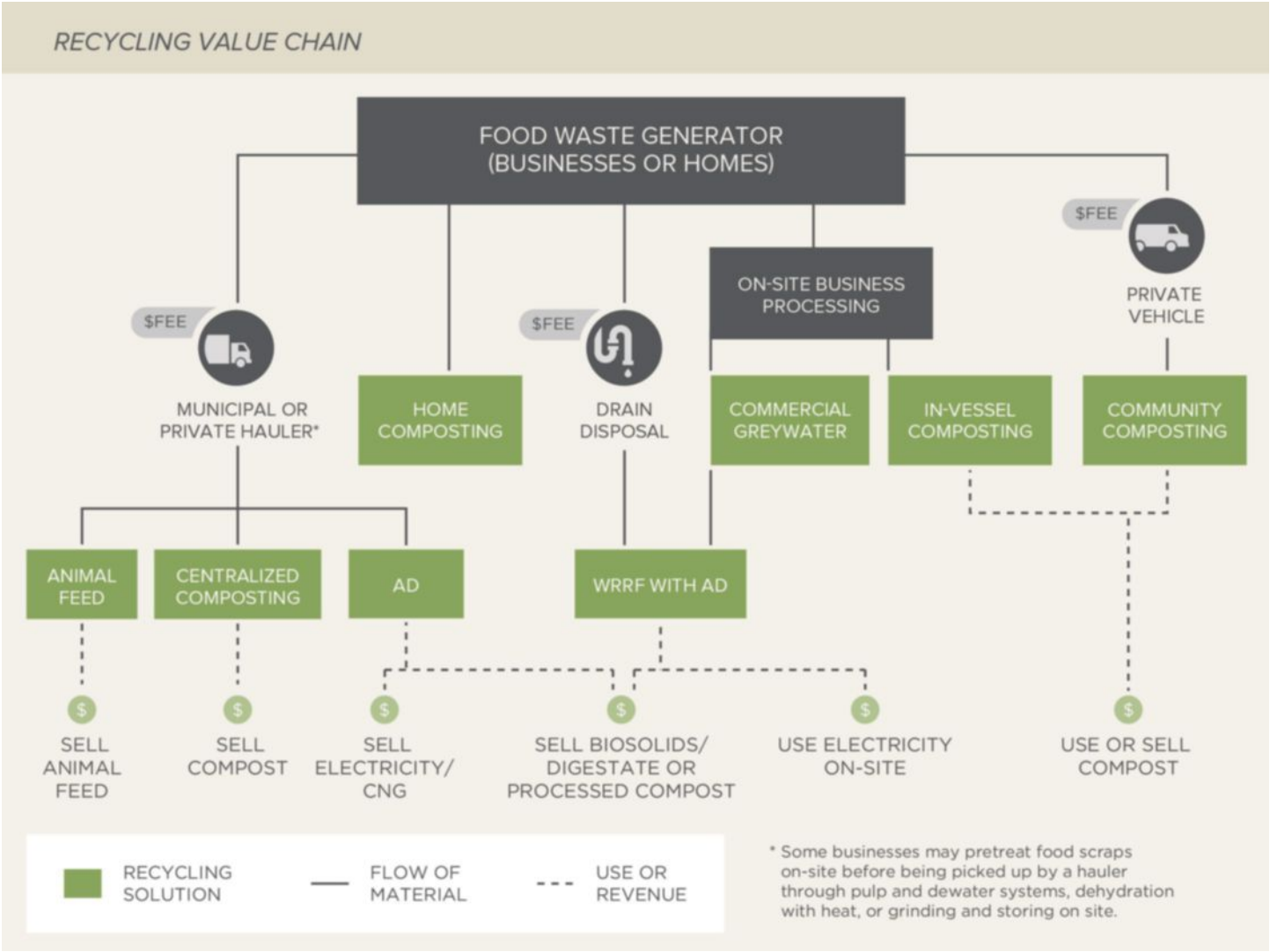
Municipal interest in organics management is growing due to three drivers: increasing number of landfills that are reaching capacity, better understanding of the environmental impacts of landfilling food scraps, and the improving economics of recycling facilities that have reduced contamination rates and increased e□ciencies over time.

Even with this growing interest, most cities still landfill the vast majority of food scraps. To overcome the status quo, three elements must be present. First, “generators” (i.e. homes and businesses that create waste) must face a risk of penalty and incentive to motivate them to sort food scraps into separate waste. Second, haulers must expect a higher profit from collecting food scraps and taking them to organics recycling facilities versus landfills. Finally, there must be available infrastructure in place to process the organics. Processing facilities have to carefully set the tipping fee — the disposal fee they receive for accepting waste — low enough to attract su□cient hauler volumes to keep their facilities at capacity but high enough to generate a profit margin.

In the Roadmap analysis, nearly three-quarters of food waste reduction comes from recycling. Roughly 73% of the recycling opportunity is expected to come from the creation of Centralized Composting and Centralized Anaerobic Digestion (AD) facilities. Another 17% comes from new and upgraded digesters at water resource recovery facilities (WRRF with AD), also known as wastewater treatment plants. The remaining 10% comes from smaller-scale decentralized solutions in homes and businesses — similar to how rooftop solar is decentralizing our energy system. Decentralized systems are more e□ective in rural areas or highly dense urban areas where collection infrastructure is cost-prohibitive.

IN THE ROADMAP ANALYSIS, NEARLY THREE-QUARTERS OF FOOD WASTE REDUCTION COMES FROM RECYCLING.

RECYCLING VALUE CHAIN



REGIONAL VARIATIONS

Recycling solutions in aggregate generate $121 million a year in Economic Value, a significant value to society but lower than for prevention and recovery. The economics of recycling is highly sensitive to the local prices of labor, property, disposal fees, compost values, and energy prices. These complexities can be observed in areas like California, which uses numerous state and municipal policies, often driven by environmental goals, to incentivize organic waste to be recycled instead of landfilled.

For Centralized Composting, the Northeast, Midwest, and Northwest generally show the most economic promise due to the favorable combination of higher disposal fees and high market prices for compost. The Roadmap estimates that 53% (2.7 million tons per year) of composted material will come from these regions, with an average net societal benefit of nearly $30 per ton. The remainder is expected to come from California (2.3 million tons), where the net benefit is close to breakeven due to lower disposal costs. High recycling rates are still expected due to the subsidies created by the state's progressive policies.

In the case of AD facilities, the Northeast and Northwest are the most promising regions. Based on local economics, these facilities may target the electricity, transport, or heating sectors. For example, New England facilities can generate strong revenues due to a high price for biogas-derived electricity. In the Northwest, a base of hydro power results in lower electricity prices, which leads project developers to explore using biogas to power compressed natural gas (CNG) vehicles or supply heat to nearby users.

These regional variations are rules of thumb with multiple exceptions at the local level. For example, new AD projects have been announced in Colorado and other regions not emphasized in the economic modeling. Any metropolitan area can find it economically rational to adopt food scraps recycling when faced with certain drivers, including a lack of additional landfill space, landfills located far away from the urban core, or strong policy support reflecting sustainability, renewable energy, or local economic development goals.

ReFED's analysis on the opportunity for recycling was based on current costs, pricing, and constraints. The ability to overcome a number of critical bottlenecks described in this chapter could further unlock the diversion potential and Economic Value of recycling, which would require higher levels of financing to build out the additional infrastructure.

FOR CENTRALIZED COMPOSTING, THE NORTHEAST, MIDWEST, AND NORTHWEST GENERALLY SHOW THE MOST ECONOMIC PROMISE.

PROMISING REGIONS FOR DEVELOPING PROCESSING CAPACITY

CENTRALIZED COMPOSTING

CENTRALIZED AD

RECYCLING: THE CURRENT LANDSCAPE

Recycling rates vary widely throughout the food value chain. Within consumer-facing businesses and homes, where the vast majority of waste occurs, current recycling rates are only an estimated 10% of their potential.*

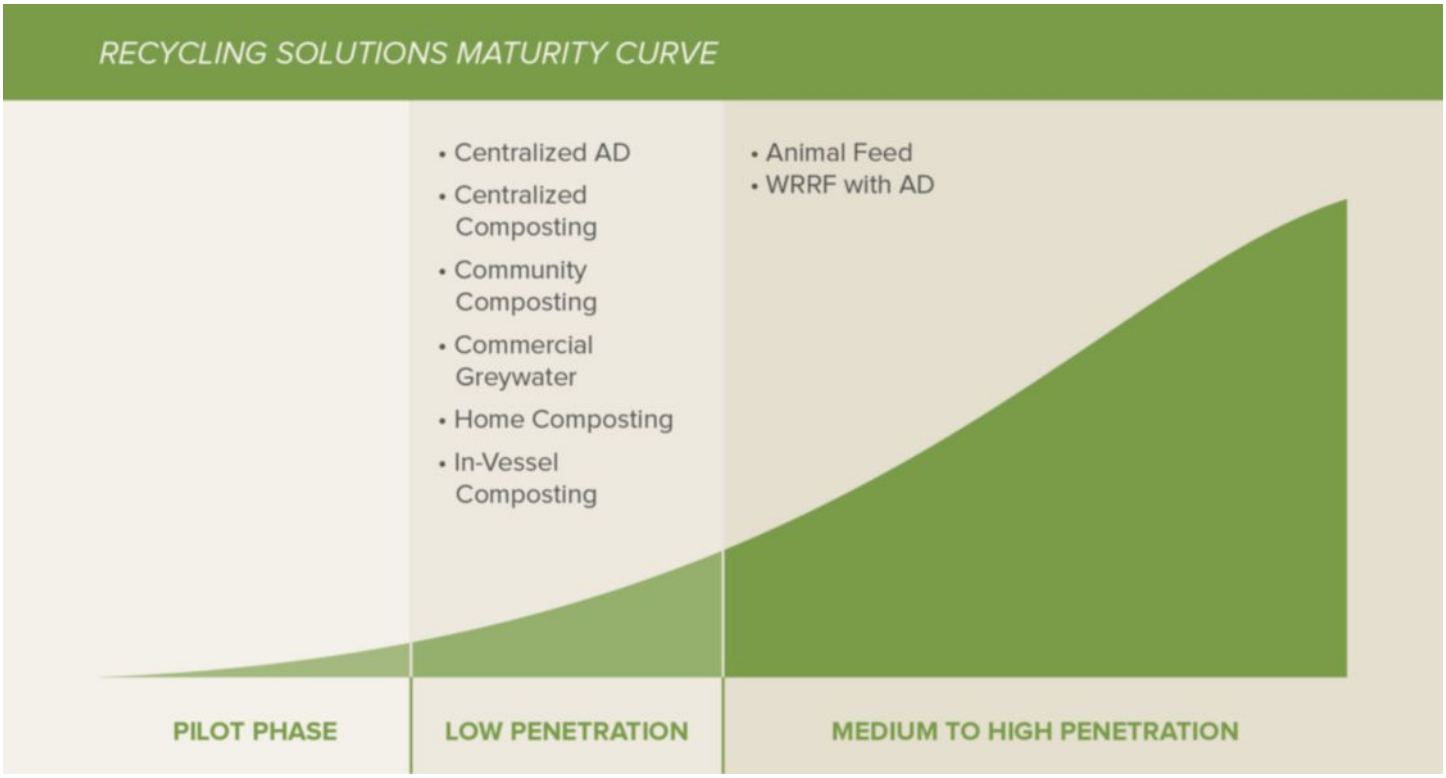
Aside from animal feed, the other highly developed organics recycling segment is the more than 1,200 ADs currently installed at WRRFs to digest municipal solid waste. A recent trend is for these facilities to accept some municipal food scraps to boost gas production.[47] Although many WRRFs apply their biosolids output as a soil amendment or fertilizer to recycle the nutrients, there is room to expand this practice to reduce large volumes that are still currently landfilled.[48]

Other solutons have existed for decades to process manure and yard scraps, but the inclusion of food scraps processing for centralized systems is somewhat newer. Overall, there is some level of commercial acceptance for all recycling solutions:

- There are roughly 40 Centralized AD facilities in operation today targeted at accepting food scraps. There is also an opportunity to add food scraps to the roughly 250 smaller AD systems that have been installed on farms to digest manure.[49] Food scrap recycling in on-farm digesters is expected to grow in the future, although it was not a focus of the Roadmap.
- Roughly 500 composting facilities across the country accept food scraps, out of a highly fragmented market of roughly 5,000 composting facilities.[50] Most composting facilities are small, just a few acres in size, and lack the e□ciencies of larger, industrial facilities that are able to purchase mechanized equipment such as turners and depackaging technology.
- Community Composting, In-Vessel Composting, and Commercial Greywater systems within food businesses are established solutions with varying degrees of market acceptance based on regional economics.

The maturity curve below shows the range of penetration of recycling solutions analyzed. While the recycling of organics is advanced, there is still opportunity to innovate to make distributed recycling more viable and bring centralized systems to scale.

WITHIN CONSUMER-FACING BUSINESSES AND HOMES, CURRENT RECYCLING RATES ARE ESTIMATED TO BE LESS THAN 10% OF THEIR POTENTIAL.



* This excludes on-farm losses and food manufacturing, where almost all waste finds some beneficial use as either nutrient for the soil or animal feed. According to the Food Waste Reduction Alliance, 95% of all manufacturing food waste is believed to be diverted today, with more than 85% of this going to animal feed, leaving little remaining potential for additional growth.[46]

REGIONAL INITIATIVES & POLICY

Food scrap recycling can be incentivized by local, state, and federal policies including landfill bans, renewable portfolio standards, and economic incentives.

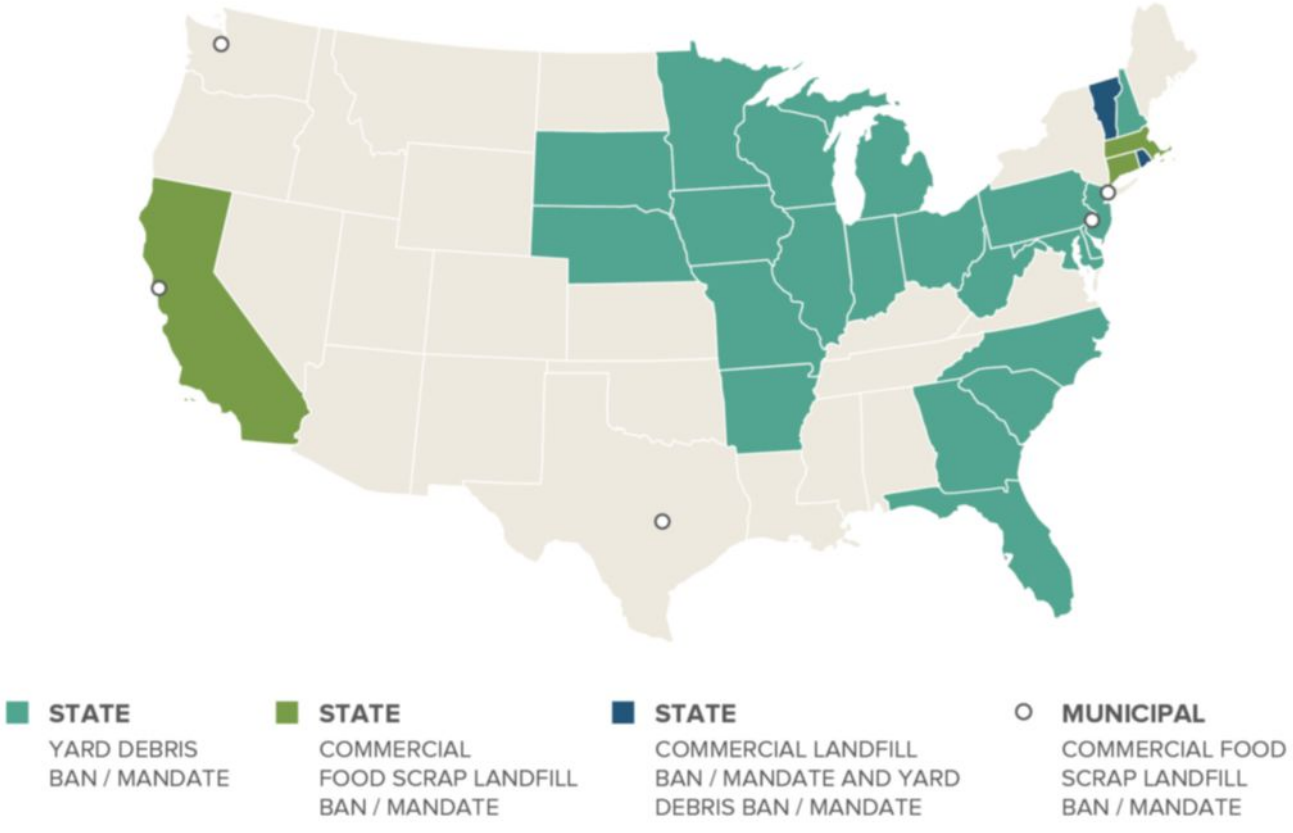
LANDFILL BANS: Some states are beginning to address organics directly by implementing highly e□ective landfill bans or by mandating large organic waste generators to divert their waste from landfills through recovery or recycling. For example, Vermont banned the disposal of mandated recyclables by 2015, yard waste by 2016, and food waste by 2020, providing strong market guidance and increasing assurance of organics materials supply to recycling facilities over time.

RENEWABLE ENERGY: Renewable energy portfolio standards (RPS) play a role in encouraging organics infrastructure. California, Connecticut, and Massachusetts each have an RPS that allows organic feedstocks, including food waste, to be classified as a Class I Renewable Energy Source, which contributes toward the portion of the state's electricity required to come from renewables.

ECONOMIC INCENTIVES: State and local governments also use proven local economic incentives to drive solid waste behavior. For example, "pay-as-you-throw" (PAYT) pricing is an increasingly popular incentive that promotes diversion of organics by charging fees for waste based on the amount disposed to landfill. There are numerous examples of PAYT across the country. Variations have been implemented in 40% of Massachusetts' towns and cities. Portland, Ore. has a base level of residential service that includes weekly recycling, weekly composting, and every-other-week garbage collection, with additional fees charged for increasing cart sizes. Successful programs require funding for education and local enforcement to minimize contamination and the risk of illegal dumping.

The map below illustrates the variety of organics policies implemented at state and municipal levels.

REGIONAL ORGANICS POLICIES



DATA ANALYSIS

The Roadmap used current regional data to calculate where it will be cost-effective to deploy each recycling solution. A detailed assessment was done for the top 50 largest U.S. metropolitan statistical areas (MSAs), which combine a number of towns and cities around an urban core. The top 50 MSAs account for roughly half of all waste nationwide.

The analysis of food waste diversion potential factored in the strength of current policies supporting organics as well as the levels of existing waste going to landfills. The analysis was extended to the rest of the country using a broader set of assumptions. The analysis considered the full costs to the system, including collection and processing.

The Roadmap proposes additional organics infrastructure in MSAs where it would create net positive or near-breakeven Economic Value. For the top three solutions, the data analysis led to the following results:

- Centralized Composting can be expanded in roughly half of the largest municipal areas. Windrow composting has more favorable economics than aerated static pile technology. Key geographies for expansion include southern and northern California and the greater Chicago area.
- Centralized AD can be expanded in 10 large municipal areas with high disposal fees and energy prices. Key regions for expansion include the greater New York City, Philadelphia, Washington DC, Boston, and Seattle areas.
- WRRF WITH AD can be significantly expanded in up to 30 MSAs, with the potential for minor increases in all large metro areas. Additional waste diverted per MSA is smaller than Centralized Composting and Centralized AD due to processing and material transport constraints from existing infrastructure. Key geographies with the potential for relatively high capture rates include Boston, southern California, upstate New York, as well as some application in Texas and other southern states.

LOOKING TO THE FUTURE

Municipal decision-makers should pay particular attention to the following five factors, which could have the strongest effect on recycling program economics over the next decade:

1. Cost of Disposal: If the average landfill tipping fee were increased by 50%, Centralized Composting would be economically viable in a total of 36 MSAs, nearly doubling the potential food waste diverted for a total of 9.1 million tons processed through composting facilities. For Centralized AD, eight additional MSAs would achieve positive economic value, for a total of 18 MSAs processing up to 2.9 million tons.
2. Collection Routes: Improved collection efficiencies would have a major impact on system costs. Three areas of opportunity are closer facility siting to urban centers, greater route density, and reduced route redundancy through municipal organized collection. If these optimizations could increase collection efficiency by 20%, diversion to composting would be near break-even or profitable in approximately 30 of the largest MSAs. In these areas alone composters could capture 8.6 million tons of material.
3. Price of Energy: Successful AD projects depend on the ability to find favorable off-take contracts for energy produced. Energy prices will have a significant impact on the economics. If the price of natural gas triples back to 2007-2008 levels, 34 MSAs could support AD projects with positive Economic Value. If these were developed to their potential, it would increase the amount of commercial food waste captured for AD by 160% versus the baseline scenario, for a total of 5 million tons recycled annually.
4. Market Prices for Compost/Digestate: Both composting and AD economics rely on favorable end markets for compost and/or digestate. If increased demand were to double the market price of compost, 35 MSAs would be positioned to cost-effectively scale up the amount of food waste processed through composting and handle 8.3 million tons annually. Similar end-market conditions for digestate would enable standalone AD systems to economically capture 3.9 million tons across 25 MSAs — increasing the overall economic value 4-6x.
5. Cost of Capital: If 10% of all AD project capital could be supplied in the form of grants or low-interest loans, whether from federal and state programs or impact investors, up to 2 million tons of additional diversion could be achieved through these facilities.

If multiple factors were implemented at the same, each factor would not need to have as dramatic of an increase to achieve similar improvements in program economics.

OVERCOMING BARRIERS TO RECYCLING

Successful recycling programs require municipal decision makers, haulers, investors, and businesses to optimize across a wide variety of variables: cost of disposal, transportation and logistics costs, material supply assurance, packaging and contamination, access to finance, end-market development, and permitting and siting. Levers to influence the economics of these system-wide variables will impact the economics of the recycling technology solutions outlined on pages 60 to 66.

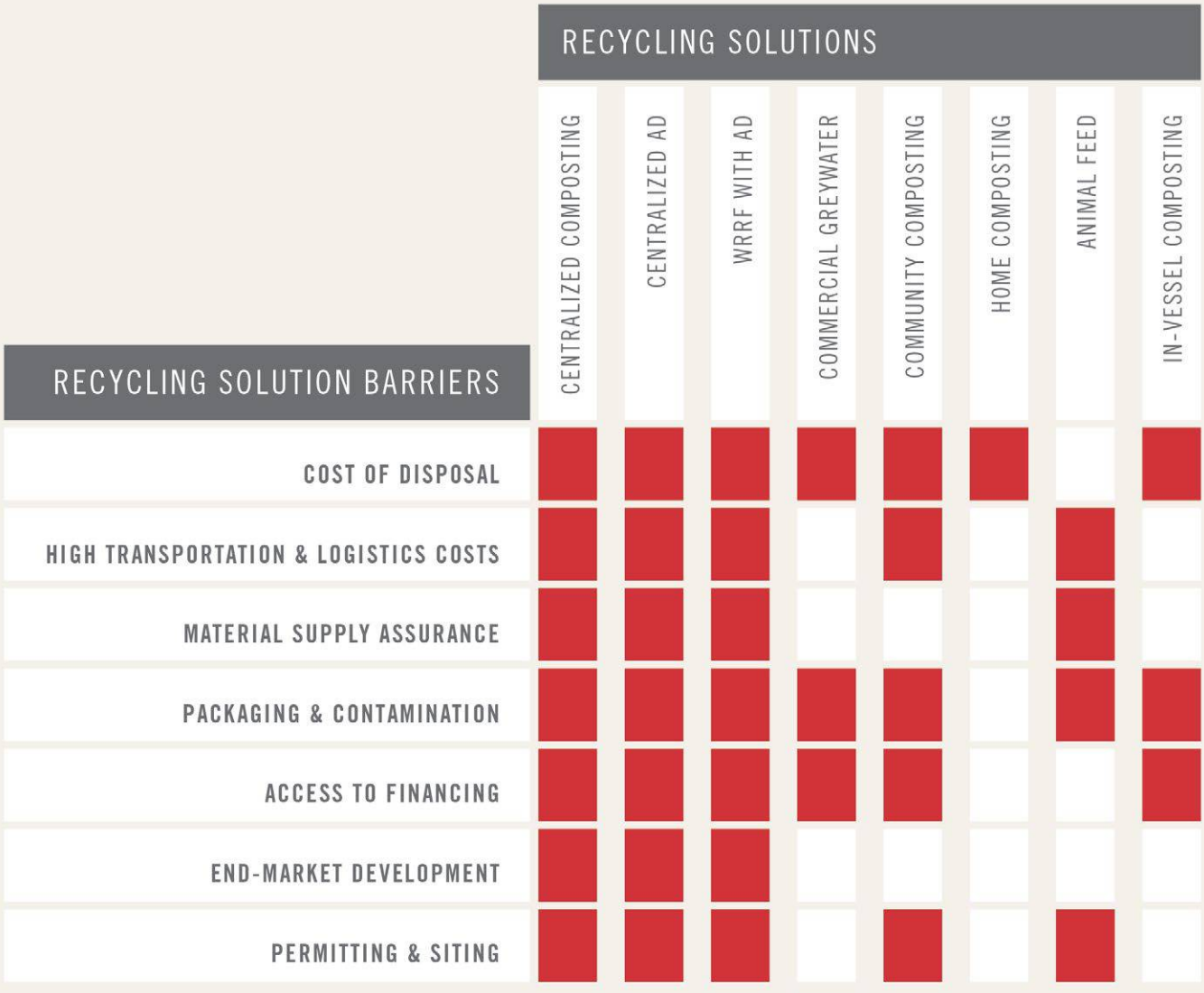
BARRIER 1: Cost of Disposal

Landfill disposal rates (i.e. tipping fees) have remained exceptionally low in the U.S., especially beyond the Northwest and Northeast, relative to many other developed countries. Since tipping fees are typically the largest revenue streams for recycling processing facilities, this has hurt the business case to expand organics recycling infrastructure.

LEVER TO DRIVE ACTION

- Twenty states or more have implemented landfill taxes, an e□ective policy tool that can be expanded to directly change tipping fees. The income from the tax can be used in support of recycling e□orts, including grants for new infrastructure or business and consumer education.

BARRIERS TO RECYCLING SOLUTIONS



BARRIER 2: High Transportation and Logistics Cost (i.e. Hauling)

In e□cient programs, the incremental vehicle, labor, and fuel costs from recycling generally add a 5% to 10% net increase in collection costs versus landfill-only programs. For residential programs, when paired with existing yard waste programs, there is minimal extra cost, as food scraps are simply added into existing collection routes. For collection from food businesses, food scraps represent up to 80% or more of the waste stream once other recyclable materials are removed. Once at scale, recycling haulers are expected to become the predominant waste provider, reducing general trash collection services to once or twice per month.

For ine□cient programs, collection costs can be the driving factor for low cost-e□ectiveness. For new or sub-scale programs, organics trucks and other infrastructure can be redundant with other waste collection programs. When commercial food businesses are spread out, lack of route density or ine□cient scheduling of pickups leads to a high labor and fuel cost per volume collected.

Once waste is collected and deposited to a transfer station, the distance that it must travel to a recycling facility versus a landfill becomes the key driver for system economics. If hauling costs to a recycling facility are high, haulers may not bring enough food scrap volumes to keep the facility at the high capacity rate needed to be profitable.

LEVERS TO DRIVE ACTION

- Reduced route redundancy through municipal organized collection or franchised service can bring e□ciencies through fewer miles traveled per truck.
- Immense savings can be gained by siting recycling facilities much closer to urban centers than the landfill disposal alternative. Municipalities should seek excess space in current infrastructure such as material recycling facilities, transfer stations, food manufacturing facilities, and WRRFs. A compost or AD facility located 50 miles closer to a city than a landfill would on average result in a $20 per ton system cost savings stemming from lower truck depreciation costs and the bypass of transfer station fees, which can be shared with the hauler in the form of lower tipping fees.⊕
- Municipalities with existing yard waste collection services can explore adding food scraps, since bundling existing collection bins and trucks can cut the incremental cost by over 50%.
- Retailers can use reverse logistics practices to transport food scraps from stores to distribution centers where they can be stored and collected for recycling in larger quantities. They can also use on-site processing technologies to “dewater” food scraps, reducing the costs associated with hauling excess water.
- Haulers can use analytics and logistics software to optimize routes and reduce pick-ups of partially full loads to reduce fuel and labor costs.

THE DISTANCE THAT WASTE MUST TRAVEL FROM A TRANSFER STATION TO A RECYCLING FACILITY VERSUS A LANDFILL IS A KEY DRIVER FOR SYSTEM ECONOMICS.

BARRIER 3: Material Supply Assurance (Quantity)

A long-term guarantee of material is necessary for recycling facilities to access project finance and maintain long-term profitability. However, most cities and businesses are reluctant to sign long-term waste supply contracts due to long-term price uncertainty. Over time, when a new policy or MSA program introduces a new stream of recycled

CASE STUDY: SENSITIVITY ANALYSIS

For Washington, DC, the Roadmap analysis estimates that the total cost of commercial material collection for AD is $89 per ton, and the total aggregate system cost is -$4 per ton. A 10% reduction in collection cost would shift this municipality from a negative to positive total system cost resulting in an aggregate net benefit of $5 per ton recycled. Similarly, if it were possible to reduce the cost of collection for composting in the Baltimore area by 10%, an annual system-wide net cost of $700,000 to collect and process 140,000 tons of food waste could become a net benefit of $230,000. If it were possible to reduce the cost of collection in the Los Angeles area by 15%, an annual system-wide net cost of $5 million to collect and process 800,000 tons of food waste could become a net benefit of $1.2 million.

⊕ More details are available in the Technical Appendix on refed.com.

material into a “wasteshed,” a rush to build recycling processing infrastructure can lead to overcapacity and cause a deterioration of industry profitability.

LEVERS TO DRIVE ACTION

- Material supply assurance begins by incentivizing businesses and homes to continue to sort their food scraps into separate waste bins. Local and state governments can incentivize this behavior by o□ering free compost, pay-as-you-throw pricing, or rebate systems.
- Cities and states with organics bans can provide sta□ to enforce the local policies. Enforcement can be a simple letter to all participants or a more time-intensive audit of waste loads at points of generation or transfer stations.
- Local planning commissions can publish data on planned prevention, recovery, and recycling activities to ensure “right-sizing” of recycling facilities across a wasteshed.
- Municipalities can encourage local generators to sign long-term contracts for food waste directly with project developers or haulers to lower the risks of maintaining long-term supply.

BARRIER 4: Packaging and Contamination (Quality)

The issue starts with the waste generator, where the hassle of removing food from its packaging significantly reduces food recycling rates among businesses and consumers. While compostable packaging has helped reduce this problem in quick-serve restaurant settings, it has not been widely adopted among retail grocers due to a concern over shortened product shelf life. In addition, weak education campaigns tied to new organics programs have led to confusion over what can and cannot be recycled. Common contaminants include plastic, foam, or disposable food packaging that appears compostable but is not. One community recycling coordinator stated that 90% of commercial contamination comes from 10% of customers, showing how a few non-compliant actors can have a large system impact.

The problem continues at the treatment facility. Compost or AD facilities that receive highly contaminated feedstock must spend more costs on pre- and post-processing, which may hurt profitability. Many composting facilities are resistant to accepting compostable packaging due to legitimate concerns regarding longer residence times required for biodegradation and an increased risk of cross-contamination from non-compostable products.

LEVERS TO DRIVE ACTION

- Municipalities can provide su□cient education to residents regarding which items can be composted and o□er financial incentives to residences and businesses that demonstrate low contamination rates through random audits.
- Municipalities can encourage compostable takeout packaging and disposable utensils in restaurants and institutions with clear instructions to avoid contamination, as has been demonstrated by Seattle’s e□ective program.
- Entrepreneurs can partner with the composting and AD industry to bring innovative packaging solutions to market that can both improve shelf-life performance and be readily processed by organics recycling infrastructure. Additionally, they can develop low-cost depackaging equipment that can be used by businesses and processors to reduce contamination.
- Businesses can ensure that packaging is clearly marked as compostable, is certified with BPI or ASTM International’s voluntary standards for compostability, and is able to be processed in local composting facilities.
- Entrepreneurs and processors can continue to bring innovative, low-cost depackaging equipment to the market to be widely distributed to food waste generators and processors.

BARRIER 5: Access to Financing

Capital-intensive projects, like Centralized AD, are the most sensitive to variations in financing rates, which can be a di□erentiator for success. Projects can typically only secure low debt capital rates if they also secure long-term feedstock and product o□take agreements with credit-worthy counterparties to lend against. Long-term

CAPITAL-INTENSIVE PROJECTS, LIKE CENTRALIZED AD, ARE THE MOST SENSITIVE TO VARIATIONS IN FINANCING RATES, WHICH CAN BE A DIFFERENTIATOR FOR SUCCESS.

o□take agreements are more common in the energy sector and are challenging to achieve for compost or animal feed.

LEVERS TO DRIVE ACTION

- Many projects proposed today would be able to move forward If federal and state programs or impact investors could supply 10% of all project capital in the form of grants, 2 million additional tons of diversion could be achieved.
- Renewable energy mandates that encourage long-term contracts can lower the cost of financing.
- Long-term material supply assurance allows project debt to o□er low-cost financing.
- Government projects, such as USDA financing, lower the total blended cost of capital for a project by o□ering grants or low-cost capital at a rate of 4% or below.
- New impact investment funds from corporate stakeholders, high-net-worth families, or foundations — such as the $100 million Closed Loop Fund that o□ers 0% financing to cities and low-cost debt for hard-to-finance municipal solid waste recycling projects — can fill a critical project financing gap to help lift the profitability of a project with borderline economics.

BARRIER 6: End-Market Development

Recycling facilities must maintain high prices for their end products (compost, digestate, energy) to maintain financial viability over time. This is impacted by customer demand.

Energy demand is massive and linked into regional markets. However, for AD projects, the sharp ups and downs of natural gas market prices make it challenging to finance projects that require stable, long-term cash flows.

Compost markets are smaller and constrained by transportation costs. Therefore, market demand for compost must keep pace with the millions of new tons of compost generated in the Roadmap or else a market imbalance will negatively impact compost prices and system economics.*

CASE STUDY: ACCESS TO FINANCING

Several states provide grants and incentives to recycling infrastructure. However, current grant amounts are a small fraction of what is demanded by developers or the levels available for renewable energy projects:

- California: In 2014, CalRecycle granted $14 million to five AD and composting projects to recycle 2.8 million tons over 10 years. However, the overall requested funding was nearly $100 million for 20+ projects that would have added 10 million additional tons in that timeframe.
- Connecticut: Connecticut Green Bank awards grants, loan enhancements, or power purchase incentives to finance the cost of AD. Connecticut's Green Bank has allocated $95 million in low-interest loans to five AD projects, which is expected to unlock an additional $400 million in bank financing and equity.
- Federal: Additional sources of funding include the EPA Global Methane Initiative; the DoE's Qualified Energy Conservation bonds; and the USDA's Advanced Biofuel Payment Program and Rural Energy for America Program.

LEVERS TO DRIVE ACTION

- Local governments and state agencies can promote compost for greater agricultural applications as a way to improve soil health and mitigate the e□ects of drought, and for industrial applications such as highway right-of-way revegetation, slope stabilization, and wetland rejuvenation.
- Municipalities can include incentives for compost use into RFPs for construction and landscaping programs to create an end-use market for locally generated compost.
- Industry and impact investors can host competitions to spark innovation to build "high value" compost markets such as value-added products and applications. For

*Current demand is not well-documented on a national scale, but research done in Boulder, Colo., suggests that landscaping accounts for as much as 65% of demand, followed by agriculture at 15% of demand.[51]

example, recent advances in “compost socks” are helping absorb stormwater in areas sensitive to flooding or combined sewer overflows.

- Government resources should be made available as a resource or clearinghouse to help connect generators of compost products with potential users.

BARRIER 7: Permitting and Siting

Compost and AD facilities have trouble rallying local support because the benefits are often hidden to communities.

Compost facilities typically require 12 to 20 acres per 50,000 tons of waste processed per year if onsite truck queuing and other operations are to be accommodated. For densely populated municipalities, such as New York City and surrounding areas, a limited number of sites are feasible for Centralized Composting. In addition, communities often object to compost facilities from NIMBY concerns related to odors, pests, or increased truck tra□c, impacts which vary greatly based on the management of the compost facility.

Centralized AD faces similar issues of scale. They typically are only economical when processing 50,000 to 250,000 tons of feedstock per facility and must be sited near waste suppliers and energy users, a challenging requirement for both very rural and very dense urban areas.

LEVERS TO DRIVE ACTION

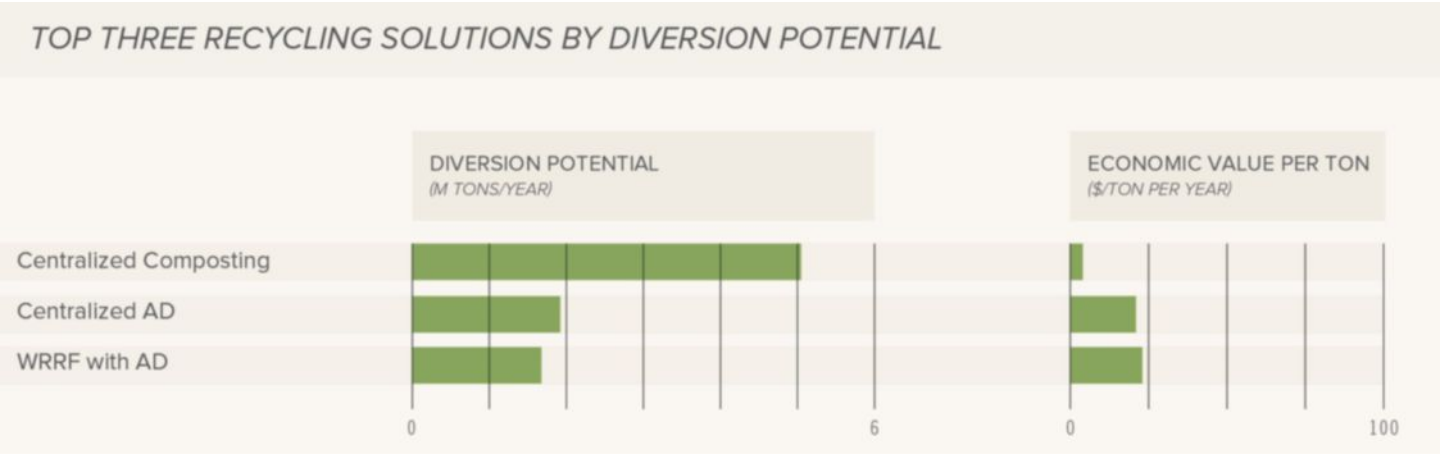
- Policymakers can reduce barriers for Centralized Composting, Community Composting, and large-scale Centralized AD facilities by better coordinating existing state agency regulations so that they have clear standards to meet.
- Nonprofits can compile permitting best practices and provide assistance to galvanize community support for new projects undergoing community and environmental impact studies.
- Case studies of well-managed compost facilities can help disprove myths regarding odors and pests and provide benchmarks for future operators.
- Beyond the immediate economic benefits of food waste reduction, greater environmental and social impacts of waste diversion can be factored in locally to determine the total system cost-benefit analysis of food waste reduction. These include the cost of siting and building new landfills; health impacts related to incineration; the societal cost of greenhouse gas emissions; infrastructure constraints; and benefits associated with removing trucks from roads, increased local job creation, and improved energy security.

CASE STUDY: FILTREXX INTERNATIONAL

Filtrexx founder Rod Tyler, an agronomist, understood that the use of organics for environmental applications — to retain storm water, filter and bio-remediate, and establish vegetation — would work better than man-made products already accepted by the engineering community. In 2001 he harnessed these properties to invent the compost filter sock, a novel sediment and erosion control technology. The annual marketplace for construction site erosion control is about $2 billion and utilizes roughly 1 billion feet of filtration fence. Serving just 1% of this market with compost socks would create demand for 20 million additional tons of high-value finished compost, absorbing well above the additional supply projected in the Roadmap and beyond.

RECYCLING SOLUTION DESCRIPTIONS

The top three solutions represent 89% of the total recycling diversion potential: Centralized Composting, Centralized AD, and WRRF with AD.



1. CENTRALIZED COMPOSTING

DEFINITION

Composting is the process of transforming organic waste into humus, a critical component of healthy, fertile soil. In rural areas, this can be accomplished by periodically turning large piles, or windrows, of organic waste over themselves using specialized equipment. In more urban areas, aerated static pile (ASP) composting is generally preferred, where piles can be covered and mechanically aerated in order to minimize the site's footprint and odors.

DIVERSION POTENTIAL

5M TONS

ECONOMIC VALUE

$18M

TIMEFRAME

MEDIUM TERM

PENETRATION

LOW

WHO BENEFITS

MUNICIPALITIES

COMPOST OPERATORS

WHO CAN TAKE ACTION

MUNICIPALITIES

COMPOST OPERATORS

CONSUMER-FACING BUSINESSES

HAULERS

OVERVIEW

There are 5,000 composting facilities nationwide, yet it is a highly fragmented market, with only 500 facilities accepting food scraps.[52]

A relatively large facility — processing up to 40,000 tons per year — is expected to cost $5 to $9 million in upfront capital and $17 to $28 per incoming ton to operate. Most existing compost facilities are much smaller, lacking economies of scale — the national average is closer to 5,000 tons per year.[53] For example, a 50,000 ton-per-year facility incurs nearly half the capital cost of a 10,000 ton-per-year facility on a per-ton basis. Since contamination is a critical issue in large-scale composting, the Roadmap modeling assumes state-of-the-art depackaging and screening equipment is used despite the higher capital costs incurred. From a system perspective, higher costs of screening feedstocks will most likely be offset by higher market value of cleaner compost.

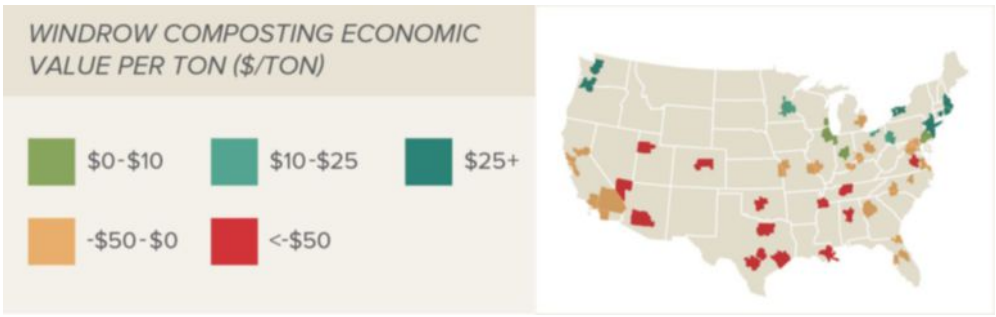
In the near term, adding new compost facilities is expected to be most successful in the Northeast and the Northwest due to high market values for compost and high costs of disposal. Given the mandate to divert commercial food waste in California, the Roadmap also assumes an increase in composting facilities there, despite slimmer profit margins. The Windrow Composting map below illustrates how Economic Value varies for composting regionally based on Roadmap modeling.

CHALLENGES

- It is difficult for compost to compete on price with synthetic fertilizer, which benefits from cheap oil and large production economies of scale driven by industrial agriculture.
- Food waste, high in nitrogen content, requires additional carbon sources to reach an optimal mix necessary for healthy compost piles. Availability of carbon-rich feedstocks (e.g. yard waste) to balance the food waste is limited in some regions. Competition for carbon sources from other buyers, such as biomass power plants, has driven costs higher in recent years.
- Climatic conditions can greatly impact composting operations and processing time. In northern geographies, winter conditions can turn windrows dormant for part of the year.

STAKEHOLDER ACTIONS

- Investors and project developers should target areas with diversion mandates for project investment. Populous regions lacking those mandates need consistent effort from industry to support progressive policies.
- Facility operators and municipalities should focus on revamping existing compost facilities that process only yard waste to accept food waste and delivering the proper training for handling and processing this source-separated material.
- Municipalities, haulers, and facility operators should pay attention to the recommended actions in the "Overcoming Barriers to Recycling"section on pages 56–60, particularly the "End-Market Development" and "Packaging and Contamination" sections.



2. CENTRALIZED ANAEROBIC DIGESTION (AD)

DEFINITION

A series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen resulting in two end products: biogas and digestate. There are many different AD technologies, including wet and dry versions, the latter being generally better suited for food waste mixed with yard waste.

DIVERSION POTENTIAL

1.9M TONS

ECONOMIC VALUE

$40M

TIMEFRAME

MEDIUM TERM

PENETRATION

LOW

WHO BENEFITS

MUNICIPALITIES

AD OPERATORS

WHO CAN TAKE ACTION

MUNICIPALITIES

AD OPERATORS

HAULERS

CONSUMER-FACING BUSINESSES

OVERVIEW

More than 2,000 sites in the U.S. utilize ADs, primarily in agricultural, wastewater, and urban settings,[54] but only 40 to 50 are dedicated to processing food scraps today.

The primary physical byproduct of AD is a digestate. The liquid fraction of digestate can be applied to fields seasonally as a biofertilizer, and the solid fraction can be composted. Biogas, the primary economic byproduct, consists of roughly 60% methane and can be:

- minimally treated and used to generate heat on-site, offsetting natural gas,
- treated to remove contaminants and fed into a natural gas pipeline,
- treated and converted to compressed natural gas (CNG) as a renewable vehicle fuel, or
- converted to electricity and heat with a combined heat and power (CHP) system.

Capital costs for a larger AD facility (50,000 tons per year) are expected to be over $20 million.

Similar to Centralized Composting, the combination of high disposal fees, high compost values, and high electricity prices make the Northeast the most favorable area for Centralized AD economically. The Northwest has very cheap electricity, but if the gas is used to power vehicles rather than create electricity, it can be profitable. Areas like Las Vegas and Tampa, Fla., show profit potential, but low disposal fees and high collection costs make it unlikely that projects will be developed without additional policy support.

CHALLENGES

- The cost of capital is both critical to project economics and correlated to uncertainty in the supply of feedstock for the life of the project. AD facilities often need to secure a complex set of contracts with multiple points of waste generation. Large anchor generators are preferred but are hesitant and unlikely to sign long-term contracts since renegotiating contracts on a regular basis can lower costs for the generator.
- A survey of producers in California identified the negotiation of power purchase agreements with local utilities as the most difficult challenge for AD.[55]

STAKEHOLDER ACTIONS

- Policymakers can offer broader recognition of the ability for biogas to contribute to renewable energy portfolios. The Department of Energy is helping facilitate this transition with its recent expansion of the definition of “biomass” to include “wet waste,” including food waste, for renewable fuel standards.[56]
- Further development of AD in agricultural settings is needed. A very small proportion of U.S. dairy farms — about 250 out of 51,000 — are currently digesting manure.[57] The USDA estimates the market for AD installations could approach 11,000 farms nationally.
- Leasing models could allow for a third-party owner or operator to manage regional sets of medium-size digesters.
- More consistent markets for digestate products would boost the stability of AD projects. One step is to develop organics certification for digestate-derived fertilizer through channels like the National Organics Program (NOP) in order to be recognized as organic by the USDA.
- Impact investors can offer lower-cost sources of financing to enable projects that are unable to complete their financing today.

3. WRRF WITH AD

DEFINITION

Delivering waste by truck or through existing sink disposal pipes to a municipal water resource recovery facility (WRRF), where it is treated with anaerobic digestion; the remaining biosolids can be applied to land for beneficial reuse

DIVERSION POTENTIAL

1.6M TONS

ECONOMIC VALUE

$38M

TIMEFRAME

MEDIUM TERM

PENETRATION

MEDIUM-HIGH

WHO BENEFITS

MUNICIPALITIES

WRRFS

WHO CAN TAKE ACTION

MUNICIPALITIES

WRRFS

OVERVIEW

There are over 1,200 AD facilities installed at WRRFs today, typically in the 20% of WRRF facilities in large MSAs that treat 80% of U.S. wastewater.[58, 59] Electricity costs are typically the largest operational expense of WRRFs, and the recent trend of accepting municipal food scraps is a way to boost gas production of existing AD facilities.[60] Expansion of existing facilities is the most cost-e□ective option, but some WRRFs may build new AD facilities designed from the start to digest both food scraps and municipal waste sent down the drain. Today, only 55% of WRRF ADs recover the biosolids for beneficial reuse versus landfilling. Given that WRRFs are generally operated by the municipality, most WRRF AD projects are publicly financed and operated and therefore developed based on the net public benefit.

Food scraps can go to WRRFs in one of two ways: by truck or down the drain by pipe. Many factors specific to local communities and infrastructure will influence the benefits and costs of each delivery method. The Roadmap modeled the expansion of WRRF AD systems using assumptions of a drain-and-pipe-based system, which will eliminate collection trucks and routes. However, there are advantages to consider with truck-based collection and delivery. Truck-based collection systems help avert unintended impacts of food scraps to pipes, such as blockages, and eliminate the high energy demands and costs associated with primary treatment at the WRRF. Once delivered, food may be injected directly into a digester at the WRRF, preferably into a dedicated unit which can keep material separate from sewage and maximize the end market material value. Some research indicates the greatest environmental value may come from truck delivery.

The case for drain disposal focuses on in-sink grinders (ISGs) in larger urban areas equipped with modern water treatment plants and in sewer systems with capacity to handle extra waste. ISGs have been utilized in commercial settings, and the Roadmap incorporates the potential to expand their use by residential users — also known as garbage disposals or by the brand name InSinkErator — under the right conditions. Proponents of drain disposal promote its convenience, which can increase participation rates, reduce the need to purchase and operate a truck fleet, and eliminate storage odors.

For it to be economically attractive to send food scraps down the drain, WRRFs must use primary treatment to remove a high fraction of carbon, the most energy-intensive component of wastewater treatment. Otherwise, the high energy cost to treat the additional organic content in the waste can run into the hundreds of dollars per ton treated, outweighing any gains from the AD. In addition, a drain-based approach will only be e□ective at large-scale WRRFs in big cities that utilize advanced energy-e□cient processes to further reduce the cost of treating the organic material.

CHALLENGES

Industry concerns exist regarding the conditions under which drain disposal can be a cost-e□ective and scalable solution. The following concerns reflect the potential for many MSAs to consider a truck-based transportation system for incorporating additional food scraps at a WRRF AD facility:

- Cities vary in ISG policy due to pipe concerns or questions about whether WRRF facilities can handle the material load. Some cities prohibit ISGs in commercial facilities but allow them in restaurants, institutions, and homes. Detroit, for instance, requires commercial ISGs while New York City prohibits ISGs for commercial establishments.
- Commercial businesses often require grease traps to prevent fats and oils from causing blockages and odor issues within sewer pipes. It is unclear if this is feasible in homes.
- Benefits of ISGs vary geographically. Colder climates with steeper pipe gradients have sewers that move wastewater to the WRRF at a higher velocity and experience fewer fugitive GHG emissions in the pipe. Warm regions with flatter pipe gradients will experience a higher degree of fugitive emissions and sewer maintenance complications. Areas facing drought may also have concerns that putting additional

CASE STUDY: TACOMA, WASHINGTON

The City of Tacoma needed to reduce emissions and divert waste using existing infrastructure. An evaluation showed food waste sent to ADs at the WRRF could fuel 50 CNG refuse haulers at net-zero cost. A demonstration project was performed to address potential concerns around the quality of the digestate, excessive digester foaming due to lower pH of food waste, and impacts to current solid-waste operations. Food waste was collected from 66 commercial generators and processed with a depackager to pulp the material and create a slurry ready to be digested.

The project showed no unusual or unexplained effects during digestion and no observed changes in the digestate quality. However, the project did highlight the challenges around contamination from metals and plastics as well as fibrous or dense organic waste (e.g. corn cobs, avocado pits) that can result in loads being rejected. After evaluating potential transport options, the city will also begin receiving additional food waste material through the sewer.

food waste down the drain will increase net water usage.

- ISGs are not suitable for transporting all types of household food waste to WRRFs (e.g., animal products).
- Without proper pretreatment, additional biological loading from food waste can significantly increase the operating cost at a WRRF, from $200 to $300 per ton.[61]
- Regardless of how waste is transported to the facility, communities often resist the land application of biosolids produced from AD projects due to concerns around negative health effects and contamination from pharmaceuticals and industrial materials. Increasing biosolids output without addressing these concerns will result in biosolids in landfills rather than more beneficial applications such as farming.

Additional research is needed to understand the scalability of drain disposal to WRRFs versus truck-based collection systems from commercial establishments.

STAKEHOLDER ACTIONS

- Today, approximately half of residential households are equipped with ISGs in kitchen sinks. Cities with high existing penetration or lower density where collection by trucking is especially expensive can be good targets for expansion.
- WRRF plant managers need a financial incentive and end-market customer for biosolids to ensure that it is repurposed for beneficial use and not sent to the landfill. Cooperation between relevant organizational stakeholders can foster transparent, reliant markets for biosolids. For example, the National Biosolids Partnership, which is hosted by the Water Environment Federation, promotes safe and best practices for biosolids applications.
- The capacity of existing WRRF ADs in urban areas to accept additional materials to boost gas production can be explored. Successful WRRF co-digestion projects have demonstrated the potential for this AD approach for food waste in places such as Oakland, Calif.; Tacoma, Wash.; and Milwaukee.

4. COMMERCIAL GREYWATER

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 595K TONS

ECONOMIC VALUE: $19M

Who Benefits:

RESTAURANTS, FOODSERVICE, EQUIPMENT VENDORS

Who Can Take Action:

EQUIPMENT VENDORS, NONPROFITS, CONSUMER-FACING BUSINESSES

DEFINITION

An on-site treatment technology, greywater aerobic digesters use combinations of nutrients or enzymes and bacteria to break food organics down until soluble, where it is flushed into the sewage system.

CHALLENGES

- Units are expensive, ranging from $40,000 to $75,000, and are more popular in Europe and East Asia where higher landfill fees offer a faster economic payback than in the U.S.
- There is limited transparency of biological processes and the nature of material going down the drain, which is a major concern of municipal water authorities responsible for preventing pipe clogs and running WRRFs.
- These units can be controversial since they do not fully digest the food scraps and may require additional processing by WRRFs, which may or may not have the capacity for processing in place.
- Units require electricity to operate and release greenhouse gases during partial digestion, leading to uncertainty regarding environmental impacts.

STAKEHOLDER ACTIONS

- Nonprofits and manufacturers should conduct additional research on biological processes and potential environmental impacts to ensure commercial greywater systems do not have adverse and unintended impacts.
- Large restaurants or cafeterias should research whether a three- to five-year payback period is achievable through waste collection savings.

EXAMPLES

- The Intercontinental Miami uses ORCA, a popular commercial greywater system, to reduce its monthly waste bill by $2,600 per month.[62]

5. COMMUNITY COMPOSTING

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 167K TONS	ECONOMIC VALUE: -$6M
Who Benefits: **CONSUMER-FACING BUSINESSES, CONSUMERS, MUNICIPALITIES**	Who Can Take Action: **NONPROFITS, CONSUMERS, MUNICIPALITIES**

DEFINITION

Transporting food from homes by truck, car, or bicycle to small, community, or neighborhood-level compost facilities that process 2,500 tons per year on average

CHALLENGES

- Programs often struggle to be financially viable and need to charge homeowners and businesses a direct subscription fee to support the collection of material.
- Programs typically use volunteers and less sophisticated equipment, which can reduce quality of output and increase processing time.
- The total capital needed to add 140 programs is expected to cost over $60 million, roughly $380 per ton of food composted, which is much higher than larger-scale compost facilities.

STAKEHOLDER ACTIONS

- Communities can utilize excess land near community gardens, schools, or even other waste-management infrastructure to set up composting sites.
- Colocating composting sites with other community assets will enhance Non-Financial Benefits such as job creation, food access, and educational opportunities for children.
- Foundations and local governments can provide grant funding to support site development, resulting in environmental and community benefits.

EXAMPLES

- The Lower East Side Ecology Center provides New York City residents with free food waste drop-o programs. The resulting compost is incorporated into a potting soil product and sold. [63]

6. HOME COMPOSTING

PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 97K TONS	ECONOMIC VALUE: $14M
Who Benefits: **CONSUMERS**	Who Can Take Action: **CONSUMERS, MUNICIPALITIES, EQUIPMENT VENDORS**

DEFINITION

Keeping a small bin or pile for on-site waste at residential buildings to be managed locally; also known as “backyard composting”

CHALLENGES

- After a few months, consumers may not maintain their compost pile.
- For apartment dwellers or those in cold climates, it may be challenging to find a convenient location for the compost bin.

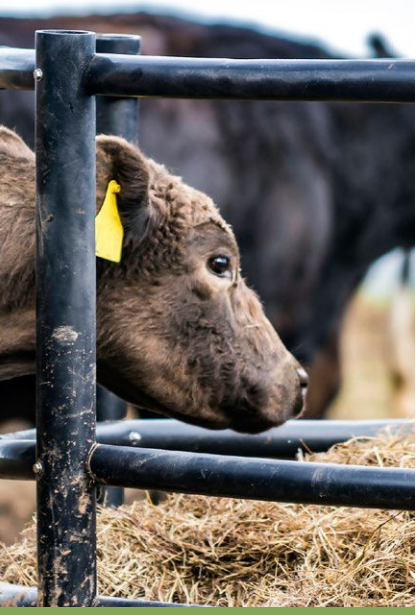
STAKEHOLDER ACTIONS

- Cities that don’t o er curbside composting pick-up can provide grants or free systems, which should pay for themselves within three to five years through reduced collection costs and tipping fees.[64]
- The Roadmap estimates that 750,000 new households could feasibly begin home composting, which would require a massive consumer education and marketing campaign.
- Consumers can create or purchase their own composting system. Typical costs range from free (utilize backyard materials) to $100.

EXAMPLES

- The City of Orlando provides free home composting systems to residents and used funny videos to market the program.[65, 66]

7. ANIMAL FEED



PENETRATION: **MEDIUM-HIGH**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 49K TONS	ECONOMIC VALUE: -$3M
Who Benefits: **FARMERS, MANUFACTURERS, CONSUMER-FACING BUSINESSES**	Who Can Take Action: **FARMERS, MANUFACTURERS, CONSUMER-FACING BUSINESSES**

DEFINITION

Feeding food waste to animals after it is heat treated and dehydrated and either mixed with dry feed or directly fed

CHALLENGES

- Hog and cattle farmers can substitute treated food waste for commercial feeds to reduce costs.
- The vast majority of waste appropriate for use in animal feed is already being used.[67]
- Expensive dewatering and treatment equipment is needed at a transfer station to process mixed food scraps into something appropriate for animals.[68]
- Finding locations with proximity to large generators as well as large animal production operations is tough.[69]

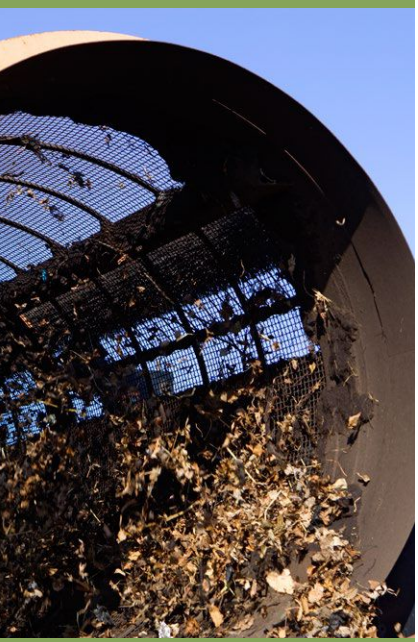
STAKEHOLDER ACTIONS

- Entrepreneurs and waste haulers could create a dynamic network to match food waste generators with nearby farms.
- New research into animal nutrition may unlock additional potential, as most livestock managers seek feed sources with consistent nutritional qualities to ensure a balanced diet.

EXAMPLES

- Sandwich Me In, a Chicago restaurant, sends food scrap waste to local chickens and then serves the eggs from the chickens to close the loop.[70]
- Quest Resource manages Walmart's waste stream and is able to send 60% of Walmart's organic waste to animal feed, due to a high number of store locations that are close to rural areas.[71]

8. IN-VESSEL COMPOSTING



PENETRATION: **LOW**
TIMEFRAME: **NEAR TERM**

DIVERSION POTENTIAL: 12K TONS	ECONOMIC VALUE: -$1M
Who Benefits: **CONSUMER-FACING BUSINESSES**	Who Can Take Action: **CONSUMER-FACING BUSINESSES, EQUIPMENT VENDORS**

DEFINITION

Composting at small-scale at institutions or businesses with heat and mechanical power to compost relatively quickly (less than one month versus more than two months for windrow composting)

CHALLENGES

- Equipment is relatively expensive.
- Use requires managing a small composting operation in addition to primary business operations.
- Since these units are most e□ective at sites with both a large supply of food scraps and large demand for compost, this technology is likely to continue to occupy a niche market.

STAKEHOLDER ACTIONS

- Case studies can be developed for application at the strongest target customers: universities, sports facilities, farm-to-table restaurants, and small grocery stores.
- Entrepreneurs can continue to innovate to bring down the cost of equipment and automate operation.

EXAMPLES

- For Solutions LLC installed an in-vessel composting machine at a large university and saved the university $25,000 in trash-hauling fees while producing compost to use for local landscaping.[72]

THE PATH AHEAD

Four Tools for Action

THE ROADMAP shows the wide array of scalable solutions that can generate significant Economic Value and Business Profit Potential. But as the report demonstrates, these solutions will not scale up without a concerted multi-stakeholder e□ort. To achieve the Roadmap vision, four tools are needed:

FINANCING
Corporate, Government, and Philanthropic

POLICY
Federal, State, and Local

INNOVATION
Technology and Business Model

EDUCATION
Awareness and Training

TWO PHASES FOR CHANGE

The Path Ahead has two phases. First, an initial investment of capital and resources is required to achieve the 20% waste reduction outlined in the core Roadmap economic analysis. This chapter identifies the specific tools to implement these solutions.

For the second phase, ReFED has taken the learnings from the Roadmap to envision what transformational changes are required to achieve the broader national goal of a 50% waste reduction by 2030. For each of the four tools, a set of hypotheses is presented to fuel future research and present a first look at the scale of the challenge and opportunity ahead.

KEY INSIGHTS

The Roadmap will require an $18 billion investment, less than a tenth of a penny of investment per pound of food waste reduced, which will yield an expected $100 billion in societal economic value over a decade.

- The estimated funding need is $8 billion of government support via mostly existing legislation, $7 billion of market-rate private investments, and $3 billion of philanthropic grants and impact investments.

Four crosscutting actions are needed to quickly cut 20% of waste and put the U.S. on track to achieve a broader 50% food waste reduction goal by 2030.

- **Financing** – To overcome the bottlenecks to unlocking $18 billion in financing, $100-$200 million annually is needed in catalytic grants, innovation investments, and low-cost project finance. Today, few investors or foundations focus explicitly on food waste.
- **Policy** – Commonsense policy adjustments are needed to scale federal food donation tax incentives, standardize safe handling regulations, and boost recycling infrastructure by expanding state and local incentives and reducing permitting barriers. The biggest lever to accelerate change is comprehensive federal legislation.
- **Innovation** – Key technology and business-model innovations are needed around packaging and labeling, IT-enabled transportation and storage, logistics software, value-added compost products, and distributed recycling. These could be accelerated through a national network of food waste innovation incubators.
- **Education** – Launching a widespread training effort to change the behavior of food business employees is critical. In addition, campaigns to raise food waste awareness among consumers need to attract additional funding and support to expand to the scale of anti-littering and anti-smoking efforts.

FINANCING

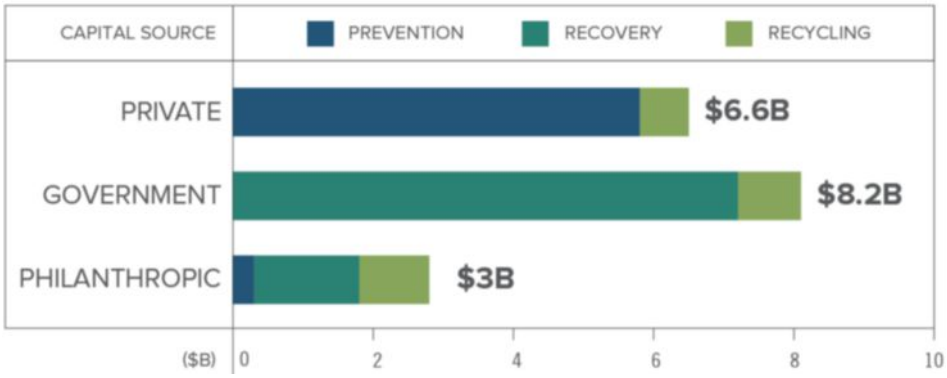
EVERY SOLUTION requires funding, whether a few hundred thousand dollars to fund a cold chain management pilot or hundreds of millions of dollars for new recycling infrastructure.

The Roadmap estimates that an aggregate $18 billion of new financing is needed to achieve a 20% waste reduction — or roughly $2 billion per year averaged over the next decade. While this may seem large, it amounts to only a tenth of a penny of investment for each pound of food waste reduced. This one-time investment will yield roughly $100 billion of economic benefits for society, including an estimated $20 billion of total business profit opportunity over the same period. ⊕

The financing needed to achieve the 20% reduction goal can be broken out into three broad categories: private, government, and philanthropic.

To overcome the bottlenecks to unlocking $18 billion in financing, $100-$200 million annually is needed in catalytic grants, innovation investments, and low-cost project finance.

FINANCING NEEDS FOR 20% REDUCTION IN FOOD WASTE OVER A DECADE



The financing sources were estimated using a three-step process. First, it was assumed that private finance would flow to solutions that o□er market-rate returns: corporate purchases of products, services, or equipment; equity investments into growing businesses; and project finance for infrastructure. Next, the growth in government funding was estimated based on existing policies, including tax incentives and subsidized finance for recycling infrastructure. Finally, philanthropic grants and impact investments were calculated to fill the gap, providing the additional funding required to achieve scale.

Most financing needs can be met from a variety of sources. These estimates are not meant to be prescriptive; they are an approximation of the scale of resources needed to tackle the food waste challenge.

PRIVATE CAPITAL

Three types of private capital are required: internal corporate finance, private equity investment, and private project finance.

- **INTERNAL CORPORATE FINANCING: $5.2 BILLION** | When a company invests its own capital in a food waste solution, it must be mature enough to meet an internal return hurdle rate relative to other opportunities. Nearly 70% of corporate finance is needed for two capital-intensive prevention solutions: Secondary Resellers and Packaging Adjustments. Secondary Resellers require investment to build out new

⊕ More detail on the methodology for estimating the financing gap can be found in the Technical Appendix available at refed.com.

retail sales infrastructure, while making packaging adjustments requires upgrades to existing packaging production equipment and ongoing annual investment into more expensive packaging in some areas. Other major corporate investment areas include Smaller Plates, Spoilage Prevention Packaging, and distributed equipment for several recycling solutions.

- **PRIVATE EARLY-STAGE AND GROWTH EQUITY: $800 MILLION** | Private equity investments range from a $500,000 seed investment from an angel investor to a $20 million growth equity investment in a profitable but growing business. Priority sectors for this funding that are ready to scale include Spoilage Prevention Packaging, Waste Tracking & Analytics, Centralized Composting, Centralized AD, and Commercial Greywater. The dollar estimate is conservative as breakthrough innovations are not included in the 20% Roadmap analysis.
- **PRIVATE PROJECT FINANCE: $500 MILLION** | Project equity and debt fuels the development, construction, and operation of multi-million dollar infrastructure projects. Most of this funding is needed for large AD facilities, which typically finance 20% to 30% of the upfront costs through project equity, with the remainder funded through project debt after subtracting out subsidies. Smaller projects can also use project finance, including new packaging facilities, animal feed processing, and on-site pre-processing equipment. Lower cost financing will stimulate a larger number of projects to be built.

GOVERNMENT FUNDING

Government funding includes tax rebates or subsidies, as well as direct municipal, state, or federal project financing or grants to businesses to promote broader public goals.

- **TAX INCENTIVES: $7.2 BILLION** | The economic analysis found that Donation Tax Incentives for food businesses have an opportunity to stimulate an additional 380,000 tons annually of donated food. It is assumed that a maximum of $720 million per year of tax subsidies will be needed over the next decade to directly offset the additional time and labor costs incurred by businesses making food donations. These incentives are already supported by existing legislation passed into law in late 2015. Historically, a portion of businesses that qualify for tax incentives do not file for them, which likely reduces the actual tax burden by hundreds of millions of dollars per year below this estimate. Further research should explore a more detailed state-level assessment of donation tax incentives, as well as other tax incentives to support recycling projects or general corporate R&D that were not within the scope of this study.
- **PUBLIC PROJECT FINANCE: $11 MILLION** | The economic feasibility of recycling projects often depends on partial funding from public sources in the form of municipal bonds, debt, or utility public-private partnerships. Most of this funding will be directed to WRRF with ADs, which are publicly owned facilities managed by municipal wastewater authorities. Community Composting and some centralized recycling projects will also leverage public funding. Public finance typically is priced with a 3% to 5% interest rate, which is lower than most sources of private project finance.
- **GOVERNMENT SUBSIDIES:** Some government programs give direct grants to projects that promote the public good. These grants could cover a number of Roadmap solutions, including Consumer Education Campaigns, research and development, recovery programs, and recycling infrastructure pilots. For simplicity, all expected grant funding was allocated to the philanthropic sector.

PHILANTHROPIC FUNDING

Philanthropic funding includes grants and impact investments to fund solutions that create public benefits or have costs and benefits that accrue to different organizations. Foundations are typically the main source of philanthropic capital, but funding can also come from private impact investment funds, high-net-worth individuals, and nonprofit industry associations. It is estimated that foundations currently allocate less than $10 million per year explicitly to food-waste-related solutions. To achieve the objectives in the Roadmap, funding levels will need to be dramatically scaled.

FINANCING NEEDS BY TYPE

PRIVATE

Corporate Finance - **$5.2B**
Private Equity - **$0.8B**
Project Finance - **$0.5B**

GOVERNMENT

Tax Subsidy - **$7.2B**
Project Finance - **$1.1B**

PHILANTHROPIC

Grants - **$2B**
Impact Investments - **$1.1B**

- **GRANTS: $2 BILLION** | Grants help support the scaling of solutions using six main methods: capacity building for local multi-stakeholder coalitions, direct education and training for consumers and businesses, policy advocacy and support, research and pilots, direct funding of critical infrastructure, and data tracking and monitoring.

  Philanthropic funders should prioritize their grant funding based on their mission. For those focused on hunger, there is ample opportunity to support the food recovery sector through storage, transportation, education, and advocacy e□orts. Foundations focused on the environment or community development are recommended to back a multi-stakeholder national Consumer Education Campaign. Other priorities include stimulating Centralized Compost and AD projects in municipalities that face barriers, catalyzing innovation around compostable packaging and Value-Added Processing social enterprises, and fueling pilot projects around Standardized Date Labeling and Produce Specifications.

- **IMPACT INVESTMENTS**: **$1.1 BILLION** | In the Roadmap, impact investors are defined as those who seek a financial return but are willing to accept more risk or potentially lower returns in pursuit of measurable social or environmental impact. Recipients of these investments typically include social enterprises, infrastructure projects, early-stage innovators, and nonprofits.

  Impact investments mostly consist of low-interest loans and high-risk equity investments. The majority of capital is expected to come from foundations. Low- or no-interest loans and loan guarantees in the form of program-related investments are needed to fund food recovery and recycling infrastructure, particularly capital-intensive Centralized AD and WRRF with AD that support clean energy goals. Centralized Compost facilities may also be attractive due to high levels of job creation. Today, startups are seeking funding for solutions including Donation Transportation and Donation Matching Software. Finally, a small pool of high-risk, high-yield debt is needed to support sub-scale projects or pilots lacking a source of risk capital, including Value-Added Processing and Community Composting.

THE NEED FOR CATALYTIC CAPITAL

The majority of the financing required will flow naturally from existing government regulation and basic market forces. However, an estimated $100 to $200 million per year of catalytic capital is needed to unlock scale for solutions that face continual financing barriers.

Catalytic capital is defined as financing that has a multiplier e□ect in stimulating larger amounts of future financing and waste reduction by overcoming system-level barriers. Catalytic capital includes the majority of impact investments as well as smaller amounts of grants and other finance. There are five levers that generate this multiplier e□ect:

- De-risking new innovations – Startups need early-stage funding, subsidized pilots, or flexible debt to demonstrate they are e□ective in real-world settings to attract follow-on private investment.
- De-risking novel projects – Any project with a first-of-its-kind component faces an extra risk premium. Low-interest debt or credit enhancements can help get these projects deployed and de-risked to lower the cost of future financing.
- Unlocking bottlenecks – Some types of infrastructure projects struggle to attract funding due to marginal profit margins, but they are critical to lowering costs for the system as a whole. Trucks and storage facilities, for example, are bottlenecks within the recovery and recycling ecosystems.
- Overcoming agency problems – Some solutions fail to get funded because no one stakeholder benefits enough to justify the costs, such as various recycling projects or Standardized Date Labeling. Catalytic capital shifts the economics so other stakeholders are incentivized to invest.
- Stimulating marginal projects – Many projects with valuable social and environmental benefits are not financed due to marginal profitability. A slice of catalytic capital can shift the economics of these projects above the necessary hurdle rate to attract market-rate financing.

REGIONS RIPE FOR RECYCLING INVESTMENT

Investment potential is highest for recycling in regions with high landfill costs, high energy prices, and policies that provide clear market signals, including the Northeast, West Coast, and some Midwest regions. Refer to Recycling Solutions on page 52 for more information.

THE PATH TO A 50% REDUCTION

An estimated $18 billion of financing is needed over the next decade to achieve a 20% waste reduction target. The broader 2030 reduction target will be more challenging to finance because many of the most profitable and highest cost-benefit investments will have already been made. Two wide-scale efforts are needed to jumpstart financing and put the country on a path to reach the broader 50% goal:

THE OPPORTUNITY

Form new impact investment funds to galvanize investment in food waste reduction solutions, while better incorporating Non-Financial Impacts into government budgeting

1. **AGGREGATE IMPACT INVESTMENTS USING A PURPOSE-BUILT FOOD WASTE SOLUTIONS FUND**

   A dynamic opportunity to accelerate the Roadmap implementation is to create new funding models that aggregate catalytic, impact-oriented capital. The opportunity exists to unlock market-rate capital that is available for promising investments by forming impact investment funds designed specifically to help de-risk new innovations and remove bottlenecks for projects not yet attracting capital.

   Current investments in novel food waste solutions are often made with limited staff time and resources. Larger pooled impact investment funds — such as DBL Investors, a fund for environmental growth equity investments — have demonstrated the advantages of reaching $100 million or larger. Larger funds can invest in research staff to deepen their expertise on each sub-sector, widen their geographic coverage to source quality investments, develop a systemic methodology for due diligence, and leverage broader networks to help portfolio companies thrive.

   A purpose-built food waste solutions fund offers additional benefits to private, corporate, and philanthropic funders. For example, a grocery chain would benefit by catalyzing new recycling infrastructure where none existed before, lowering the costs of food waste disposal for stores in that region. By making it easier for all grocers to recycle their food scraps, the grocer could lower its own water and greenhouse gas footprints to help achieve corporate sustainability goals. Investments in prevention innovations would also have a direct impact on grocer profitability by reducing food purchasing costs, while recovery investments can increase employee morale and community relations.

2. **QUANTIFY NON-FINANCIAL BENEFITS TO INCREASE GOVERNMENT SUPPORT**

   The largest expected financing category is government support in the form of tax incentives, project finance, and other subsidies. Although government funds are designed to support the public good, advocates have lacked data to include non-financial benefits into decision-making.

   There are three main Non-Financial Impacts that could be better integrated. First, there is early evidence that food recovery may be an extremely cost-effective source for food assistance programs. Deeper research on this topic could help recovery efforts tap the tens of billions of federal dollars that support local food assistance. Second, the Roadmap has demonstrated the enormous potential water and GHG savings from prevention solutions. Food waste advocates should push for the inclusion of a social price on carbon and the economic benefits of agricultural water conservation in water-stressed regions into cost-benefit analysis frameworks.

   Finally, since most food waste actions occur locally, there is an untapped opportunity to advocate for additional municipal funding. The benefits of job creation, reduced municipal spending on landfills, and energy security from local biogas supply all align with municipal goals. This could encourage municipalities to streamline permitting and offer better prices for electricity, including lower barriers for AD facility grid connections or utility quotas for distributed energy production.[73] Combined, adding Non-Financial Impacts into government planning could generate billions of dollars of additional funding by 2030 to cost-effectively support public goals.

CASE STUDY: THE CLOSED LOOP FUND

The Closed Loop Fund (CLF) was formed in 2013 after a convening led by Walmart resulted in a commitment of over $100 million from manufacturers, consumer goods companies, and retailers to help increase recycling rates in cities across North America. CLF began with a unique thesis that a lack of access to debt funding at affordable rates was hampering the growth of municipal recycling programs across the country. CLF provides municipalities zero-interest loans and gives private firms engaged in public-private partnerships access to capital at below-market rates. The corporate funders of CLF, as well as the entire consumer packaged goods industry, benefit financially by increasing the availability of recycled material to put back into their supply chains. Projects are screened based on clear metrics of financial viability, scalability (including the ability to solve key industry bottlenecks), and reporting metrics.

POLICY

CURRENT STATE OF U.S. FOOD WASTE POLICY

The Roadmap highlights a number of areas where policy can facilitate the adoption of food waste solutions. To achieve the 20% goal, the immediate priority is to spread best-practice policies at the local and state levels. Over the long-term, a 50% diversion goal will likely require a comprehensive federal food waste policy that sets national guidelines to significantly boost investment from national food businesses.

Policy treatment of food waste diversion differs dramatically throughout the country. Some states and even a few cities have implemented complete organics landfill bans to force businesses to invest in prevention, recovery, and recycling. While these bans incentivize waste reduction, they also create challenges for large businesses that operate across geographies. Similarly, the lack of standardized national regulation around date labeling and clear guidance on food safety for donations has hampered progress in building the business coalitions required to achieve major change.

NEAR-TERM POLICY PRIORITIES

The Roadmap was framed to focus on solutions that can scale under existing policy or with only minor adjustments. The near-term priorities focus on two solutions related to food recovery policy:

- Maintaining the recent expansion of permanent federal tax incentives for all farms and business sizes for food donations.
- Reforming food donation standards and standardizing safe handling practice regulations coupled with donation liability education.

In addition, a number of solutions call for straightforward policy adjustments to help overcome barriers. For example, many large compost and AD facilities are constrained by stringent regulations that vary by state and can lead to permitting processes that last three to five years. Often compost facilities that accept food waste must be permitted as solid waste facilities, which can cost over $10,000 per site. While it is important that facilities are safely sited and well designed, permitting agencies could put recycling projects on a fast track by giving them higher priority than landfill expansions and waste incinerators.

Commonsense policy adjustments that expand state and local incentives and reduce permitting barriers are needed to scale federal food donation tax incentives, standardize safe handling regulations, and boost recycling infrastructure.

Refer to Donation Tax Incentives (page 44), Standardized Donation Regulation (page 45), and Donation Liability Education (pages 48) for more information on stakeholder actions that can facilitate policy changes.

POLICY ACTIONS TO INCENTIVIZE FOOD WASTE CHANGE

SOLUTION	REGULATION TODAY		RECOMMENDED POLICY CHANGE
	FEDERAL	STATE/LOCAL	
Donation Tax Incentives	Yes (recently passed)	Yes (scattered))	Permanent federal tax incentives for all farms and business sizes
Standardized Date Labeling	No	No	Improved FDA guidance on: · standardized date labels · food donation safe handling rules · using plate waste for animal feed
Standardized Donation Regulation	No	Yes (scattered)	
Animal Feed	Yes	Yes (scattered)	
Centralized Anaerobic Digestion	Yes (temporary)	Yes	Organics bans for landfill or incineration Pay-as-you-throw pricing Streamlined permitting for large facilities Local incentives for distributed solutions
Centralized Composting	No	Yes (scattered)	
Commercial Greywater	No	Yes	
Home Composting	No	No	
Community Composting	No	Yes	
WRRF with AD	No	Yes (scattered)	

Multiple ReFED Advisory Board members have noted the importance of local recycling policy enforcement to ensure that waste streams have low levels of contamination. Only then do they o□er enough Economic Value to fuel financially viable processing facilities.

THE PATH TO A 50% REDUCTION

Beyond these immediate priorities, 10 Roadmap solutions are in some way inhibited by the lack of national food waste legislation. The table on page 73 outlines solutions for which transformational policy would unlock significant additional opportunity.

Historically, national-level policy has not gained much ground due to a general lack of awareness of the issue and the complexity of engaging a large multi-stakeholder coalition. Many stakeholders do not realize that national food waste policy has the opportunity to generate jobs, cut the federal tax burden, and improve food and energy security, all of which could be drivers of bipartisan support.

However, comprehensive federal legislation bundles multiple policies together making it easier to create legislation where every key stakeholder group wins. Consumer-facing businesses, farm groups, and landfill associations are critical stakeholder groups that need to see the economic benefits of legislation. In addition, comprehensive federal policy will generate minimum common standards, removing barriers to action for food businesses related to deciphering the panoply of local regulations for topics such as safe food donation handling and compost siting.

STEPS TO POLICY SUCCESS

In late 2015, Rep. Chellie Pingree of Maine introduced a comprehensive Food Recovery Act that pushes for many of the policy goals highlighted in this section. Based on the success of other similar campaigns, the following steps are needed to succeed in passing this or other comprehensive federal policy:

1. **BUILD A COALITION WITH A LEADER:** Considerable preparation is needed to ensure policymakers are aware of the issue and willing to invest political capital to support it. A strong nationwide, multi-stakeholder coalition should lead this e□ort by developing common goals, communicating unified messaging, and securing commitments from a□ected groups. This coalition can attract a wide range of stakeholders, including businesses, industry associations, and nonprofits, to educate policymakers on the issue.
2. **BRING THE FUNDING:** Considerable resources will be needed to coordinate a food waste advocacy e□ort. This financial support should come from the business and philanthropic communities, including advocates for the food insecure, farmers, and the environment. This is an issue with many winners and few losers — messaging should demonstrate how everyone's boat will rise by reducing waste.

When ReFED started the research on the Roadmap, comprehensive federal policy seemed like a distant aim. However, the recent passage of the FY2016 budget included a wide broadening of federal tax incentives for food donations. As this report goes to press, indications show that the potential for major policy wins is growing.

THE OPPORTUNITY:

Pass a federal-level comprehensive food waste bill that ties together policy opportunities and signals a market shift to food businesses

CASE STUDY:

CALIFORNIA FOOD WASTE POLICIES

In California, progressive policies have paved the way to create more food waste recycling projects in the pipeline than in any other state:

- AB 1826 banned organics from the landfill and requires food manufacturers, restaurants, supermarkets, and large foodservice providers to source separate and recycle food and yard waste.
- AB 1594 prevented organics from being used as alternative daily cover at landfill.
- AB 939 set a 50% disposal reduction mandate for cities and counties.
- AB 341 set a 75% collective recycling goal for the state for target year 2020 and requires that businesses and multi-family residences meet recycling requirements.
- AB 32 required California to reduce its GHG emissions to 1990 levels by 2020 by focusing on a series of major warming contributors including CO2 and methane. The California Air Resources Board, in direct response, implemented a Low Carbon Fuel (LCF) incentive to prompt the adoption of low-carbon transportation fuels, o□ering significant benefit to AD facilities that choose to convert biogas to CNG to power vehicles.

INNOVATION

AT A HIGH LEVEL, there are five priority categories of innovation that can drive the greatest impact on food waste reduction: packaging and labeling, IT-enabled transportation and storage, logistics software, value-added compost products, and distributed recycling.

The Roadmap solutions were analyzed "as is" with their current technological limitations, in existing markets, and using prevailing business models. Considerable innovation has already occurred to bring these solutions to market.

While disruptive innovation is not needed to achieve a 20% reduction, incremental innovation is expected to naturally improve performance and decrease costs over the next decade:

Key technology and business-model innovations are needed around these five areas:

- *packaging & labeling*
- *IT-enabled transportation and storage*
- *logistics software*
- *value-added compost products*
- *distributed recycling*

PREVENTION

- Consumer Education Campaigns will become more e□ective through new community-based social marketing tools, such as mobile phone apps that send text message reminders targeted to shoppers at grocery stores.
- Advancements in materials will make Packaging Adjustments and Spoilage Prevention Packaging more cost-e□ective over time.

RECOVERY

- Value-Added Processing will become a□ordable at smaller scales as new business models for food incubators and shared commercial kitchens become more widespread.
- Donation Matching Software will leverage advances in other sharing economy software to improve ease of use and location-based optimization.

RECYCLING

- Centralized Composting and AD facilities will benefit from innovations that squeeze higher yields out of equipment, reduce contamination through depackaging, increase throughput, or capture heat or energy more e□ectively.
- Compost profitability will rise as new value-added products mature in the market to mitigate stormwater runo□ and enhance agricultural production.

CASE STUDY: WISERG HARVESTER USING SMART SENSORS TO TURN WASTE INTO FERTILIZER

One innovator is working to combine on-site recycling and waste analytics into a single package. In 2010, WISErg partnered with PCC Natural Markets in Seattle to pilot an on-site system called the Harvester, which converts up to 4,000 pounds of food scraps daily into a nutrient-rich liquid. A store employee enters an access code, food type, and reason for discard, and then deposits food scraps into the Harvester. A sensor gathers data on food weight, temperature, and time of day. WISErg applies cloud-based analytics to provide management insights to modify purchasing and handling behavior or to redirect edible batches to local food banks. Food scraps processed by the Harvester are then transported to a central facility to be mined for nutrients. The flagship byproduct, WISErganic, is a liquid fertilizer marketed to the agriculture industry. WISErganic has been shown to improve soil nutrient content and crop yields based on data from over 200 commercial growers actively using the product.

THE PATH TO A 50% REDUCTION

Over a third of Roadmap solutions can achieve major gains in market penetration through breakthroughs in technological and business innovations. In addition, several emerging innovations o□er enormous potential if they become cost-e□ective over the next decade.

Because the food system is tightly interconnected, innovations often simultaneously benefit multiple parts of the value chain. For example, compostable packaging not only reduces recycling labor costs for waste generators who no longer need to separate food from packaging, but it improves the economics of Centralized Composting (and some AD facilities) due to reduced contamination rates.

In addition to technology innovation, business-model innovations that share risk across the supply chain in novel ways can be a large driver in waste reduction. For example, supply contracts between retailers and suppliers could be modified so farmers are not incented to over-produce to satisfy vendor contracts. Catering contracts could include clauses stipulating that clients are comfortable with running out of food at their events to relieve caterers of the need to over-prepare.

The table below highlights 15 high-priority technological innovation areas that can drive transformation in the food waste value chain. The greatest innovation opportunities occur within the prevention and recycling solutions.

THE OPPORTUNITY:

Build a network of food waste innovation incubators across the U.S. with dedicated funding, mentorship, and facilities to achieve technology and business-model breakthroughs across five priority innovation areas

HIGH-PRIORITY INNOVATION AREAS: PREVENTION SOLUTIONS

SOLUTION	MARKET CHALLENGE	INNOVATION OPPORTUNITY
BREAKTHROUGHS IN EXISTING SOLUTIONS		
Cold Chain Management	Real-time monitoring of trucks, warehouses, and shipping containers could reduce waiting times and errors through RFID/sensors.	Lower sensor costs to less than $10 per pallet and improve e□ectiveness to meet needs of logistics providers.
Inventory Management	Half of the market does not utilize advanced inventory management systems today.	Target small- and medium-size customers through development of low-cost, flexible solutions.
Packaging Adjustments	Consumers haven't demanded adjustments, and modifications raise concerns about unintended consequences such as breakage.	Conduct consumer behavior research to identify core needs. Fund product R&D to pilot disruptive packaging such as edible films or nonstick bottles.
Spoilage Prevention Packaging	Applicability is limited to certain food types and types of storage.	Improve performance across a wider variety of food types and storage settings.
Waste Tracking & Analytics	Market penetration of solutions is small to date.	Minimize manual measurement through low-cost cameras and sensors and integration with inventory data.
EMERGING TECHNOLOGIES		
Dynamic Store Merchandising	System costs are tremendous, relying on real-time price screens, strong inventory management systems, smart carts, and handheld devices.	Verify NPV through a retail pilot, and identify path to reduce costs. Experiment with location-based mobile phone discounting to reduce total solution cost.
Smart Labeling	The NPV of this solution has not been proven through the limited pilots to date.	Achieve labels that are cheap enough to drive a food-safety or waste-reduction value proposition when placed on the majority of perishables.

HIGH-PRIORITY INNOVATION AREAS: RECOVERY SOLUTIONS

SOLUTION	MARKET CHALLENGE	INNOVATION OPPORTUNITY
BREAKTHROUGHS IN EXISTING SOLUTIONS		
Value-Added Processing	Facilities are expensive and require large scale, reducing applicability for smaller recovery opportunities.	Develop distributed and mobile technologies, combined with new preservation technologies, to cost-effectively link processing on farms to businesses and recovery organizations.
Donation Transportation, Donation Storage & Handling	New infrastructure can be costly and limited in the amount of time it is actually in use.	Identify novel tools to allow for effortless sharing of existing, under-utilized infrastructure not currently linked to recovery networks.

HIGH-PRIORITY INNOVATION AREAS: RECYCLING SOLUTIONS

SOLUTION	MARKET CHALLENGE	INNOVATION OPPORTUNITY
BREAKTHROUGHS IN EXISTING SOLUTIONS		
Centralized AD	Additional labor cost is needed to depackage food, reducing the quantity and quality for recycling.	Scale down large depackaging technology to enable systems at every retailer and manufacturer location.
Home Composting	Current adoption is low due to poor designs, lack of space, and odors.	Achieve odor-free, beginner-level home composting systems for under $50 per unit.
Centralized Composting	Compostable packaging underperforms vs. industry standards and can decrease shelf life of perishables while costing 25% to 100% more.	Conduct R&D in compostable packaging to achieve products on par with conventional price and performance.
Animal Feed	Facilities currently rely on individual relationships.	Leverage sharing economy to create a network of waste generators and farms.
EMERGING TECHNOLOGIES		
Small-Scale AD	Biogas cleaning and electricity conversion is not economical at small business scale, utilization for heat is seasonal,[74] and on-site handling of digestate is challenging for small businesses.[75]	Achieve transformational cost reductions to be commercially viable, which would drive massive collection cost reductions in low-density municipalities and rapid scale similar to distributed energy systems.
Collection	Collection costs can make up 50% to 75% of the overall cost for collecting and processing food waste.	Develop new route optimization technology and new tools to reduce water weight of food scraps before or during transit.

STEPS TO INNOVATION SUCCESS

A network of Food Waste Innovation Incubators across the country with dedicated funding, mentorship, and facilities would be one of the biggest enablers of bringing these 15 innovations to market. Incubators could sponsor dedicated cohorts focused on each of the five major innovation challenges: packaging and labeling, IT-enabled transportation and storage, logistics software, value-added compost products, and distributed recycling. Development of this incubator network will require the following:

1. **ADDITIONAL SERVICE OFFERINGS:** Many startups come to an incubator looking for funding. But equally as valuable is access to a variety of non-financial support, such as business mentors, lab equipment, and connections with consumer-facing businesses and recycling facilities for testing. Foundations can partner with food businesses and universities to fund the use of existing but underutilized equipment and facilities, including commercial kitchens.
2. **PLEDGE TO PILOT:** Food waste innovations need to be tested in the market to ensure that they meet industry expectations. The incubator network should partner with food businesses that commit to pilot new technologies and to reduce the costs and measurement burdens of pilots.

A number of existing food-related incubators, accelerators, and networks could provide a fertile starting point for this e□ort. For-profit and nonprofit organizations include:

- California: Food System 6, Farm2050, and the Mixing Bowl
- New York City: Food-X, Food Future, Inc. (Food Next) and Accel Foods
- Illinois: Good Food, Now We're Cooking
- Boston: Branchfood, Greentown Labs

A number of larger food companies, including Chobani, Diageo, Mars, and Coca Cola, have also recently launched food innovation accelerators and incubators, demonstrating the benefits to business of joining this e□ort. These entities could be guided by a more formal industry association or by a loose coalition to reduce redundancy and share best practices.

EDUCATION

THE LARGE number of Roadmap barriers that are behavioral in nature highlights the need for education, training, and capacity-building for consumers and food business sta to enable change at scale. The path to a 20% reduction in waste includes Consumer Education Campaigns as a standalone solution given its ability to be implemented nationwide. Employee training is embedded as part of the cost of implementation of most solutions.

In addition to campaigns that raise food waste awareness among consumers, it is critical to launch a widespread training effort to change behaviors of food business employees.

CONSUMER EDUCATION

Consumer education is one of the most cost-e ective and scalable Roadmap solutions, as it will directly influence food purchasing and eating behaviors. Examples of behavior changes include reducing over-purchasing, gauging when to use or freeze near-expired food, and incorporating leftovers into soups or other flexible recipes.

Consumer education is also critical to the success of other Roadmap solutions. Standardized Date Labeling and Packaging Adjustment solutions will be much more e ective if consumers are aware of them. When food is ready for disposal, education also impacts whether consumers decide to put it down the drain, separate it for composting, or combine it with regular trash. Previous home recycling programs have demonstrated the need for clear, frequent and consistent communications about proper separation of materials and pickup schedules. Finally, consumer education drives increased demand for business products and services that reduce waste, including imperfect produce and trayless all-you-can-eat facilities.

Lessons can be gleaned from similar education campaigns, specifically around residential energy e ciency and other recycling programs:

- Say Hi Neighbor: In the energy e ciency sector, the biggest motivator of action is often comparison to one's neighbors. Campaign planners should seek a neighborhood waste benchmarking for food.
- Goal-setting: Consumers can be encouraged to set and track waste-reduction goals, as goal-setting has been proven to be a powerful motivator for action.
- Make It Fun: Consumers have a greater emotional connection to food than many other resources they use, so waste reduction can be rebranded as a way to cherish farmers, love our bodies, and build healthy families.
- Make It Easy: Even small hassles, like walking outside in the cold to compost food scraps, can be a barrier to action. Home Composting and Spoilage Prevention Packaging solutions must be nearly painless to gain widespread adoption.

Refer to Consumer Education Campaigns (page 31) for more information on stakeholder actions that can support consumer education.

EMPLOYEE TRAINING

Half of ReFED's solutions require hands-on employee involvement in day-to-day execution. These roles include:

- Knowing how to avoid removing product from shelves when it is still safe and edible
- Identifying and preparing food that can be donated
- Depackaging and properly source-separating food waste to remove contaminants before transport for recycling, which is critical to the viability of recycling processors

The Roadmap assumes that employee training is part of the cost of implementation modeled for each solution. However, given the sector fragmentation, one key short-term need is the dissemination of best-practice training materials. This could take the format of online training videos, printed signage and labeling for kitchen and retail environments or at points of disposal, or low-cost training and consulting services. Similar to food safety information, guidance on how to reduce food waste should be visible throughout food businesses to keep the issue top of mind and easily actionable for employees.

Recycling employee training is more complex due to the diversity of waste feedstocks that are acceptable at each facility. Many programs continue to see higher-than-targeted contamination rates, which hurt their cost-effectiveness. In these environments, messaging and implementation need to be kept simple. For example, many cities have seen municipal solid waste recycling rates double or triple after they switched to combined bins that did not require employees or homeowners to separate out paper, plastic, and metals.

THE PATH TO A 50% REDUCTION

To create a systemic transformation in consumer and employee awareness to reach a 50% reduction, a coordinated campaign is needed to increase the average American's ability to articulate what actions are most effective at home and in the workplace. An audacious program to expand national education on the issue would have two components: a national consumer education campaign and employee certification program.

NATIONAL CONSUMER CAMPAIGN

In 2016, NRDC and the Ad Council will launch the first widespread public service campaign promoting food waste awareness, similar to a program launched in the U.K. by WRAP in recent years. This program will likely begin by targeting behavior around a few key decision-making points, such as standing in grocery store aisles or storing food in the refrigerator.

A 50% reduction will require a campaign that is deep, broad, and long, approaching the awareness penetration of other major campaigns that have promoted increased seat belt use, smoking prevention, litter reduction, or forest fire prevention. Significant additional funding is a starting point. This can help fund research to identify the best messaging, recruit key influencers, experiment with viral messaging approaches, and iterate. To be effective, a multi-stakeholder coalition will likely be required to coordinate messaging and priorities among constituents.

THE OPPORTUNITY

Expand emerging efforts to achieve a national social-based marketing campaign that achieves awareness and behavior change, comparable to Smokey the Bear or other successful education efforts, in coordination with a national employee food waste certification effort.

EMPLOYEE CERTIFICATION PROGRAM

With the high turnover rates in food businesses, employee training is a key barrier to achieving waste reduction at scale. Beyond basic training and awareness, a rigorous certification program would raise the stakes for measuring, verifying, and promoting best practices throughout the country.

The quickest path would be to link food waste certification to existing food safety certification programs, as they are already mandatory in many food businesses and are a top priority for management teams. The first step in this process would be for businesses to work with certifying bodies to begin collecting best practices and training materials on a voluntary basis.

ReFED RECOMMENDS INTEGRATING FOOD WASTE CERTIFICATION INTO EXISTING FOOD SAFETY PROGRAMS.

STEPS TO EDUCATION SUCCESS

Specific strategies to roll out national consumer and employee certification campaigns would include similar steps:

1. **FOCUS ON SOCIAL DYNAMICS AND SELF-INTEREST:** Experience has shown that while some people are interested in social or environmental impacts, most behavior is influenced by interpersonal dynamics or personal financial benefits. Messaging should focus on family, budgets, and freeing up money for aspirational purchases.

   Similarly, businesses will have to make food waste matter to individual store and kitchen employees through a certification program. As one ReFED Advisory Council member explained, “It didn’t really click with our kitchen sta until they saw how much time they could save by not prepping extra food — which meant they could take a longer break, or go home early.”[76]

   With support from industry associations and nonprofits to collect case studies, businesses can communicate metrics that will resonate with employees. These could include time saved during food prep, extra hours available to prep food for donation and recycling, or increased ease in knowing what product to move o store shelves. Similar to how businesses nominate energy e ciency champions, a program to unleash “Food Waste Champions” could empower an army of influencers.

2. **MEASURE AND ADJUST:** Both consumer and employee campaigns need to track impact to inform further targeting or messaging needs. While studies have been conducted in the U.K. and elsewhere to measure the impact of consumer awareness, there has been minimal tracking on what works in U.S. culture. Nonprofits can partner with businesses to track impact in specific markets or campaigns. Waste characterization studies, similar to energy audits, are a powerful tool for businesses or municipalities to set a baseline of waste, a standard monitoring process, and collective goals.

While the Roadmap‘s initial Consumer Education Campaign solution is expected to cost roughly $25 million per year, a comprehensive and aggressive national education and employee certification campaign would require five to 10 times more funding. For example, the recycling industry spends on average $1 per household and $5 per business annually to keep people aware and engaged in programs. Yet the return on investment in terms of dollars saved and strengthened communities is likely to be many times greater.

FUTURE RESEARCH OPPORTUNITIES

Throughout the development of the Roadmap, several areas were identified that would strongly benefit from additional research. Given the diversity of research that needs to be undertaken, ReFED recommends that a coordinating entity ensure that research continually builds upon itself and is not duplicative. In Europe, FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was developed to help coordinate the research agenda. It includes 21 project partners from 13 countries, bringing together universities, consumer organizations, and businesses.[77]

QUANTIFYING FOOD WASTE ALONG THE VALUE CHAIN
The Roadmap relied on the best available data for developing a baseline of where food is wasted. However, in some cases, the quantity of food waste is extrapolated from only one or two studies. It is recommended that future research focus on developing additional data, leveraging the Global Food Loss and Waste Protocol as a framework. This research should focus on the following areas:

- On-farm losses, including variations by different types of products, sizes of farms, geography, reasons for losses, and final destination
- Differences among small and large businesses
- Regional differences
- Seafood waste on ships
- Specialty Institutions, including corporate cafeterias and prisons
- Food waste disposed down the drain in homes and businesses

QUANTIFYING CURRENT LEVELS OF FOOD WASTE INVESTMENT
To more efficiently direct philanthropic, government, and investor resources toward food waste solutions, better data tracking is needed to quantify current investment levels and types of investments.

DRIVERS OF CONSUMER AND EMPLOYEE BEHAVIOR
Effective messaging strategies require a better understanding of the drivers of behavior. Currently, the best available data on consumer response to a food waste social marketing campaign comes from WRAP in the U.K. There is a need for U.S.-based research on responsiveness to various marketing strategies. This research can benefit from an emerging body of work that seeks to apply behavioral economics to environmental and social issues.

ADDITIONAL SOLUTIONS
While the Roadmap includes opportunities across the entire supply chain, the primary focus was on actions that can be taken by consumer-facing businesses. Future research could this research to focus on solutions for farmers, manufacturers, and consumers. High-priority areas that currently have a lot of interest include gleaning, farm forecasting, online grocers, local farming, and subscription meal services.⊕

SYSTEM COMPLEXITIES AND INTERDEPENDENCIES
As discussed earlier, there is a lack of research available to assess the macro level changes that may occur in our food system from a large reduction in waste. A high priority area for research is to better understand the macro-level economic and environmental impacts of waste prevention.

⊕ A comprehensive list of additional solutions can be found in the Technical Appendix on refed.com.

MOVING TO ACTION

Food waste represents a unique opportunity to protect the American economy, conserve natural resources, create jobs, reduce the tax burden, and feed the nearly 50 million Americans who experience food insecurity. The Roadmap has demonstrated that it is feasible using existing solutions that have positive or breakeven Economic Value to reduce food waste by 20% over the next decade. The primary barrier is galvanizing new sources of philanthropic, public, and private financing to scale up these known solutions. ReFED has also identified the transformational changes that need to be made in the areas of policy, innovation, and consumer and employee education to achieve the national goal of reducing food waste by 50% by 2030.

Many of the solutions analyzed are ready to be implemented today. There is a compelling business advantage for companies to act quickly to market imperfect produce, develop new packaging solutions, and nudge consumers with redesigned all-you-can-eat facilities. These solutions o□er a chance for businesses to improve their profitability while creating stronger brands and customer engagement.

Additional solutions will require stakeholders to collaborate across the value chain. Standardized Date Labeling, improved Donation Transportation, and upgraded WRRF with AD facilities will require new and potentially challenging industry partnerships between the public, private, and social sectors. Even so, the expected payo□s from these e□orts will be enormous, delivering multiple times more economic value than can be created by acting as individual entities.

Finally, the Roadmap represents a snapshot in time. As food waste issues continue to evolve, future research opportunities abound to expand upon the analysis and insights presented within this report. Key research priorities include gathering better data around where food is wasted along the value chain, researching drivers of consumer and employee behavior, and expanding to new solutions outside the scope of the Roadmap. The most valuable area for future research is likely in understanding the opportunities behind systemic transformations. A national organics landfill ban, for example, though seemingly improbable, would send a huge economic signal overnight that would catalyze innovation and create new markets.

ReFED has developed refed.com as a hub to help all stakeholders collaborate and take action. The Roadmap Cost Curve is available in a dynamic format to allow adjustment of the data and timeframe represented. The website will be updated to integrate new research, data, and partnerships.

The Roadmap is meant to not just be a research report for academic use, but a data-driven playbook for the whole food sector to take action. We invite you to join us in making the next decade known as the time in history when the United States finally dedicated the resources and willpower to make significant strides in solving the food waste challenge.

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GLOSSARY

TERM	DEFINITION
Anaerobic digestion (AD)	A series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen resulting in two end products: biogas and digestate
Biogas	A mixture of methane and carbon dioxide gases produced during the anaerobic digestion process; can be used for heat and electricity or converted into vehicle fuel
Biosolids	Properly treated and processed sewage sludge; often used as a fertilizer for soils
Business Profit Potential	The expected annual profits that the private sector can earn by investing in solutions after adjusting for initial investment required, differentiated costs of capital, and benefits that accrue to non-business stakeholders
Catalytic funding	Grants or other impact investments that are meant to unlock larger pools of capital by de-risking or improving the return profile of investments
Consumer-facing businesses	Retail grocers, restaurants, foodservice providers, and institutions. Distributors are also added to this category for this report.
Cosmetic imperfection (Imperfect Produce)	Produce that is undersized, blemished, misshapen, or otherwise unmarketable for sale
Digestate	Produced after anaerobic digestion is completed and can be processed into compost
Diversion	The process of diverting food waste from landfills or farmland tillage for a higher value and more productive purpose, like prevention, recovery, animal feed, or composting
Economic Value	The annual aggregate financial benefits to society (consumers, businesses, governments, and other stakeholders) of a solution minus the costs
Food loss	Generally refers to unintended loss of food during harvesting, post-harvest handling, processing, and distribution; included as part of “food waste” as defined in this report
Food recovery organization	An organization that seeks to alleviate hunger through the distribution of recovered food
Food scraps	Generally used to refer to food that is no longer fit for human consumption
Food waste	Food grown and produced for human consumption but not eaten. This includes food still safe to eat — surplus, damaged, or expired — as well as unavoidable waste, such as bones or rinds
Gleaning	Harvesting leftover crops, typically by volunteers
Impact investors	Those investors who seek a financial return but are willing to accept more risk or potentially lower returns in pursuit of measurable social or environmental impact, often through low-interest loans and high-risk equity investments
Institutions	Hospitals, schools, prisons, government buildings, and military bases
Landfill	A place to dispose of refuse and other waste material by burying it and covering it with soil; as used in this report, also includes incineration
Meals recovered	Wasted food recovered for human consumption, using a conversion of one meal equal to 1.2 pounds
Metropolitan Statistical Area (MSA)	A statistical area representing a number of towns and cities around an urban core of at least 50,000
Net present value	Represents the sum of all costs and benefits for each solution over 10 years discounted to the current year using a standard social discount rate of 4%
Non-Financial Impacts	The social and environmental benefits and costs from reducing food waste
On-farm loss	Food loss that occurs on farms and in packinghouses; distinguished from food waste in landfills because the majority of this loss is tilled into soils as nutrients
Tipping fee	The fee paid by haulers for waste disposal at landfills or recycling facilities
Transfer station	A place where local waste collection vehicles deposit their waste cargo prior to loading into larger vehicles for transportation to a different MSA
Water resource recovery facility (WRRF)	A municipal facility that treats water and runoff from disposal pipes, including material from sink disposals; sometimes referred to as a wastewater treatment plant

APPENDIX

ReFED FOOD WASTE SOLUTIONS DATA SET

TYPE	SOLUTION	DIVERSION POTENTIAL (K TONS / YEAR)	ECONOMIC VALUE PER TON DIVERTED	ECONOMIC VALUE ($M / YEAR)	BENEFIT ($M / YEAR)	COST ($M / YEAR)	BUSINESS PROFIT POTENTIAL ($M / YEAR)
Prevent	Consumer Education Campaigns	584	$4,531	$2,648	$2,669	($22)	
Prevent	Waste Tracking & Analytics	571	$2,282	$1,303	$1,378	($75)	$1,003
Prevent	Standardized Date Labeling	398	$4,547	$1,812	$1,820	($8)	
Prevent	Produce Specifications	266	$1,039	$277	$389	($112)	$228
Prevent	Packaging Adjustments	208	$3,443	$715	$949	($234)	
Prevent	Smaller Plates	178	$2,147	$382	$407	($25)	$315
Prevent	Secondary Resellers	167	$218	$37	$1,265	($1,229)	$29
Prevent	Trayless Dining	83	$2,253	$187	$190	($3)	$154
Prevent	Spoilage Prevention Packaging	72	$2,326	$167	$312	($145)	$17
Prevent	Improved Inventory Management	59	$1,194	$71	$114	($44)	$56
Prevent	Manufacturing Line Optimization	20	$1,770	$35	$39	($3)	$28
Prevent	Cold Chain Management	18	$1,816	$32	$35	($4)	$26
Recover	Donation Tax Incentives	383	$1,230	$470	$1,103	($633)	
Recover	Standardized Donation Regulation	193	$2,863	$553	$557	($4)	
Recover	Donation Matching Software	150	$2,879	$432	$433	($1)	
Recover	Donation Transportation	110	$2,294	$252	$317	($65)	
Recover	Donation Storage & Handling	103	$2,366	$244	$297	($53)	
Recover	Value-Added Processing	102	$2,783	$285	$295	($10)	
Recover	Donation Liability Education	57	$2,810	$159	$164	($4)	
Recycle	Centralized Composting	5,037	$4	$18	$520	($502)	$47
Recycle	Centralized AD	1,884	$21	$40	$348	($308)	$43
Recycle	Water Resource Recovery Facility (WRRF) with AD	1,637	$23	$38	$189	($151)	
Recycle	Commercial Greywater	595	$33	$19	$57	($38)	
Recycle	Community Composting	167	($34)	($6)	$13	($19)	
Recycle	Home Composting	97	$149	$14	$18	($3)	
Recycle	Animal Feed	49	($52)	($3)	$2	($4)	
Recycle	In-Vessel Composting	12	($95)	($1)	$1	($2)	
TOTALS		**13,201**	**771 (AVG)**	**10,181**	**13,883**	**(3,702)**	**1,945**

APPENDIX

ReFED FOOD WASTE SOLUTIONS DATA SET

TYPE	SOLUTION	FINANCING COST OVER 10 YEARS ($M)	GHGS (K TONS / YEAR)	MEALS RECOVERED (M MEALS / YR)	WATER CONSERVATION (B GALS / YR)	JOBS CREATED (PARTIAL LIST)
Prevent	Consumer Education Campaigns	$247	2,336		281	
Prevent	Waste Tracking & Analytics	$89	2,306		317	
Prevent	Standardized Date Labeling	$82	1,593		192	
Prevent	Produce Specifications	$133	422		39	
Prevent	Packaging Adjustments	$1,872	830		100	
Prevent	Smaller Plates	$246	711		86	
Prevent	Secondary Resellers	$2,250	510		58	
Prevent	Trayless Dining	$27	332		40	
Prevent	Spoilage Prevention Packaging	$1,095	329		44	
Prevent	Improved Inventory Management	$140	181		20	
Prevent	Manufacturing Line Optimization	$4	61		7	
Prevent	Cold Chain Management	$4	62		6	
Recover	Donation Tax Incentives	$7,179	874	638	110	
Recover	Standardized Donation Regulation	$48	714	322	93	
Recover	Donation Matching Software	$10	555	250	72	
Recover	Donation Transportation	$729	407	183	53	1,604
Recover	Donation Storage & Handling	$580	381	172	50	2,145
Recover	Value-Added Processing	$108	299	171	38	153
Recover	Donation Liability Education	$48	210	95	27	
Recycle	Centralized Composting	$981	2,605			9,000
Recycle	Centralized AD	$957	1,179			1,933
Recycle	Water Resource Recovery Facility (WRRF) with AD	$823	728			100
Recycle	Commercial Greywater	$88	0			
Recycle	Community Composting	$72	163			230
Recycle	Home Composting	$4	53			
Recycle	Animal Feed	$7	34			
Recycle	In-Vessel Composting	$8	11			
TOTALS		**17,830**	**17,885**	**1,829**	**1,632**	**15,165**

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