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

11,000

TOP SOLUTIONS BY DIVERSION POTENTIAL

CENTRALIZED COMPOST
CENTRALIZED AD
WRRF WITH AD

MAIN BENEFICIARIES

MUNICIPALITIES
ENVIRONMENT
BUSINESSES

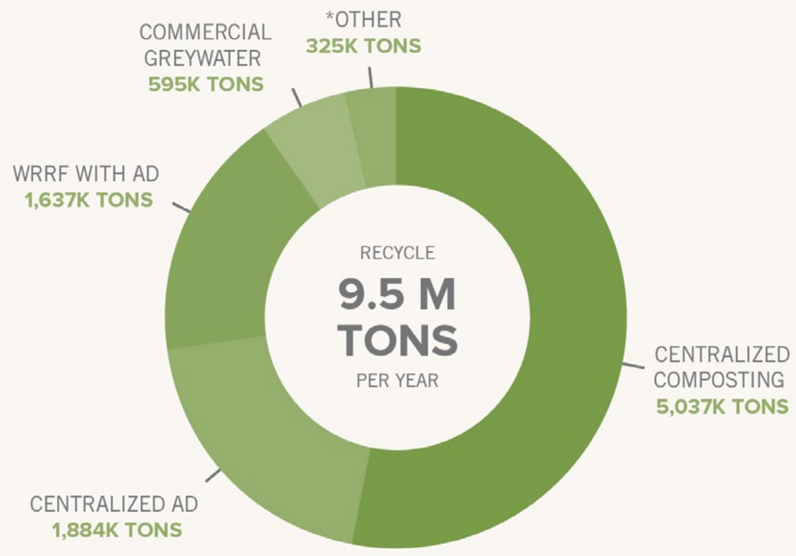
RECYCLING OFFERS the most scalable path to reducing food waste nationally. Action taken by a handful of large cities alone can prevent millions of tons of food scraps from being landfilled. In almost any scenario to reduce food waste nationwide by 50%, recycling will represent the majority of the volume.

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 efforts 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.

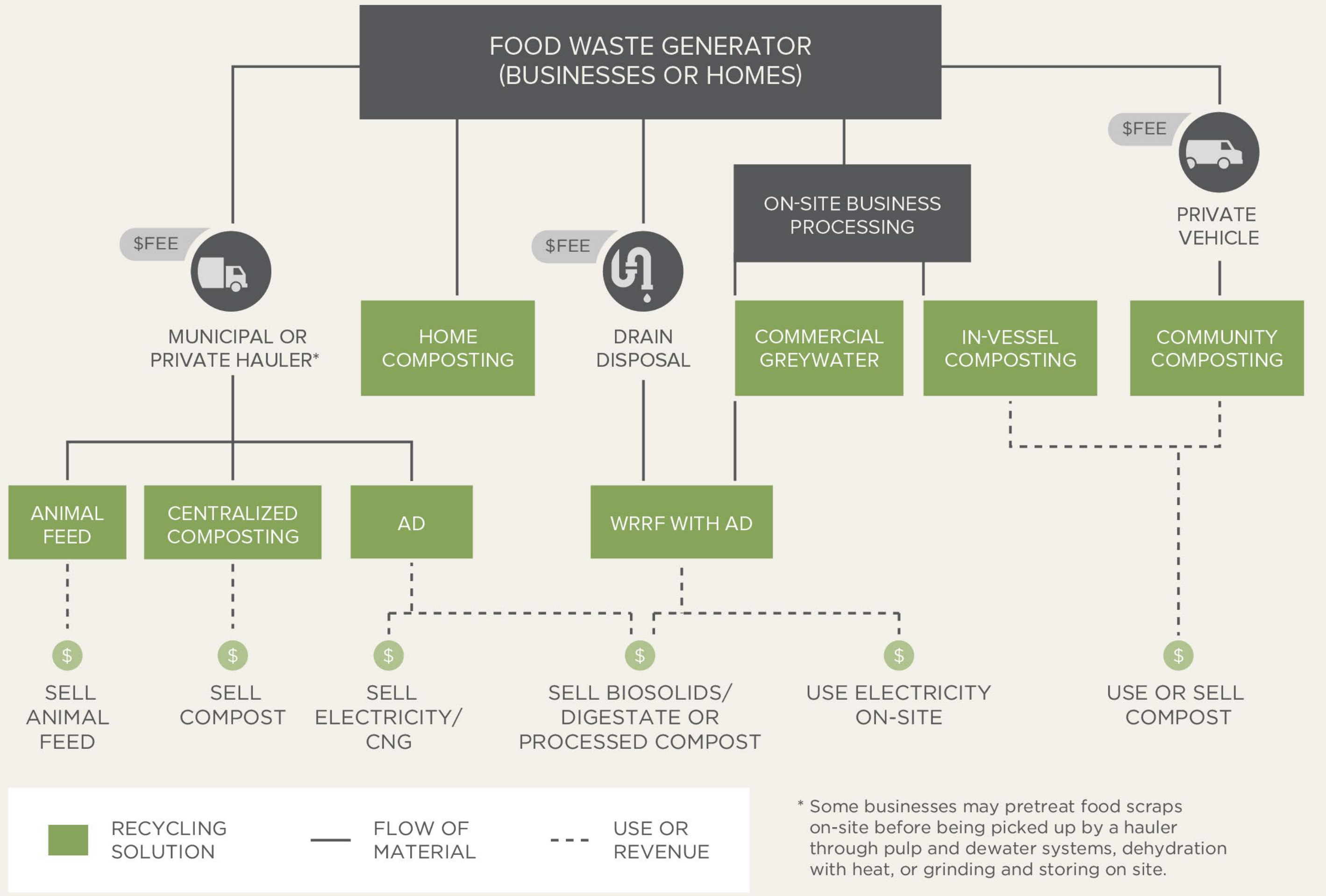
Municipal interest in organics management is growing due to three drivers: increasing number of landfills that are reaching capacity, better understanding of the environmental impacts of landfilling food scraps, and the improving economics of recycling facilities that have reduced contamination rates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



* Some businesses may pretreat food scraps on-site before being picked up by a hauler through pulp and dewater systems, dehydration with heat, or grinding and storing on site.

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.

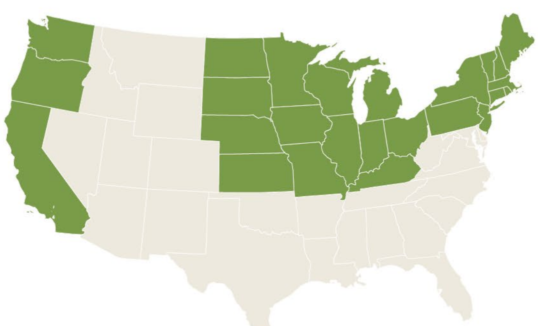
These regional variations are rules of thumb with multiple exceptions at the local level. For example, new AD projects have been announced in Colorado and other regions not emphasized in the economic modeling. Any metropolitan area can find it economically rational to adopt food scraps recycling when 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.

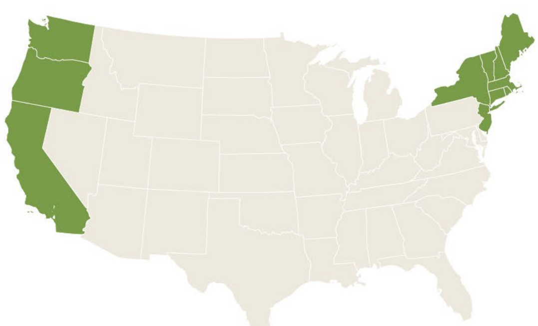
FOR CENTRALIZED COMPOSTING, THE NORTHEAST, MIDWEST, AND NORTHWEST GENERALLY SHOW THE MOST ECONOMIC PROMISE.

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]

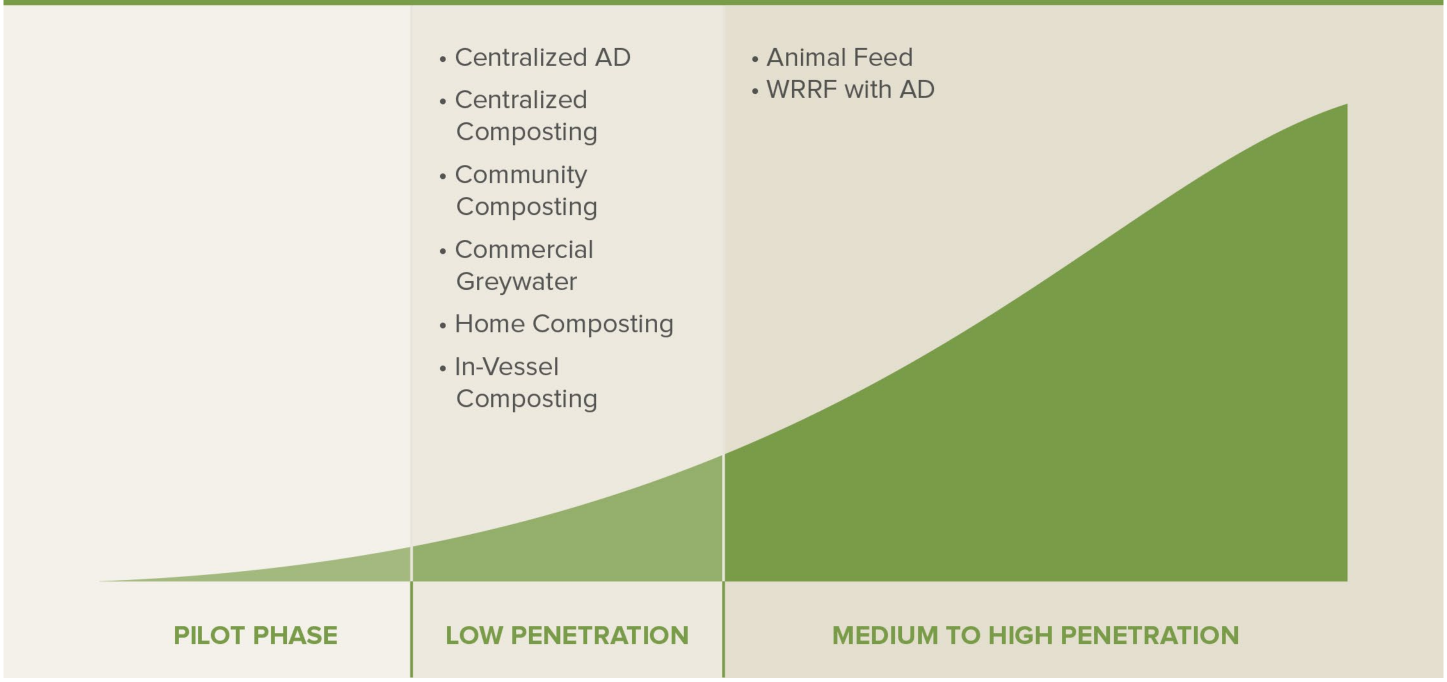
Other solutons have existed for decades to process manure and yard scraps, but the inclusion of food scraps processing for centralized systems is somewhat newer. Overall, there is some level of commercial acceptance for all recycling solutions:

- 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 efficiencies 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.

RECYCLING SOLUTIONS MATURITY CURVE



** 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.

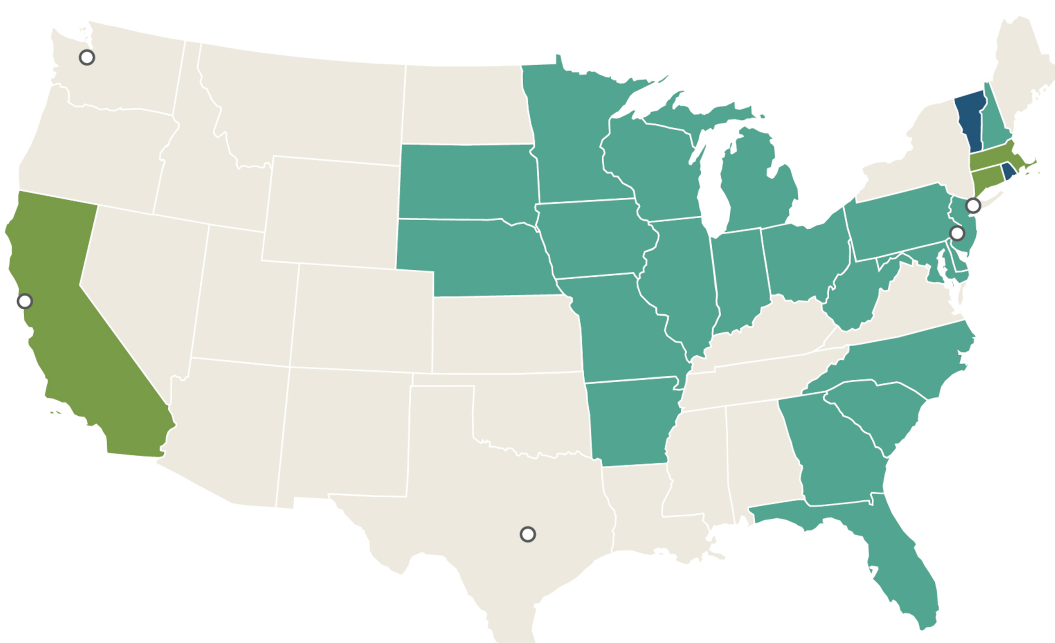
LANDFILL BANS: Some states are beginning to address organics directly by implementing highly effective landfill bans or by mandating large organic waste generators to divert their waste from landfills through recovery or recycling. For example, Vermont banned the disposal of mandated recyclables by 2015, 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



STATE
YARD DEBRIS BAN / MANDATE

STATE
COMMERCIAL FOOD SCRAP LANDFILL BAN / MANDATE

STATE
COMMERCIAL LANDFILL BAN / MANDATE AND YARD DEBRIS BAN / MANDATE

MUNICIPAL
COMMERCIAL FOOD SCRAP LANDFILL BAN / MANDATE

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 time, 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 effective policy tool that can be expanded to directly change tipping fees. The income from the tax can be used in support of recycling efforts, including grants for new infrastructure or business and consumer education.

BARRIERS TO RECYCLING SOLUTIONS

RECYCLING SOLUTION BARRIERS	RECYCLING SOLUTIONS: CENTRALIZED COMPOSTING	CENTRALIZED AD	WRRF WITH AD	COMMERCIAL GREYWATER	COMMUNITY COMPOSTING	HOME COMPOSTING	ANIMAL FEED	IN-VESSEL COMPOSTING
COST OF DISPOSAL	■	■	■	■	■	■		■
HIGH TRANSPORTATION & LOGISTICS COSTS	■	■	■		■		■	
MATERIAL SUPPLY ASSURANCE	■	■	■				■	
PACKAGING & CONTAMINATION	■	■	■	■	■		■	■
ACCESS TO FINANCING	■	■	■	■	■			■
END-MARKET DEVELOPMENT	■	■	■					
PERMITTING & SITING	■	■	■		■		■	

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

In efficient 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 inefficient programs, collection costs can be the driving factor for low cost-effectiveness. 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 inefficient 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 efficiencies 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.

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

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

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 offering free compost, pay-as-you-throw pricing, or rebate systems.
- Cities and states with organics bans can provide staff 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 sufficient education to residents regarding which items can be composted and offer 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 effective 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 differentiator for success. Projects can typically only secure low debt capital rates if they also secure long-term feedstock and product offtake 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.

offtake 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 offer low-cost financing.
- Government projects, such as USDA financing, lower the total blended cost of capital for a project by offering 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 offers 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 effects 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

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**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 traffic, 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.

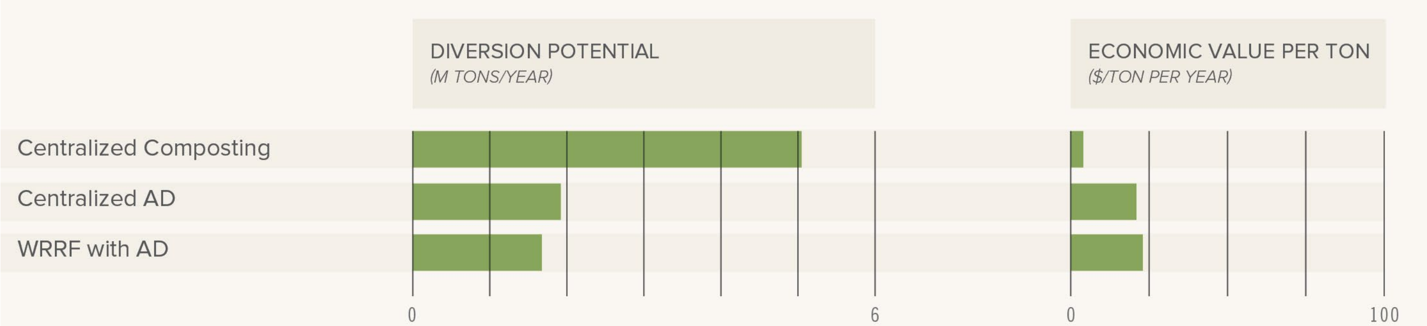
CASE STUDY: FILTREXX INTERNATIONAL

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.**

TOP THREE RECYCLING SOLUTIONS BY DIVERSION POTENTIAL



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.

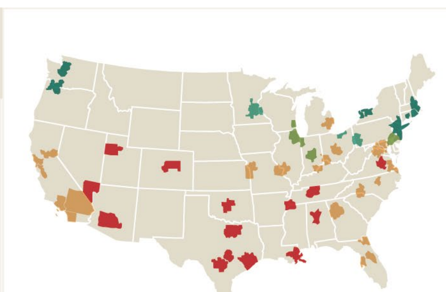
STAKEHOLDER ACTIONS

- 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.

WINDROW COMPOSTING ECONOMIC VALUE PER TON ($/TON)

$0-$10 | $10-$25 | $25+

-$50-$0 | <-$50



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-effective 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 effective at large-scale WRRFs in big cities that utilize advanced energy-efficient 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-effective 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:	*Who Can Take Action:*
RESTAURANTS, FOODSERVICE, EQUIPMENT VENDORS	**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.

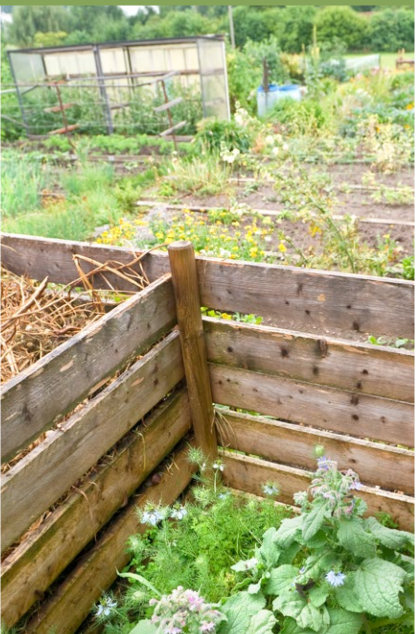
STAKEHOLDER ACTIONS

- 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-off 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 offer 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]

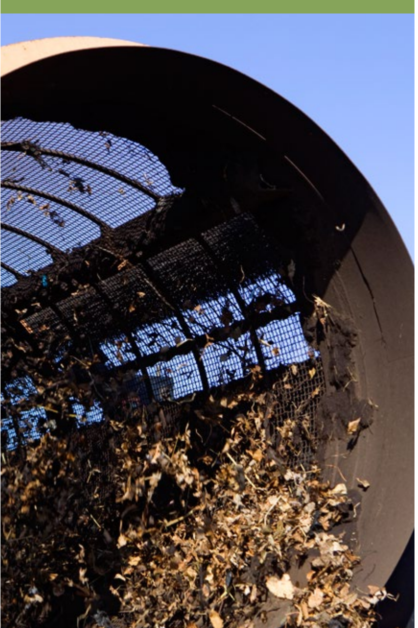
STAKEHOLDER ACTIONS

- 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 effective 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]