ECONOMIC ANALYSIS

The Business and Societal Case for Reducing Food Waste

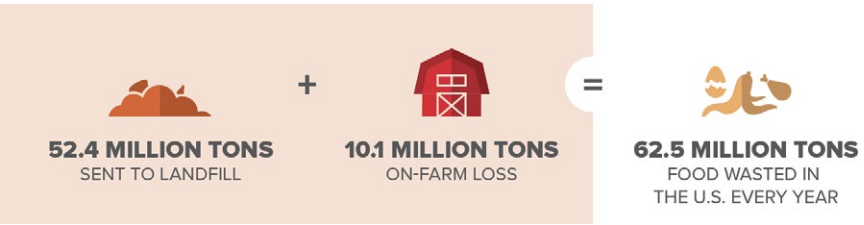
SCOPE

ReFED set out to understand the most cost-effective 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 effectiveness, 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 effort, 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 different 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 off-grade produce (short shelf life, different 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 Efficiency	**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 efforts 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 different 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.

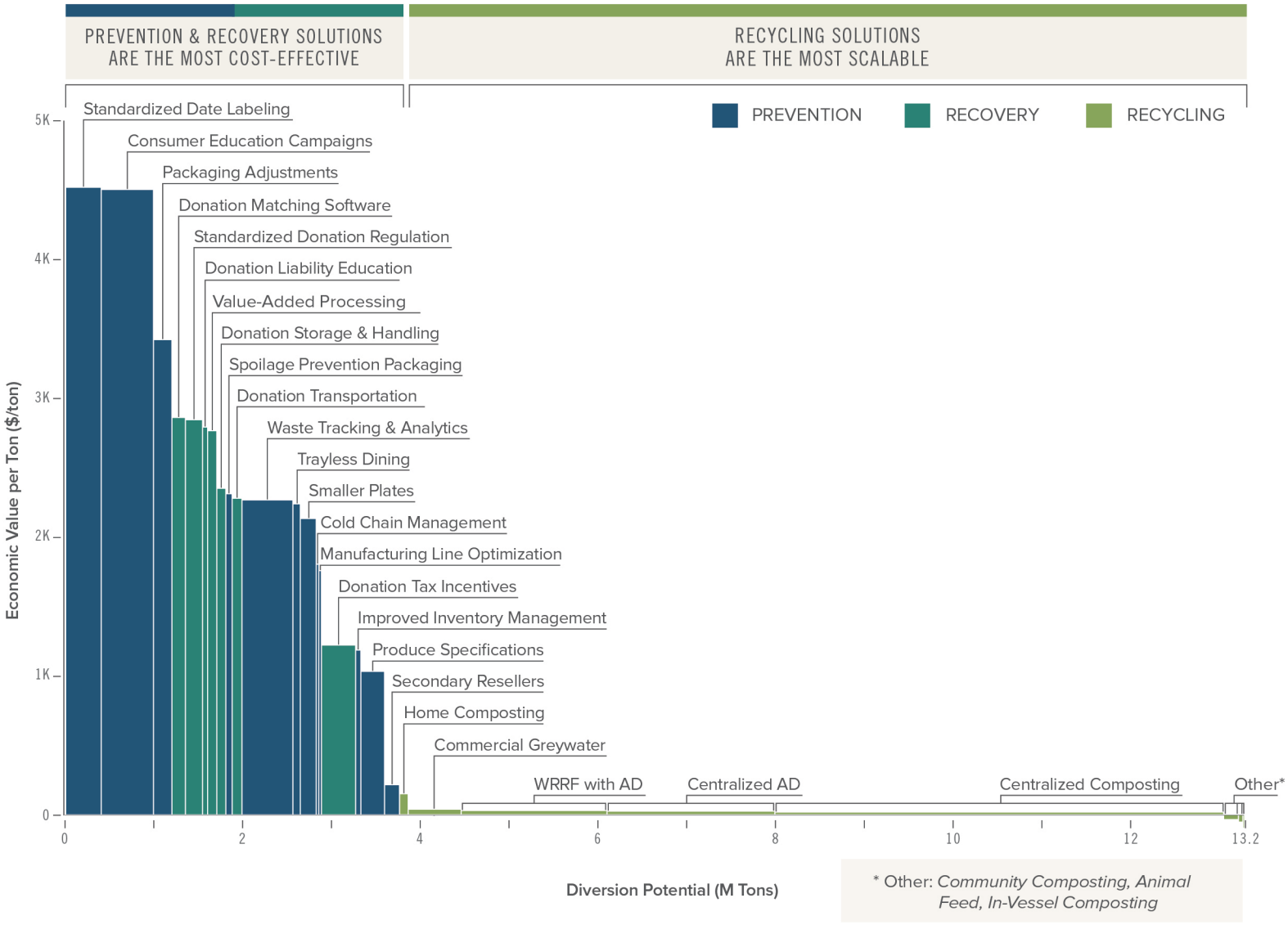
Why Build a Cost Curve? The Cost Curve ranks solutions based on cost-effectiveness, assuming that the key constraint is financial capital and that society should invest to solve food waste in the most efficient way possible. This cost-benefit approach is similar to how businesses and government agencies 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



* Other: *Community Composting, Animal Feed, In-Vessel Composting*

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**

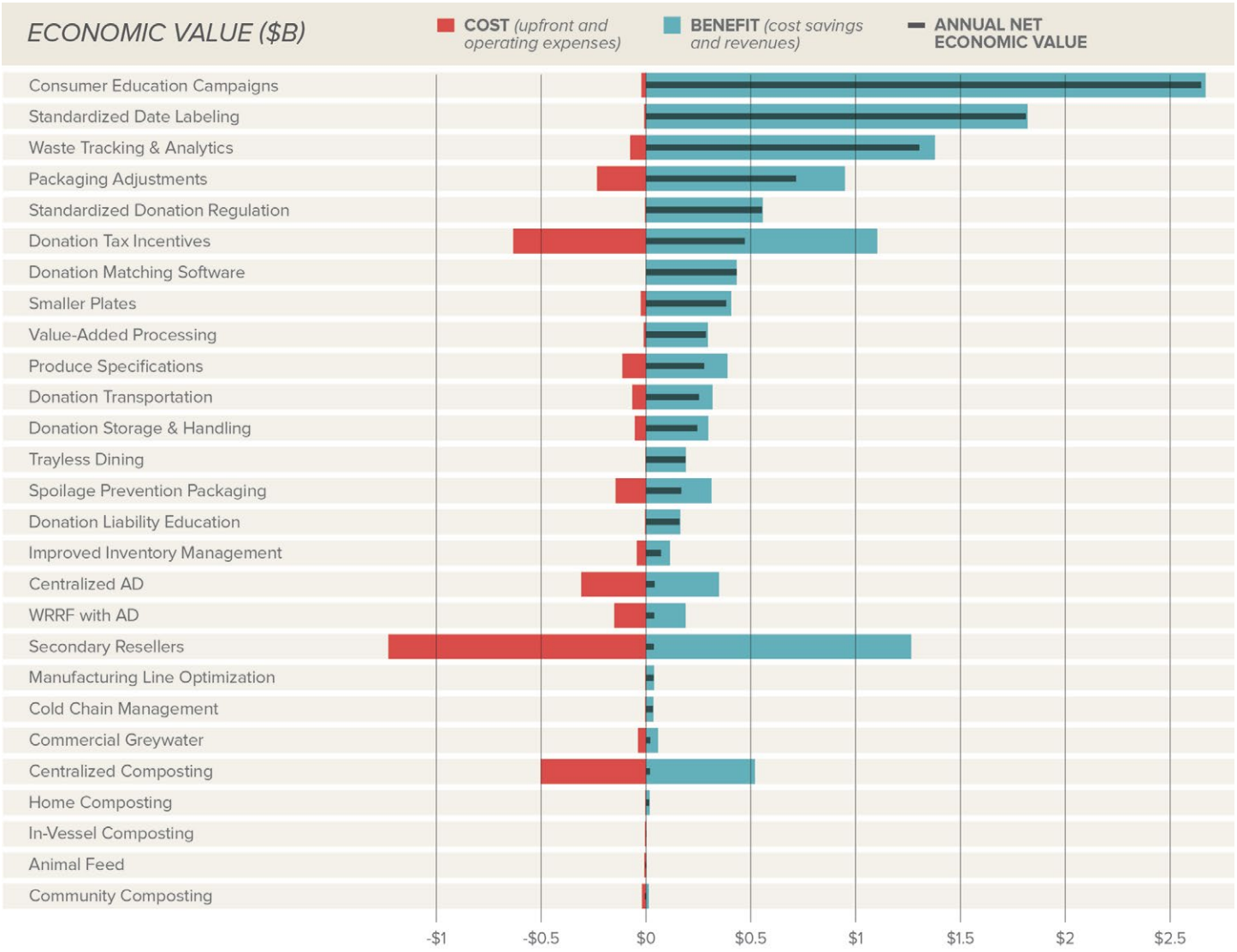
ECONOMIC VALUE ANALYSIS

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

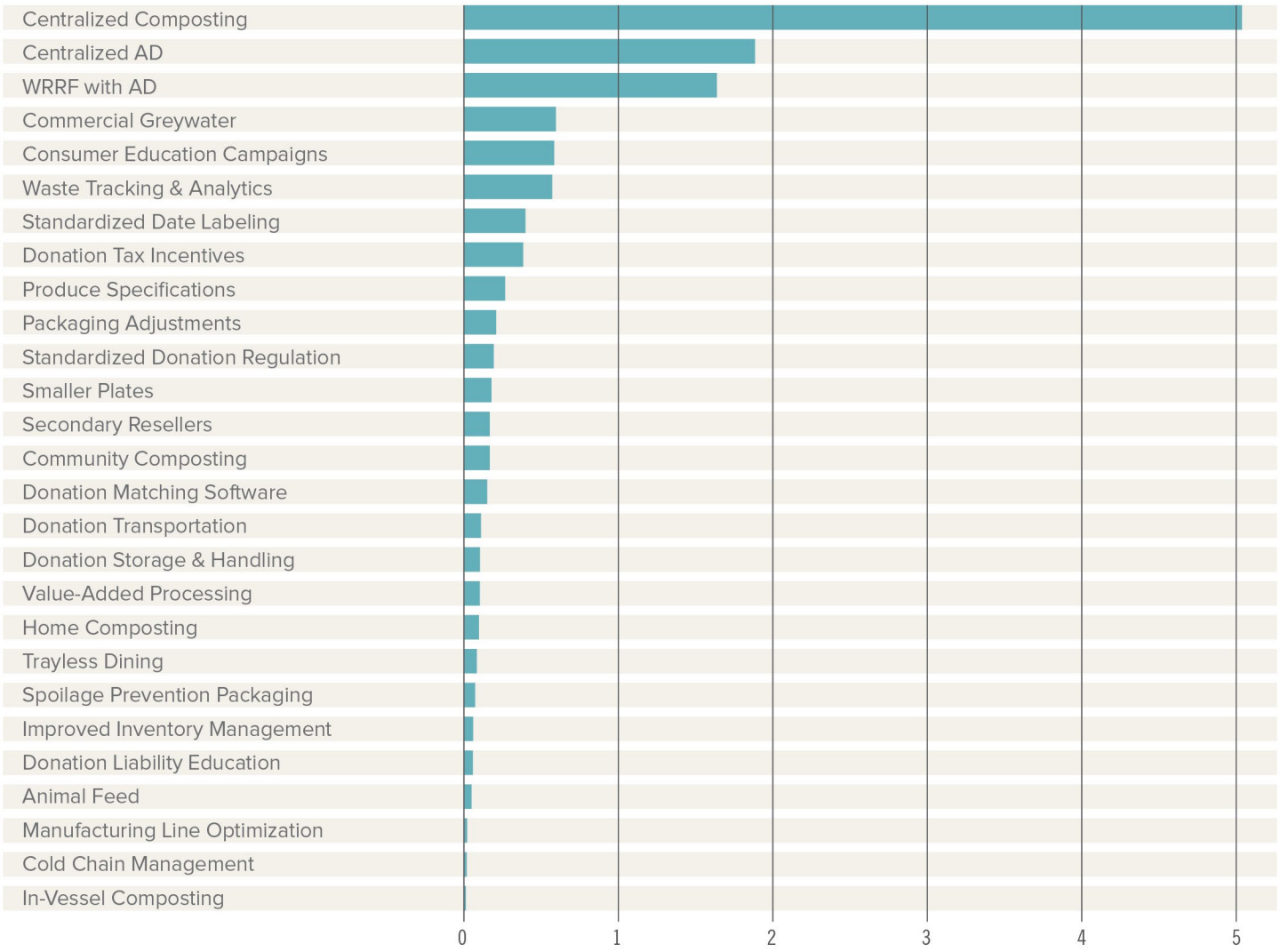
Nearly 13 million tons of annual waste was identified that can feasibly be diverted from landfills and on-farm losses.

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.

DIVERSION POTENTIAL (M TONS/YEAR)



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** offers 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.

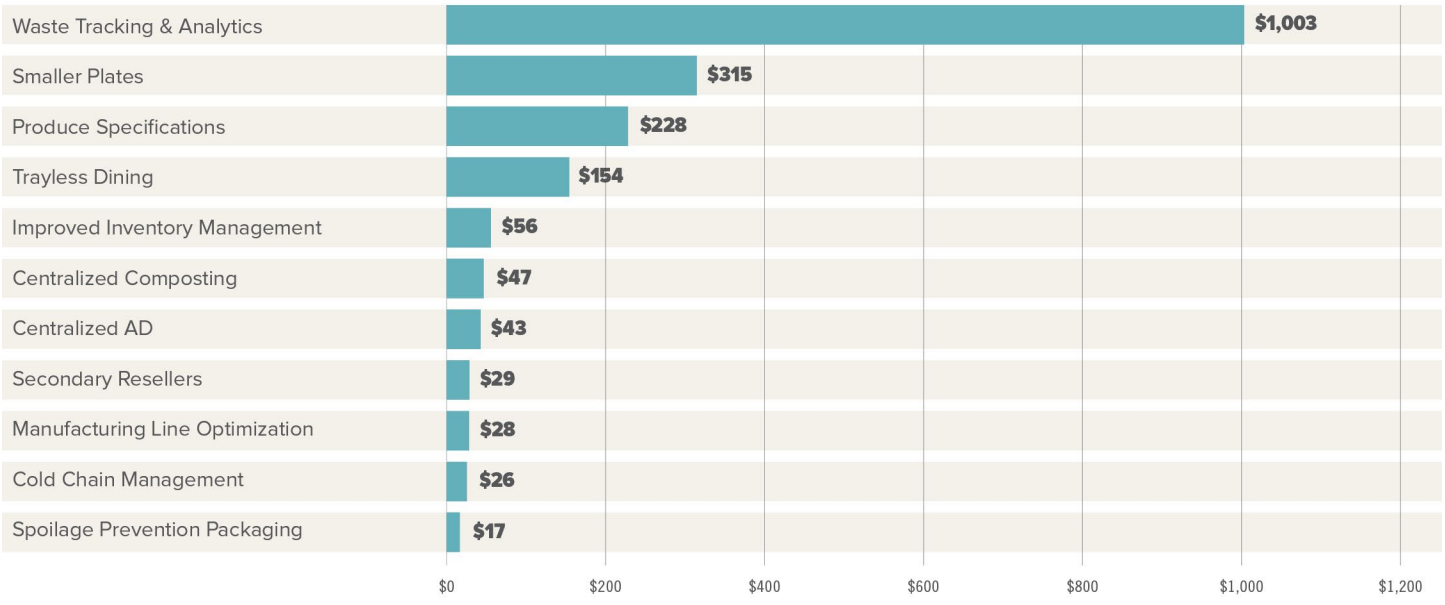
The stakeholders with the largest profit opportunity, $1.6 billion annually, are restaurants and foodservice facilities. Why has this profit not been captured already? Restaurants and foodservice facilities are highly fragmented and change their menus frequently. Stakeholder interviews identified a gap 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 inefficiencies 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, differentiated 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** offer 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 offer 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 offset 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 offer 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 efficiency 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.

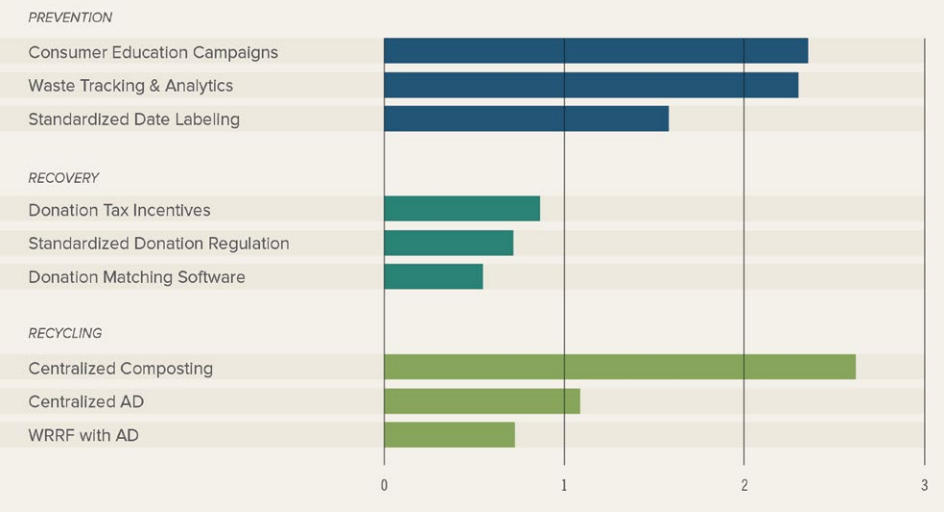
MULTIPLIER EFFECTS

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 effects 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 effects 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.