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Organic Waste Diversion Guidance for U.S. Army Installations

Curtis Fey, Colin Chadderton, Giselle Rodriguez, Dominique Gilbert, Angela Urban, and Christy M. Foran

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Organic Waste Diversion Guidance for U.S. Army Installations

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Abstract

Methods of organic waste diversion currently being employed by U.S. Army installations were reviewed to provide recommendations and case studies as well as identify best practices. As part of the Army's Net Zero Installation Strategy, it is essential that installations reduce the amount of solid waste they send to landfills. Food and other organic waste, such as yard trimmings and wood residuals, are a major component of the solid waste generated by installations that can be reduced, repurposed, or transformed. Both on-post and off-post diversion alternatives are discussed, and case studies from U.S. military installations are provided as examples. Wherever possible, examples of documentation language (e.g., contract statements, Memorandum of Agreements (MOAs)/Memorandum of Understandings [MOUs]) are provided for contractor support of diversion activities. The report identifies mature and available small-scale organic waste management technologies, and the associated benefits, concerns, and conditions for their successful use on an installation are examined. An excel-based decision tree accompanies the report to provide guidance for selecting technologies or practices that suit an installation's specific capacities and preferences. The analysis provided is applicable to any Army installation or other sizable organization in the early stages of considering how to divert organic waste from a landfill.

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Preface

This study was conducted for the U.S. Army Environmental Command (USAEC) under MIPR Number 0010512455, for "ERDC Guidance Diverting Organic Waste." The technical monitor was Curtis A. Fey (AEC-IMCOM).

The work was performed by the Risk Assessment Branch (EP-R) of the Environmental Processes Division (EP), U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Buddy Goatcher was Chief, CEERD-EP-R; Warren Lorentz was Chief, CEERD-EP; and Dr. Elizabeth Ferguson, CEERD-EM-J was the Technical Director for Military Munitions in the Environment. The Deputy Director of ERDC-EL was Jack Davis and the Director was Elizabeth Fleming.

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COL Bryan S. Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	by	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
miles (US statute)	1,609.347	meters
pounds (force)	4.448222	newtons
square feet	0.09290304	square meters
tons (2,000 pounds, mass)	907.1847	kilograms

1 Introduction

1.1 Army sustainability efforts

In 2011, the Assistant Secretary of the Army for Installations, Energy and Environment (ASA-IEE) announced the Army Net Zero Installation Strategy (ASA-IEE 2011). The main goal of this strategy was to integrate sustainability practices at the installation level, which preserves the organization's flexibility to operate in constrained circumstances, either economic or environmental. The first step in the strategy was to divide the effort into three categories: Net Zero Energy, Net Zero Water, and Net Zero Waste (Foster 2011), and select the Net Zero pilot installations that should achieve these goals by FY 2020.

In January 2014, the Secretary of the Army distributed the Army Directive 2014-02, Net Zero Installations Policy (SECARMY 2014). This memorandum established procedures and assigned responsibilities that encouraged all Army installations to strive toward Net Zero implementation. The policy applies to all permanent Active Army, Army National Guard, and U.S. Army Reserve installations. Likewise, the policy asks Commands (i.e., military units) to implement Net Zero to the maximum extent. For Net Zero Waste, the policy directs installations to reduce, reuse, recycle and/or compost, and recover solid waste streams and convert them to valuable resources, resulting in zero landfill disposal. In addition, the original Net Zero pilot installations will continue to strive reach their Net Zero goal by FY 2020. The memo goes on to state, "Commands will continually evaluate and implement efficiencies, reductions, and reuse of energy, water and solid waste to the maximum extent possible within available funding levels and as new technologies and approaches are proven cost-effective." A Net Zero Waste installation is an installation that reduces, reuses, and recovers waste streams, converting them to valuable resources with zero landfill residual (ASA-IEE 2011). A combination of different waste management practices along the life cycle of the installation should be applied to accomplish this goal. These practices are divided into two main components: waste minimization and waste diversion.

U.S. Environmental Protection Agency (EPA) studies show that food waste alone constitutes 14.5 % of non-hazardous U.S. municipal solid waste (MSW), and when all compostable waste materials are considered, that number increases considerably (2013b). U.S. Army Installations generate a variety of compostable waste such as yard trimmings, food waste, and wood residuals. New technologies for food waste reduction are being developed. Investments in these products and evaluation of their efficiency may significantly reduce food service waste and further advance Net Zero Waste goals.

A key component for the success of these practices and technologies is the engagement of the installation's environmental staff. However, most installations face limitations including increased workload due to environmental regulations and policies compliance, declining workforce, and recruiting constraints. As such, time is limited and does not allow key personnel to remain informed on the various technologies currently available. In addition, key personnel are not able to determine if these technologies are appropriate for their particular situation, nor how to utilize/direct contractor services for reducing/diverting organic waste. Operating a waste composting facility creates a host of challenges that must be overcome on a variety of levels, including additional tasks for government employees. Installations that are successful with diverting organic waste for composting have done so with contractor or civilian inmate support.

1.2 Project objectives

The objective of this project is to provide alternatives to support organic waste diversion at U.S. Army Installations. This report will provide guidance by identifying successful contracting approaches and contract language for successfully diverting waste for composting. Further, this report will identify mature technologies that are available and the associated benefits, concerns, and conditions for successful use of the technologies towards diverting food waste from landfills. These details are also integrated in a situational based decision flow chart tool, which provides systematic guidance that enables the installation's environmental managers to select tailored options for diverting organic waste from landfills.

This report provides practical guidance on organic waste diversion practices that can be applicable to different circumstances depending on the needs of the installation. Sections 2 and 3 provide examples of successful methods practiced by installations and discuss how installations can choose between off-post or on-post initiatives given their own circumstances. For all of the diversion practices discussed, examples are provided in the form of real case studies. Also, whenever feasible, examples of documentation language (e.g., contract statements, Memorandum of Agreements [MOAs]/Memorandum of Understandings [MOUs]) are provided. In Section 2, off-post diversion opportunities are discussed. These are especially applicable to installations that do not have the resources to establish their own programs and need assistance with diversion from outside vendors. In Section 3, on-post diversion opportunities are discussed. These provide guidance to installations that have considered leveraging contractor or inmate labor support to create their own diversion programs.

Food waste management presents special challenges and cannot always be accomplished on an installation-wide scale. Section 4 contains general descriptions for commercially available technologies that can be used to divert food waste on a small-scale from a specific building or targeted area. In addition, section 4 also outlines factors to consider prior to selection of those technologies. Section 5 enumerates the process for performing a feasibility study of a technology or waste diversion method. Section 6 describes the situational based decision flow chart that accompanies. The flowchart provides guidance for selecting practices and technology that have been demonstrated to reduce the food and organic waste being disposed into landfills.

1.3 Overview of waste diversion options

When developing plans for the diversion of waste, detailed consideration must be given to declining defense budgets and labor projections. Guidance needs to be provided that considers the fact that many installations will not be able to add additional duties or implement novel technologies that require training, testing, operations time, and maintenance. An installation, which understands the particular limitations it faces, will be better poised to select the appropriate technology or practices to implement a successful food waste diversion program. The Navy Environmental Sustainability Development to Integration (NESDI) Program published NESDI report #478, Improving Non-Hazardous Solid Waste Diversion, Food Waste, which elaborates on the limitations an installation may face in section 3.2 of that report (Hamilton and Chiang 2014). Several installations have found opportunities to divert their organic waste from landfills by building capacity on-post, seeking support off-post, and by augmenting waste services contracts. Opportunities for diverting waste from landfills by processing it on-post or by having other entities process it off-post include:

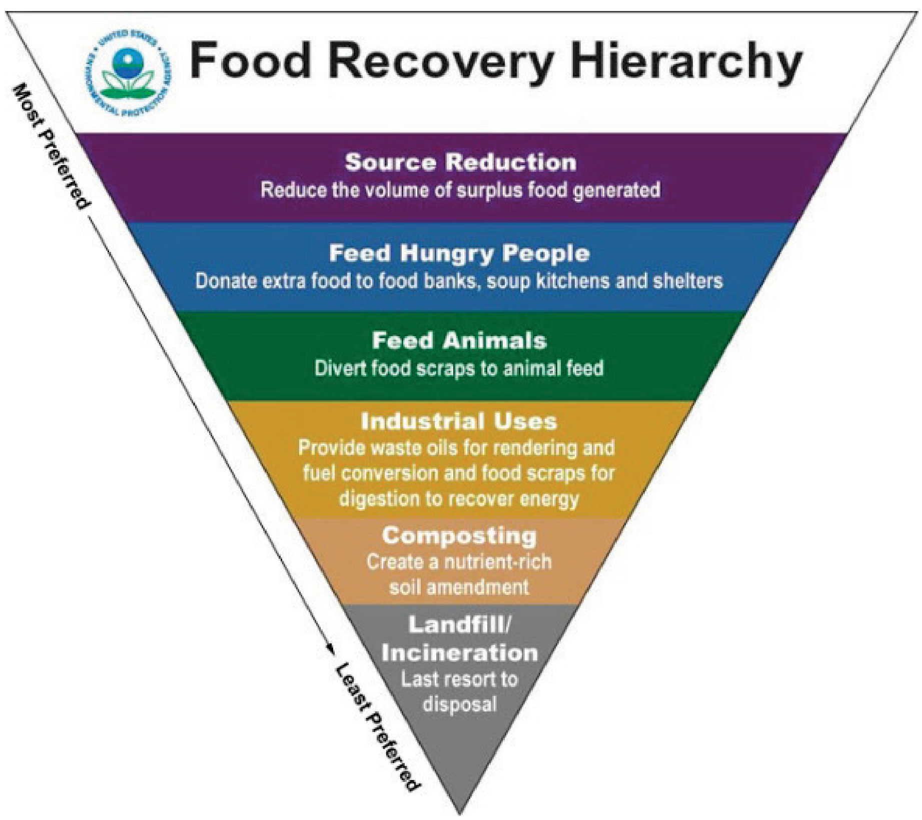
- Off-Post Diversion of Waste
  - Donate excess food and food waste
  - Partner with off-post entities that repurpose organic waste

- On-Post Diversion of Waste
  - Utilize inmate labor
  - Develop or increase on-post capacity for repurposing organic waste

2 Off-Post Diversion of Waste

Installations are encouraged to consider the benefits of off-post diversion before investing capital and manpower resources for on-post diversion. Additionally, off-post diversion follows the EPA's Food Recovery Hierarchy for food waste diversion (Figure 1). This section will cover different off-post opportunities an installation may explore to manage their organic waste.

Figure 1. The Environmental Protection Agency's (EPA's) food recovery hierarchy (U.S. EPA 2014b).



2.1 Recovery of food discards

The first initiative to improve landfill waste diversion should focus on reducing the amount of generated waste. Ideally, the amount of food purchased and prepared would better reflect the amount of food consumed on-post. However, to ensure soldiers are fed adequately, installations must provide food in excess, regardless of whether soldiers eat in the dining facility or not (Medina et al. 2014). Calculating the amount of food required for an installation is further complicated by the fact that some installation populations can vary by orders of magnitude from week to week due to training (Holsinger 2011). "Improving Non-Hazardous Solid Waste Diversion, Food Waste NESDI #478" provides reference information on food management and disposal practices that can be helpful to source reduction and food waste separation on-post (Hamilton and Chiang 2014). Food discards include any food preparation waste and uneaten food that can be recovered via food donations, rendering, composting, or as animal feed (U.S. EPA 1998).

Donation of edible food that otherwise would end up in the landfill as food waste should be the first act in recovering food discards. The Department of the Army (DA) has provided recent guidance on beginning a food donation program that serves as another vehicle for installations to donate food. In the memorandum, *Army Food Donation Procedures*, the DA describes a way to locate recipient organizations, the necessary qualifications of a nonprofit food recovery/distribution agency, and some of the logistics that need to be specified as a program is developed (2014). The memorandum additionally provides detail on installation coordination with Preventive Medicine, Veterinary Services, and Public Works to ensure appropriate containment, inspection, storage, transportation, and record keeping. Once a plan for food donation from prepared meals has been established and verified, the DA food donation program requires that a formal agreement (i.e., MOU/MOA) be developed between an installation and the food donator. (DA 2014a). The Defense Commissary Agency (DeCA) handles a separate food donation program for food that is fit for human consumption.

The first recommended step in the food donation process is involves a survey to determine the type, amount, and schedule of excess food and food waste. To encourage food donation, all 50 states and the District of Columbia have enacted "Good Samaritan" laws that protect food donors from liability if adequate measures to prevent food spoilage and contamination are taken (U.S. EPA 1998).

Another option for the diversion of edible food waste is to redirect the discarded food to farmers. In the past, hog farmers used food discards to sustain livestock; the practice continues today. In addition, farmers may provide storage containers or free pick-up service to collect the discarded food from an installation. Likewise, there are companies that convert food discards into high-quality, dry, pelletized animal feed and pet food. Although most of the discarded food is consumable, certain foods are not adequate for animal consumption (U.S. EPA 1998). An MOU may be used to document an agreement between an installation and a farm. Additional information on recovering food discards for animal feed can be found on EPA's "Feed Animals" website (U.S. EPA 2013a) and on the USDA's description of requirements for maintaining the health of farm animals (USDA 2014).

When food waste cannot be recovered in its immediate form, different types of processes can be performed to convert food waste into a useable form. Liquid fats and solid meat products can be used as raw materials in the rendering industry to produce animal food, cosmetics, soap, and other products. Many rendering companies will provide storage barrels and free pick-up service to collect discarded food (U.S. EPA 1998). According to DeCA's Enterprise Acquisition Division (DeCA), for fiscal year 2015-2016, 23 U.S. military installations, including Fort Lee and Fort Hood, were forecasted to have contracts for rendering. The members of the National Renderers Association account for over 90% of North American production by independent renderers and integrated packer/renderers. They annually publish a directory of associated members, plant locations, and products they produce (National Renderers Association 2015). In addition to rendering, food waste can undergo other processes such as composting, anaerobic digestion, and organic waste dehydration. These other processes are explained in Sections 3 and 4.

2.2 Case studies

1. Fort Lee Joint Culinary Center of Excellence Food Donation Event: Perishable fruits and vegetables from the March 2014 culinary challenge were donated to the Central Virginia Food Bank[1]. A memorandum of record was drafted wherein the Central Virginia Food Bank donation coordinator accepted liability for the donated food items and agreed that the items would be used for immediate consumption (DA 2014b). The food donation was valued at approximately $5,000 and included almost 600 lbs of fruits, vegetables, and spices (DA 2014b).

[1] R. Beu, Personal Communication, 22 September 2014.

2. Fort Hood DeCA Food Bank Program: Fort Hood's two commissaries, Clear Creek and Warrior Way, participate in DeCA's food donation program. They donate canned goods and other food related products to food banks. Data from November 2012 showed that 7.47 tons of canned goods and 8.21 tons of other food were donated[1]. As a result of these efforts, waste compactor pickup at the commissaries has been reduced. Currently at Warrior Way, the waste compactor is collected once a week compared to three times a week before the food donation program was established. This represents savings on waste hauling costs[1].

3. Fort Hood Animal Feed from commissaries: Two local pig farmers contacted Fort Hood about receiving food waste to feed their pigs. The pig farmers requested and received permits from the Texas Department of Agriculture to receive the food waste. The farmers began collecting produce and bakery food (food that had not been served for human consumption and had been deemed unsellable) from the installation in July 2013[1]. Meat, dairy, trash, or human contaminated food was not accepted. Over the first year of operation, 48.17 tons of food was donated[1].

2.3 Partner with off-post entities that repurpose organic waste

By pursuing opportunities for off-post organic waste diversion before investing in developing on-post diversion capacities, an installation can save capital and manpower resources. The installation should identify nearby opportunities off-post where organic waste can be repurposed or treated (within about 60 miles), which may include commercial composters, anaerobic biogas facilities, local farms, etc. Opportunities existing within about 60 miles of U.S. Army installations (mainly commercial composters and local farms) are found listed in Appendix A. AgSTAR, an EPA partnership program with the U.S. Department of Agriculture, provides a map and database for all of the farms with an anaerobic digester system (U.S. EPA 2014a). The American Biogas Council also provides a map of the operational biogas systems in the U.S., including landfill and wastewater feedstock sites in addition to the ones listed by AgSTAR (American Biogas Council 2015). According to the USEPA, there has been a recent movement for adding food waste to anaerobic digesters already in place at wastewater treatment facilities, which commonly use this technology to

[1] J. Rawlings, Personal Communication, 2 October 2014.

break down sewage sludge. Municipal wastewater treatment facilities including Oakland, CA, Clinton, MA, Fairhaven, MA, and Pittsfield, MA accept food waste, which may be used to create biogas for renewable energy. Some dairy farms with anaerobic digesters accept food waste from outside sources. The American Biogas Council estimates that the U.S. has over 2,000 sites using anaerobic digesters on 239 farms, 1,241 wastewater treatment plants (approximately 860 use the biogas they produce), and 636 landfill gas projects.

Each facility may accept different types of organic waste streams. Depending on the capacity of the facility and state permits, these waste streams may include food waste, yard waste, wood pallets, pulverized paper, barn and stable waste, consumer-contaminated paper, and/or sludge. The facility should arrange for collection and transportation of the organic waste; or the installation waste service contract can be leveraged to ensure organic waste is collected from dining halls, residences, and other buildings on-post, and then hauled off-post. A waste storage site may be necessary for this process. According to guidance provided by the United States General Services Administration and the United States Department of Energy, installations should ensure language is included in waste management contracts requiring documented compliance with all waste diversion requirements (2015).

2.3.1 Case studies

1. Fort Polk Diversion to Off-Post Composting Facility: In 2014, Fort Polk utilized a waste service contractor and diverted 197.68 tons of food waste to nearby R&W Farms for composting[1]. Sending the material to R&W Farms instead of a landfill resulted in a cost avoidance of $95.63 per ton[1]. Fort Polk's semi-annual installation cleanup day consists of collecting yard waste, which is chipped and used as mulch around the installation. In fact, 16.48 tons of yard waste was chipped in 2014[2]. In May 2015, Fort Polk wrote a policy letter on reusing non-perishable and semi-perishable components from MREs (Meals-Ready-to-Eat) in its' Dining Facilities (DFAC)[3].

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[1] N. Broussard, Personal Communication, 15 May 2015.

[2] T. Veillon and N. Broussard, Personal Communication, 15 May 2015.

[3] T. Veillon, Personal Communication, 15 May 2015.

2. Fort Carson Diversion to Off-Post Composting Facility: Fort Carson diverts most of their organic waste (e.g., food waste, bio-solids, grass clippings, tree trimmings, leaves, etc.) to a nearby commercial composting facility[1]. At Fort Carson, the waste service contractor is responsible for collecting and transporting the organic waste (Figure 2). Food waste is picked up from each DFAC, the Department of Public Works (DPW) building, and a child development center (CDC)[1]. Additionally, the contractor provides a minimum of 1,200 biodegradable bags per month to each DFAC and CDC (Fort Carson DPW 2013). Outside of these facilities, the contractor provides and services dumpsters for food waste collection (Figure 3). In addition, food waste from the commissary compactor is collected. Seasonally, the contractor will collect other organic waste such as grass clippings, tree trimmings, leaves, etc., in 20-yard roll-off containers. Dried bio-solids are collected in the same containers and disposed of as recycled compost. The contractor delivers all organic waste to the off-post composting facility co-located at the Midway landfill, which is operated by Waste Management (Fort Carson DPW 2013). Once finished, the compost is used as soil amendment. In 2014, 191.68 tons of waste was composted at a cost of $183 per ton. The cost for refuse disposal is approximately $112 per ton, so there are no cost savings from composting food waste alone; however, when also factoring the savings achieved via composting bio-solids and yard waste, composting becomes cost effective[1].

   In order to accomplish diversion of organics from the landfill, Fort Carson utilized their waste service contractor. An example of the contract language used to scope the composting operation in their waste service performance work statement (PWS) is presented below:

   "Organic Waste. Organic waste for the purposes of this PWS is defined as food waste, grass clippings, tree trimmings, leaves, etc. Food waste will be collected from the DFAC, child development centers [CDCs], and commissary. Biodegradable bags will be provided by the contractor for the DFAC's and CDC's. The contractor is required to maintain a minimum of 1200 bags per month to be used at those facilities. Personnel at those facilities will collect the food waste and place it in a dumpster outside the facility provided by the contractor. The commissary will provide biodegradable bags for use in that facility. A

[1] E. Buccambuso, Personal Communication, 19 May 2015.

compactor will be used to collect food waste from the commissary. An average tonnage of 25 tons per month should be expected from those facilities. All other organic wastes will be collected seasonally in roll-offs placed for the Base Operations contractor. All organic wastes will be delivered to the composting facility located at Midway land fill" (Fort Carson DPW 2013).

Figure 2. Composting contractor at Fort Carson.

Figure 3. Composting container at Fort Carson's DFACs for organic waste. A list of eligible and ineligible waste items included in the signage on each container. Materials collected in these containers are taken regularly to the composting site off-installation.

3. Fort Jackson Diversion to Off-Post Composting Facility: Fort Jackson estimates its annual food waste generation is 1,200 tons per year[1]. A nearby commercial permitted composting facility, Re-Soil Compost, has a 10,000 square foot food waste composting facility that has, as of July 2015, a capacity of 300 tons per month. The capacity is expected to increase to 1,200 tons per month after force air composting equipment is installed. At $20 per ton, the tipping fee at the composting facility is an estimated $9 less per ton than the landfill tipping fee, resulting in an estimated annual savings of $24,000. Fort Jackson has modified its refuse contract to accommodate diverting its waste to the composting facility. Fort Jackson is working on some training issues and waste stream purification (i.e., removal of plastic, Styrofoam, cans, etc.)[1].

4. Hurlburt Field Contracted Yard Waste Collection: The waste service contractor handles the refuse, recycling, and composting needs of Hurlburt Field. The contractor supplies clearly marked or color-coded containers that multi-family housing units use for composting. The

[1] T. Warren, Personal Communication, 20 August 2015.

contractor also service these containers weekly (Hurlburt Field 2010). The contractor also collects yard debris such as tree branches, cartons, non-recyclable boxes, tied bundles, or other containers placed at collection stations for composting (Hurlburt Field 2010). All compost materials are taken to Wright Landfill Compost Center and the Okaloosa County Mulching Facility, which both handle vegetative waste. In 2004, Fort Hurlburt sent 1,200 tons of scrap wood and received free mulch and compost for base personnel (DoD 2004). For each composting load, the contractor provides the load ticket number, date, and arrival time, weight, and the amount charged (Hurlburt Field 2010).

In order to accomplish diversion of organics from the landfill, Hurlburt Field utilized their waste service contractor. An example of the contract language used to scope the composting operation in their waste service PWS is presented below:

"Compost Containers. The contractor shall provide 60 to 68 gallon compost containers to all Main Base Housing and 801 Housing occupants for curbside collection. Containers shall have handle(s), hinged lid(s), and two wheels for easy movement when filled. Load Rating must be at least 150 lbs."

"Compost Collection and Processing Requirements. The contractor shall pick up yard debris placed at collection stations; for example, tree branches (4 foot in length not to exceed 50 lbs), cartons, non-recyclable boxes, tied bundles, or other containers."
"The contractor shall provide pickup, transportation, and delivery of refuse, recyclable, and compost material from MFH units to a municipal solid waste landfill transfer station, Hurlburt Recycling Center, and Wright landfill compost center respectively. The contractor will be reimbursed for all tipping fees and transfer station fees IAW the Bid Schedule."

"Okaloosa County Composting Operation. The contractor shall provide a listing, which contains the load ticket number, date and time into the composting station, weight of load, and amount charged" (Hurlburt Field 2010)

5. Hanscom Air Force Base (AFB): Hanscom AFB requires their solid waste contractor to divert their waste to a permitted off-base disposal

site. Effective October 1, 2014, the Massachusetts Department of Environmental Protection (MassDEP) solid waste disposal ban required businesses and institutions disposing of one ton or more of food waste per week to divert their food waste from landfills. Acceptable disposal sites may include farms for animal feed, compost sites, anaerobic digesters, and rendering/biodiesel operations (RWM 2015). An example of the contract language used to scope the composting operation in their waste service performance work statement (PWS) is presented below:

"Off-Base Disposal. The contractor shall transport and dispose of all municipal solid waste at a permitted off-base disposal site. All MSW shall be incinerated at a waste to energy facility. No refuse shall be deposited in landfills. Provide copies to the CO of operating permit(s) for all waste to energy facilities used for this contract. The contractor shall transport recyclable commodities to an off-base material recovery facility. The contractor is responsible for disposal being in accordance with existing local, state, and federal regulations. The contractor shall be responsible for any permit or fees associated with the use of off-base disposal locations and invoice ... for reimbursement" (Hanscom AFB 2014b).

"Off-Base Disposal. The contractor shall transport and dispose of all food waste at a permitted off-base disposal site. No refuse shall be deposited in landfills. Provide copies to the CO of operating permit(s) for all food waste facilities used for this contract. The contractor is responsible for disposal being in accordance with existing local, state, and federal regulations. The contractor shall be responsible for any permit or fees associated with the use of off-base disposal locations" (Hanscom AFB 2014a).

6. Aberdeen Proving Ground Waste to Energy Plant: Until 2016, Aberdeen Proving Ground sent all of its non-hazardous waste (3,033 tons in 2014) to a waste-to-energy plant owned and operated by a pseudo-governmental agency, the Northeast Maryland Waste Disposal Authority[1]. The waste-to-energy plant incinerates the waste, and Aberdeen Proving Ground purchases the steam that is generated for the Edgewood Area of APG.

[1] D. Rust and M. DeVecchio, Personal Communication, 21 January 2014.

7. Fort Hood Diversion to Off-Post Composting Facility (Food Waste Collection Pilot Project): Following a Material Flow Analysis and Waste Characterization Study conducted in 2012, Fort Hood realized that 25% (4,800 tons) of the material entering the landfill was food or food packaging that could be composted[1]. Fort Hood hired the Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL) to conduct an Evaluation and Survey of Feasibility for a large scale composting facility. The results of the study suggested implementing a six-month food waste collection pilot project to gather best practices and lessons learned before expanding the program installation-wide and upgrading the current on-post, yard waste compost center to accommodate food waste. Concerns about contamination of trash in the food waste prompted Fort Hood to develop a robust training and education program prior to the first pick-up of food waste on 28 September 2015. The ten food facilities participating in the pilot project have various sized indoor collection bins, composting bags, and a four cubic yard, outdoor food waste dumpster. Each food facility requires 20–40 durable compost bags per day depending on the size of the facility and average meals served per day. Fort Hood created a separate contract with their waste service contractor to pick up dumpsters once a week for the six months of the pilot project and to deliver the food waste to an off-post compost center. It was estimated that 624 tons of food waste could be diverted from the landfill annually from just the ten food facilities participating in the pilot program. Daily inspection reports were sent to the food facility managers, and weekly in person visits reminded staff members to avoid contaminating the food waste bins with trash. Prior to starting the collection program, an incentive program was announced during the training sessions, which seemed to keep the staff motivated to comply with the composting program requirements. The incentive was a large trophy presented quarterly in front of Army leadership to the food facility that has the least number of negative findings during the daily inspections. Fort Hood also disburses on-the-spot giveaways to staff members that display correct behavior during site visits. Fort Hood is currently researching options for food waste dehydrators to reduce the smells and vectors often associated with outdoor food collection programs. Using dehydra-

[1] J. Rawlings, Personal Communication, 27 October 2015.

tors will additionally help reduce weekly pickup and compost bag expenses.

3 On-Post Diversion of Waste

This section covers different opportunities an installation may explore to manage and process organic waste on-post.

3.1 Civilian labor partnerships

Several installations have developed successful partnerships utilizing federal civilian inmate labor. This approach provides practical labor experience for the inmates and assists in accomplishing tasks that would not be possible with an installation's current labor constraints. Different documents supporting this approach exists. In 1989, the Department of the Army developed a detailed description of the agreement allowing utilization of civilian inmate labor and demonstrated how it could be a viable option for the Army (Dinkle 1989). In addition, the Department of the Army provided policy and guidance for the establishment of civilian inmate labor programs and prison camps on Army installations in AR 210-35 (DA 2005).

The Office of the Assistant Chief of Staff for Installation Management (OACSIM) coordinates the Civilian Inmate Labor Program (CILP). These labor programs allow inmates to contribute labor in different ways. Some examples include preservation and maintenance of grounds/facilities, construction/repair of buildings and roads, clearing, maintaining and/or reforesting public land, building levees, and constructing/repairing other public ways or works (OACSIM 2014a). CILP produces a net cost avoidance/savings to the Army that ranges from $263K (Fort Lee) to over $6.9M (Camp Atterbury) annually for each of the participating installations (OACSIM 2014b).

CILP requires a signed MOU between the installation and the state or federal correction facility where the inmate labor is sourced. A signed MOI/SOP and a signed legal review are also required. The Senior Commander or anyone that has Delegation of Authority orders from the Senior Commander must sign these documents (DA 2005).

There is some interest and precedent for the utilization of inmate labor for waste services; however, utilization of inmates for composting has not been fully implemented. Prisons located within about 60 miles of Army installations have been identified and are listed in Appendix B. Some of the installations using inmate labor are listed in Table 1. "Resident" denotes that the prison facility is located on-post. One case in which inmate labor is successfully used is Joint Base Lewis-McChord (see case description below).

Table 1. Inmate labor supporting military installations (from OACSIM 2014a).

Location	Federal Bureau of Prisons Inmates	State Penal Inmates	Army Military Inmates
Camp Atterbury, IN		Resident	
Camp Parks, CA	Non-Resident[a]		
Carlyle Lakes, IL	Non-Resident		
Fort Bliss, TX	Resident		
Ft Devens, MA		Resident	
Fort Dix, NJ	Resident	Resident	
Fort Hamilton, NY		Non-Resident[b]	
Fort Leavenworth, KS			Resident
Fort Lee	Non-Resident		
JB Lewis-McChord, WA			Resident
Maxwell AFB	Resident		

[a] (Corwin 1993)

[b] (Kohler 2012)

The use of inmate labor for support installation operations can either take place on-post or at the inmate prison facility. If inmates reside at an on-post prison facility or a nearby prison facility where it is economical to transport inmates to the installation, they can work directly at the installation. If it is not economical for an installation to transport inmates to the installation, or there are security reasons prohibiting inmates from working at the installation, it may be possible to deliver work to the inmates at the prison where they reside.

3.2 Case studies

1. Fort Leavenworth CILP Participation:
   Fort Leavenworth does not currently use Federal inmate labor for composting or food waste diversion operations; however, inmates are used for roads and grounds operations. These operations include such tasks as cutting grass, raking leaves, and blowing snow. To utilize inmate labor, Fort Leavenworth signed an MOA with United States Peni-

tentiary Leavenworth (USP LVN). A copy of the MOA is included in Appendix C. Likewise, an example of the language used in the MOA is presented below:

"Inmates will be medically cleared for labor detail status with no medical or psychological restrictions. Inmates will have no detainers or pending charges. Inmates will receive Central Inmate Monitoring (CIM) clearance from USP Leavenworth if necessary. Inmates will have no prior personal or contractual relationship with [Fort Leavenworth] or [Fort Leavenworth] Personnel. Only inmates classified at the minimum level of [Federal Bureau of Prisons] FBOP security classification, and who have community custody status, will be used in the inmate labor program."

"The civilian inmate labor program is without direct labor cost or expense to the Department of the Army, except for nominal costs for equipment, materials, and supplies used to accomplish work during inmate labor details, program administration, telephone calls to corrections facilities, lunch time meals, and transporting inmates to and from Federal corrections facilities."

"All inmates and inmate labor details selected and provided under this MOA shall be used under 18 USC 4125(a), and are covered for any injury under the provisions of the Inmate Accident Compensation Program, 28 CFR 301, et seq."

"Specific projects will be negotiated locally within the limits of the inmate labor program and consistent with 18 USC 4125(a). Necessary approvals for use of inmate labor on any specific project will be obtained by the Host Agency or USP LVN, as dictated by the rules and regulations governing the respective agency."

"Inmates will not be allowed to operate [Fort Leavenworth] vehicles or equipment unless they possess the necessary valid operator's license(s), have been given proper training in vehicle operation and safety by Army personnel, and are authorized to operate the vehicle or equipment in accordance with AR 600-55 by both [Fort Leavenworth] and USP Leavenworth" (Fort Leavenworth n.d.).

2. Joint Base Lewis-McChord (JBLM) Civilian Prison Labor Program:

Civilian prison labor is currently used at JBLM to cultivate plants, which are used to support installation natural resource projects. In addition, JBLM uses inmate labor to bag the compost it generates. JBLM delivers the materials to the prison and picks up the finished products when the agreed labor support is completed.

3. Maxwell AFB Inmate Labor Program:
The Federal Prison Camp (FPC) on Maxell AFB was the first to supply inmates for use by the military and was primarily dedicated toward performing authorized work in support of the installation. The agreement between the two organizations is documented in a Support Agreement (SA), DD Form 1144, which covers a three-year period. The FPC is required to be capable of supplying up to 50% of the prison population, ranging from 700 to 1,110 inmates, for labor purposes. The Wing Commander provides conviction information upon request. Prisoners are required to wear distinctive uniforms at all times so they will be recognized as federal prisoners.

In order to accomplish food waste from going to a landfill, Maxwell AFB utilized inmate labor. An example of the language used in their Support Agreement (SA) is presented below:

"Subject to the terms of 18 U.S.C. 4125, federal prisoners will be used on projects mutually agreed upon by the Wing Commander, Maxwell Air Force Base (MAFB), and the Warden, FPC."

"When authorized in writing by the FPC Warden, inmates who have a valid state license are eligible to operate vehicles only on the installation for official business. The Federal Bureau of Prisons is not held responsible for any claim or property damage as a result of inmates driving Air Force vehicles while engaged in assigned duties."

Also stipulated in the SA, the FPC reimburses the MAFB for service provided to include 35% of utility costs, and five full time equivalent inmate supervisors. Maintenance and repair accomplished by Air Force support personnel is also reimbursable. The FPC is not charged for grease trap/duct cleaning and refuse pick-up (Maxwell AFB 2012).
In addition to stating the role of prisoners and the FPC's responsibilities to Maxwell AFB, the SA states the responsibilities of Maxwell AFB including the following:

"Maxwell AFB will:" 1) "provide special protective and safety equipment ...," 2) "provide tools, materials, and supplies necessary to perform work," 3) "provide supervision ...," 4) "submit work reports ...," 5) "report unusual events such as injuries, misconduct, escapes ...," 6) "establish inmate quotas and develop job descriptions," 7) "obtain ... approval before changing inmate work detail assignments," and 8) "ensure inmate work will not displace civilian employees, impair existing contracts for service, or exploit inmate labor" (Maxwell AFB 2012).

3.3 Develop or increase on-post capacity for the treatment organic waste

Composting and anaerobic digestion are two methods to manage large volumes of organic waste and generate useful residual products. Composting can take place in an in-vessel composter, a windrow, or an aerated pile. The compost generated by these two methods can be used to amend soil, prevent erosion, as a fertilizer, or as mulch for aesthetic landscaping purposes. In the case of anaerobic digestion, natural gas can also be produced and used as fuel or to generate heat. The size and capability of these operations will depend largely on the installation's capacity to generate the waste needed to operate and manage operation logistics such as material storage and transportation. The residual liquid digestate from the anaerobic digestion process can be reused in the digester, and residual solid digestate can be further processed into compost, ethanol, or fiberboard (Verma 2002; Teater 2010; Winandy and Cai 2008). Composting facilities and anaerobic digestion facilities typically use one or several waste streams including food waste, yard waste, wood pallets, stable waste, pulverized paper, consumer-contaminated paper, and/or sludge.

If an installation has (or is developing) its own capabilities to handle organic waste on a large scale and it has a supportive and active relationship with the communities surrounding it, the installation may consider augmenting or bolstering its waste streams by sourcing waste from these surrounding communities. The local community entities that might be able to provide waste sources may include, but are not limited to, local farms, paper or fabric manufacturers, food manufacturers, wastewater treatment plants, grocery stores, and residences. Waste service contracts can be leveraged in order for organic waste to be collected from dining halls, residences, and other on- and off-post locations. The waste can be hauled to an on-post organic waste repurposing or treatment facility such as a composting center or anaerobic digestion facility; then, the waste services contractor or installation personnel such as the Directorate of Public Works would operate the organic waste conversion/reduction facility.

3.3.1 Case studies

1. Fort Riley Composting Facility: Fort Riley's Environmental Waste Management Center Composting Facility accepts leaves, grass clippings, horse and buffalo manure, and wood debris from both residential and non-residential areas of Fort Riley and neighboring city, Junction City. In addition to DPW-collected yard waste, contractors transport yard waste from on-post residential areas, the color guard delivers manure and straw from the stables, and Junction City delivers yard waste to the composting facility[1] . The composting facility uses windrows and is operated by Department of Public Works employees (Figure 4). In 2014, the facility processed about 214 tons of material, creating about 53 tons of compost[1]. The compost is available to Fort Riley residents free of charge. It is also used on Fort Riley as mulch, wildflower fertilizer, and to restore damaged areas under reclamation (Randall 2011; Healey 2013). The composting program is estimated to save the installation over $50,000 annually in reduced disposal costs and reduced purchase costs of new mulch (Randall 2011).

[1] R. Smith, Personal Communication, 21 January 2015.

Figure 4. Fort Riley's composting facility.

2. Fort Leonard Wood Contractor Operated Composting Site: Fort Leonard Wood's Directorate of Public Works Trash and Refuse Collection Contractor operates a compost site that only accepts yard waste. Material accepted includes: grass, leaves, twigs, straw, and garden vegetation (Fort Leonard Wood DPW-ED 2014). At the end of 2014, Fort Leonard Wood's Plans, Analysis and Integration Office (PAIO) installed an in-vessel composting system to conduct a demonstration for the diversion of food waste from their dining facilities.

   In order to accomplish diversion of organic waste, excluding food waste from going to a landfill, Fort Leonard Wood utilized their waste service contractor. An excerpt of the contract language used to scope the labor and operation of the compost material sites in the waste service PWS is presented below:

   "*Operation of the Compost/Clean Fill Area: The Contractor shall furnish all labor to operate the Fort Leonard Wood compost and clean fill areas. Operation shall consist of monitoring the Clean Fill area to allow only clean fill material, and monitoring the Compost Site to allow only yard waste. Contractor shall remove and properly dispose of any items that are not classified as clean fill or yard waste, i.e., trash bags, boxes, etc. The Government reserves the right to change location of the clean fill area at any time during the contract period.*"

"Operation of the Brush/Stump Area: The Contractor shall furnish all labor to operate the Fort Leonard Wood brush/stump area. Operation shall consist of monitoring the area to allow only brush and stumps to be placed here. The area is located directly across the road from the compost/clean fill area and as such could be operated by the same personnel. The Government reserves the right to change location of the brush/stump area at any time during the contract period."

"Clean Fill/Compost Area: The Contractor shall furnish a monthly report (original and two copies) to the [Contracting Officer Representative] COR by the fifth day of the following month, stating how many loads of demolition wastes were disposed in the clean fill area, how many loads of yard wastes were disposed in the compost area, the names of the Contractors or Government organizations that used the facilities, and any loads turned away as unsuitable, and the reasons therefore, for that landfill and/or compost area"
"Brush/Stump Area: The Contractor shall furnish a monthly report (one original and two copies) to the COR by the fifth day of the following month, of how many loads of brush & stumps are disposed of in this area, the names of the persons using the facility, any loads turned away as unsuitable, and the reasons therefore."

"Fines: If, during the contract period, the Government is assessed fine(s) by the Missouri Department of Natural Resources due to the improper disposal of trash and refuse by the Contractor, or improper operation of the Compost/Clean Fill Area or Recycle Center by the Contractor, an amount equal to the fine(s) will be deducted from the Contractor's payments. This is in addition to any other remedies that the Government may pursue" (Fort Leonard Wood DPW 2013).

3. Joint Base Lewis-McChord (JBLM) Composting Facility and Transportation of Compostable Materials: Organic waste constitutes approximately a third of the total solid waste generated at JBLM (JBLM DPW 2013). JBLM has operated a composting program since 2006. In 2014, 4,780 tons of organic waste was diverted from the landfill. JBLM currently operates a composting facility using aerated static pile technology (Figure 5). This facility processes materials generated at the installation such as food waste from the Lewis Main and McChord Field Commissaries, installation dining facilities and food preparation

areas, horse manure bedding from stables, land clearing debris from construction and site preparation activities, timber sales waste, storm debris (branches and tree limbs), and green/yard waste from landscaping activities and other projects[1]. Food waste collection containers are pictured in Figure 6. Bio-solids from the JBLM Waste Water Treatment Plant were formerly included in JBLM's composting operations. However, as of last year, JBLM obtained an approved Site Specific Land Application Plan (SSLAP) allowing the annual land application of bio-solids to one of its landfill cover systems to provide nutrients to the cover crop[1]. Additionally, some of the wood waste is chipped and the mulch is given to units on base for area beautification.

The composting product generated by JBLM's Earthworks facility is of high quality and meets the requirements for the U.S. Compost Council's "Seal of Testing Assurance" (STA). Between July 2011 and July 2012, 2,000 cubic yards were sold to the general public via live Internet auction through "Government Liquidators" (Norton and Lee 2012). Almost all of the compost produced by JBLM is now used for on-post projects such as a native plant nursery, designed to enhance the habitat for rare and candidate species in training areas, and for turf enhancement at the Eagles Pride Golf Course (JBLM DPW 2013). Each year JBLM prepares a cost-benefit analysis of their composting operation and compares the results to outside composting operations and the cost of landfilling. The 2014 net savings from composting and chipping organic waste at JLBM was approximately $836,610. The savings are derived from waste disposal cost avoidance ($267/ton for 4,780tons) and avoiding commercial procurement of compost and wood chips ($20/cy for 2,000cy)[1]. JBLM found that training in-house DPW staff to operate the on-post composting facility proved more economical than hiring outside contractors (Norton and Lee 2012). However, a solid waste contractor delivers the waste to the composting facility.

In order to accomplish diversion of organic waste from the landfill, including food waste, JBLM utilizes their waste service contractor to transport the waste into the composting site. An excerpt of the contract language used to scope the transportation of the compost materials waste service PWS, is presented below:

[1] A. Gallagher, Personal Communication, 5 June 2015.

"Composting: JBLM will partner with the contractor to develop and expand composting of collected organic materials, such as manure from the JBLM horse stables. The contractor shall deliver compostable materials to a permitted Composting Facility such as the JBLM Earthworks, or any other as allowed. JBLM cannot ensure that its' composting facility will always be available to support this contract" (JBLM DPW 2012).

Figure 5. Joint Base Lewis McChord (JBLM) composting facility.

Figure 6. Food waste collection container at Joint Base Lewis McChord (JBLM).

4. Fort Hood Yard and Manure Waste Composting Facility: Fort Hood currently conducts a yard and manure waste composting operation. Currently composting operation and waste hauling support are conducted under separate contracts awarded to the same contractor. It is stated in their solid waste management contract language that the contractor is responsible for the collection of all wood waste, manure, vegetative waste, and other authorized compostable materials on the installation. The contractor is not only responsible for delivering those waste streams to the Fort Hood Compost Center, but also for operating the compost center. In addition, the contractor is responsible for cleaning and collecting waste from all grease traps from Fort Hood food service facilities (Fort Hood DPW 2010). This facility can handle bagged yard waste, trimmings, grass clippings, and horse manure. This operation processes an average of 3,000 tons annually in composting materials. In September 2015, Fort Hood began a food waste collection pilot project. Fort Hood's long-term goal is to upgrade the current yard waste compost center on-post to accommodate the installations' food waste, and then to sell the final product through the Qualified Recycling Program to maximize savings and reduce costs installation-wide.

In order to accomplish diversion of organic waste from the landfill, excluding food waste, Fort Hood utilizes separate contracts for their waste hauling and on-post composting site operation. Excerpts of the contract language used to scope the transportation and processing of the compost materials in the waste service PWS are presented below:

"Compost Center. The Government will provide the Contractor with a facility (Facility 56132, 100 X 60 Canopy) across the street from the Fort Hood Landfill to operate the Fort Hood Compost Center. The Contractor shall not, under any circumstances, use any other area outside or within the Fort Hood Compost Center for storage or cannibalization of vehicles or equipment."

"Compost Center Operation. The Contractor shall manage and provide a complete and comprehensive Compost Center operation to interface with and receive compostable organic waste from other authorized Contractors, troop units, DPW, and other entities approved by the Contracting Officer; pre-process and process compostable organic waste in a manner that promotes maximum diversion and re-use of compostable organic materials from Fort Hood's waste stream while maintaining "exempt" status under the TCEQ's notification, registration, and permitting requirements in 30 TAC 332, Composting Rules; post-process the finished compost material; and perform other associated tasks on a scheduled and unscheduled basis. The Contractor shall employ a Master Composter, who shall be physically present at the Fort Hood Compost Center at all times during the Landfill Operating Hours to ensure all composting operations are conducted IAW EPA, TCEQ, and Army regulatory and statutory requirements. The Contractor shall plan and perform all Compost Center tasks IAW the contract, the Contractor's Compost Center design, the Contractor's Compost Center Construction Plan, the Contractor's Compost Center Operation Plan; FH Reg. 200-10, Spill Prevention Control and Countermeasure Plan; 30 TAC 330, State of Texas Municipal Solid Waste Management Regulations; FH Reg. 200-1, Environment and Natural Resources; NFPA 1.12-2 Combustible Fibers (as directed by the Fort Hood Fire Department and AR 420-47, Solid and Hazardous Waste Management. The Contractor shall operate the Fort Hood Compost Center 6 days a week, including federal holidays, during the Landfill Operating Hours defined in section C.2.2, unless otherwise directed by the Contracting Officer. The

Contractor shall produce and submit records and perform reporting requirements IAW Compost Center Operation Plan, reference C.5.9.16. The Contractor shall grant TCEQ representatives, and others designated by the Contracting Officer, access to the Fort Hood Compost Center for inspection purposes at all times. Any time the Contractor feels, or state regulations mandate, that a change in operating procedures is prudent or required for safety, efficiency, cost savings, etc., the Contractor shall propose the change to the Contracting Officer for evaluation and approval. If the proposed change requires a formal modification or amendment to the Fort Hood Landfill permit, the Contractor shall prepare, sign, and seal all documents, drawings, etc. required for submission to the TCEQ for approval. The Contractor shall implement the change only after written notification from the Contracting Officer that the TCEQ has approved it."

"Compost Center Operation Plan. The Contractor shall develop and implement a Compost Center Operation Plan for complete performance of these work functions IAW C.5.3. The Contractor shall submit a Compost Center Operation Plan to the Contracting Officer for approval no later than 10 days prior to contract performance start date and updated annually."

"Stockpile Compostable Organic Wastes. The Contractor shall stockpile compostable organic wastes in the receiving/staging area. The Contractor shall have 3-6 stockpiles of material at the Compost Center such as (material to be chipped, clean cedar, mesquite and oak chips, material to be processed, curing material, etc.). Wood chips shall be free of any other material, screened and of one inch or less uniform size prior to allowing Fort Hood Community use. The Contractor shall provide access to the Compostable organic wastes at no charge to the Fort Hood Community. The Contractor shall assist the community with loading the material Monday through Friday between the hours of 0800 to 1000 and Saturday between the hours of 0730 to 1200. The Contractor shall incorporate this service in his Community Service Program; reference C.5.12.1.4, Compost Center Customer Training. Compostable organic wastes and/or compost windrows, curing piles, and storage piles shall not be placed where continuous contact could occur with any surface water run-on, run-off, or ground-water."

"Prepare Wood Waste. The Contractor shall screen all wood waste to remove non-compostable waste and chip the compostable wood waste to achieve a uniform particle size of one to two inches."

"Processing. The Contractor shall blend the compostable organic wastes together in a process that will produce AAA compost. The Contractor shall submit the proposed process, with anticipated quality level to the Contracting Officer for approval prior to process start. The Contractor is responsible for maintaining the optimum conditions required for the highest quality possible."

"Compost Tonnage Report. The Contractor shall provide a monthly report, reference TEN, entitled "Compost Tonnage Report" that reflects the month of service and at a minimum includes the weight, volume, types, and origins of compostable materials accepted at the Compost Center. The Contractor shall also record the weight and volume of finished compost or woodchips removed from the Compost Center, the utilizing company, person or unit, a point of contact and phone number. The Contractor shall also record the estimated amount of material being stored, processed and cured at the Compost Center sorted by type of material. The Contractor shall update the report daily and be made available for review at Contracting Officer request at any time during the current month."

"Compost Windrow Data Sheets. The Contractor shall record all compost processing data on a Compost Windrow Data Sheet and submit them monthly, reference TE N, to DPW for each windrow formed. The Compost Windrow Data Sheet shall include: Person, date and time data was collected; Weather conditions; Wind direction; Air temperature; Site observation comments (windrow turned, water ponding, odor, etc); Windrow moisture (hand squeeze observation); At five different locations in each windrow (include sketch of locations): Windrow identifier (for example a number); Windrow temperature; Windrow moisture content (lab test) stated as a percentage; Windrow pH level; Windrow oxygen content stated as a percentage; Windrow C/N ratio" (Fort Hood DPW 2010).

5. Fort Drum Composting Operation: Government employees manage the composting operations at Fort Drum. Since composting began at Fort Drum in November 2014, Fort Drum has been able to increase their

solid waste landfill diversion from 29% to 40%. Six to seven tons of food waste are collected at four of the post's military dining facilities and at the commissary each week (Block 2015)[1]. Currently, Fort Drum is only collecting pre-consumer food waste at these facilities; however, they are in the process of modifying their dining facility contract to include the separation and collection of post-consumer waste. This will, at a minimum, double compostable material coming out of each facility. Between October 2014 and May 2015, Fort Drum chipped over 400 tons of untreated wood from ammunition cases and pallets[1]. In addition, 200 tons of the wood chips were sold as a biomass fuel at the privately owned ReEnergy plant located at Fort Drum[2]. The remaining wood chips are currently mixed with collected food waste at a ratio of 2:1 in windrows. The windrows have successfully maintained the required elevated temperatures necessary for compositing within the pile, even with frigid weather conditions. Likewise, finished compost is tested, made available for base residents, and used on-post for purposes such as replenishing soil with nutrient deficiencies due to timber harvesting[2]. Since November, it is estimated that Fort Drum has seen a net savings of $38,000 from the diversion of food and wood waste from landfills[2]. The installation is in the process of constructing a five bay forced-air composting system. The bays will be 14 feet wide, 50 feet long, and six-feet high. The system will have food waste in and out in 30 days, with 30 additional days for curing. Additionally, using the research and design developed by Cornell University, Fort Drum implemented a mortality compost operation for road-kill deer and other animals. Material used in the mortality compost is left undisturbed for a minimum of six months, and the resulting compost is used for on-post site-stabilization[2].

[1] A. Reali, Personal Communication, 21 May 2015.

[2] R. Voss, Personal Communication, 28 May 2015.

4 Small-Scale Food Waste Technologies

Beyond securing alternative sites for organic waste disposal and improving installation waste services via contractor and inmate support, landfill waste diversion can be developed on a smaller scale through implementing commercially available food waste processing technologies for a specific targeted area or building. Diverting food waste requires special processing because of the problems associated with odor, messiness, vermin, etc. that other forms of organic waste generally do not present. With declining manpower and additional duties, the research of these different technologies, and the selection of one that will provide the best value for a specific installation, may not be easily achievable for installation personnel. Below is a brief evaluation of some of the small-scale technologies commonly used for diverting food waste including digesters, dehydrators, containerized in-vessel composters, and worm-based composting (vermicomposting). This section is not intended to directly compare these four technologies, but rather to provide a general description, suggestions for suitable locations, a general price range, and benefits and concerns that an installation should be aware of for each technology. It should be noted that permits for food waste conversion/reduction technologies and processes vary by state. Permitting comments for the technologies below are general and should be verified locally. Additionally, when considering implementing a small-scale food waste technology, installations should be aware of the labor requirements for preparing packaged and canned food waste for processing.

4.1 Organic waste digestion equipment

Description: An organic waste digestion system is a standalone technology in which food waste is ground and mixed with water and patented microorganism or nutrient mixes. This "add-in" accelerates the decomposition process, further optimized by the maintenance of specific internal temperatures, oxygen levels, and the use of fresh tap water. In roughly 24-hours, the process breaks down organic solids into a liquid waste effluent that can be flushed into a municipal sewer system. Note, digesters, particularly the ORCA system, have faced mechanical, odor, and personnel-use problems at several U.S. Army installations including Fort Hood, Fort Carson[1], and the Minnesota National Guard Camp Ripley[2]. The aforementioned problems faced resulted in digester use cessation at each of these installations; however, the machines were re-engineered following these issues. Improvements to the ORCA system's electronics, manufacturing process, and microorganisms may alleviate some of the problems experienced.

Location: Organic waste digesters are typically located indoors within close proximity to where food is stored and used. They require connection to a cold and/or hot water source and access to a sewage drain. If a digester is stored outside, it needs to be in a covered area (Griffith-Onnen 2013).

General Price Range: \$17,000–\$45,000 to buy; \$900–\$2,000 month to lease (Griffith-Onnen 2013; Hamilton and Chiang 2014).

Benefits: An organic waste digester is most feasible when:

- A limited amount of space (indoors) is available
- Waste must be processed within one day of entering the technology
- Low to moderate amounts of electricity (5.76 kWh-96 kWh per day) are available to process food waste (Griffith-Onnen 2013).

Concerns: Installations should be aware that an organic waste digester:

- Has a moderate likelihood of requiring a permit to discharge the effluent to sewers (may not meet maximum allowed discharge levels)
- Varies in water consumption depending on the unit, but 100 gallons of water or more is required per day. One gallon of water is necessary for every one to four pounds of organic waste (Neale 2013).
- Requires tap water (cold and sometimes hot water hookup)
- Produces a large volume of liquid effluent with a high Biological Oxygen Demand (BOD) that may be "corrosive to plumbing, detrimental to wastewater treatment systems, and may contain high levels of non-beneficial bacteria" (Neale 2013). If exposed to effluent, people should protect themselves as if they were dealing with human sewage (Dorsey and Rasmussen 2012).
- Generally requires a high level of maintenance at a high cost
- When malfunctioning can potentially result in odors
- May require additional water to ensure effluent flows down the drain

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[1] E. Buccambuso, Personal Communication, 19 May 2015.

[2] K. Auer, Personal Communication, 19 March 2014.

- Has issues processing coffee grinds, fibrous foods (e.g., corn husks), large meat bones, shells, and large amounts of oil and grease, potentially resulting in high Total Suspended Solids (TSS).

4.1.1 Case studies

1. Twentynine Palms, California, ORCA digester demonstration: From April 2012 to September 2012, an ORCA Green ™ Food Digester, Model OG 1200, was evaluated on-post in the Camp Wilson Mess Hall (Battelle 2012). Food waste from preparation, which ranged between 55,700 and 163,200 portions per month, were placed into the machine. Food waste typically consisted of bread, pastries, processed and raw fruits/vegetables, and meat remnants. It was found that fibrous food waste broke down slowly in the machine, and meat bones required more than 24 hours to process. High sugar content food waste (e.g., heavy syrups and desserts) caused a thick foam effluent, which required extra water to maintain flow down the drain. ORCA effluent had a TSS of 67,000 mg/L and a BOD over 6000 mg/L relative to background TSS and BOD of 520 mg/L and ~300 mg/L respectively (Battelle 2012). "Compared to tap water, the ORCA effluent had: lower pH (4.22 pH versus 5.49 pH), greater conductivity (5.30 milli-siemens per centimeter [mS/cm] versus 0.336 mS/cm), much higher turbidity (>999 nephelometric turbidity units [NTU] versus 30 NTU), less dissolved oxygen (6.32 mg/L versus 7.59 mg/L), higher temperature (31.2 °C versus 26.1 °C), and greater salinity (0.27% versus 0.01%)." Conductivity and turbidity data supported the visual observations of suspended solids in the ORCA effluent. 50 gallons of hot and 50 gallons of cold, potable water were required by the ORCA per day. Yearly costs for biochips, the medium that microbes adhere to during digestion, were $800. The cost for one gallon of enzymes added to the ORCA every month was $40. Odors did not escape the closed chamber. Some issues that the ORCA developed were; "(1) a main-shaft seal developed a leak; (2) the screen in the bottom of the chamber became loose, which allowed some of the BioChips and food waste to exit the machine; (3) the machine stopped running when subjected to several electrical power interruptions (requiring the system to be shut down and restarted); (4) the loading door hinge bolts became loose and required tightening; and (5) after five months of testing, the system failed to operate and was shut down, ending the on-site evaluation" (Battelle 2012). As of May 2015, Twentynine Palms was still operating the ORCA at Camp Wilson

in addition to three other 1,200 lb capacity ORCA digesters at three of its main dining facilities[1].

2. Fort Bragg Power Knot Digester Demonstration: In 2014, Fort Bragg demonstrated and purchased a Power Knot LFC-200 digester. Fort Bragg was so pleased with the performance of the Power Knot Digester that they planned to purchase 14 more units[2]. The machine is stated to have a daily capacity of 800 lbs of food waste, with the ability for food to be continuously added. Once turned on, it does not need to be turned off.

   Fort Bragg has not experienced any odor problems with the PowerKnot Digester, which decomposes most food waste within 24 hours. The LFC-200 can process all food waste except for shells and meat bones. Additionally, large amounts of fibrous material, such as corn husks, are cautioned against due to the potential to mat together, clogging the machine and causing a smell. Processed food waste is discharged to the sanitary sewer as grey water. Every three years, the Powerchip substrate needs to be replaced at a cost of $1,600 and added to the PowerKnot. The microbe enzyme blend needs to be supplemented every six months at a cost of $460. The LFC-200 uses 140 gallons of water per day, with an optimal water temperature of 100 degrees Fahrenheit. The digester uses around 8.1 kWh per day and requires a 208 V, 60 Hz, 15 A, three-phase connection (Power Knot 2014). The digester is fully automated and monitors itself, conveying if a problem arises. The digester is designed for a 15 to 25 year lifecycle (Power Knot 2014).

4.2 Food waste dehydrator

<u>Description</u>: a food waste dehydrator is another standalone technology that uses high temperatures (180 °F) and mechanical processes to decompose and reduce the volume of food waste into a dry, sterile, odorless biomass product with sterile water. This product might have potential to be used as compost feedstock or as a soil amendment; however, some installations have not been successful with this practice, and some more testing and research is needed. Even if research determines that direct land application is not possible, this system still proves effective for the diversion of

[1] J. Valls, Personal Communication, 20 May 2015.

[2] A. Oxendine, Personal Communication, 19 May 2015.

organic waste from the landfill and reduction in waste hauling costs, as the system is effective in reducing food waste volume by up to 86%.

Location: Dehydrators are typically located indoors, such as in kitchens, as sheltered areas with good ventilation are recommended. As an alternative, a loading dock with an overhang may also be a suitable location. The dehydrators should be in close proximity to where food is stored and used, but where potential odors will not impose on personnel or customers.

General Price Range: \$20,000–\$300,000 capital cost (Griffith-Onnen 2013).

Benefits: A food waste dehydrator is most feasible when:

- A limited amount of space (indoors) is available
- Water resources are limited
- The risk of effluent exceeding maximum discharge levels is a concern
- Waste must be processed within one day of entering the technology
- A dry sterile solid is desired as a product. While it may have potential uses as a soil amendment or feedstock for composting/anaerobic digestion, it is still considered solid waste and may need, at least, pH adjustment for post-processing. Note, research is ongoing regarding repurposing of dehydrated material.

Concerns: Installations should be aware that a food waste dehydrator:

- Has a moderate likelihood of requiring a permit depending on local regulations
- Generates a moderate amount of liquid waste residue (1 gallon for about every 10lbs of food waste)
- Uses a moderate to high amount of electricity (42 kWh–1400 kWh per day) to process food waste (Griffith-Onnen 2013).
- Has issues processing large items of food waste such as big meat bones or coconuts
- Generally requires a medium to high level of specialized maintenance
- When malfunctioning can potentially result in odors.

4.2.1 Case studies

1. Fort Lee Food Dehydrator Pilot Projects: Fort Lee installed 650 lb capacity dehydrators in four different locations around post, including one of its dining facilities (DFAC 3500, Figure 7), the Commissary (Figure 8), the Field Operations Training Branch (FOTB) (Figure 9),

and the Culinary School (Mertens 2015). By utilizing dehydrators, Fort Lee was able to divert 163 tons of food waste from the landfill in 2014. The reduced weight and volume of waste that was processed by the dehydrators has led to fewer garbage pick-ups, thus weekly savings for the installation (Mertens 2015). In 2016, the Army plans to add twelve 650 lb capacity dehydrators at Fort Lee's other dining facilities (Mertens 2015).

Before deciding what kind of equipment was needed and where to install it, the Fort Lee team performed a considerable amount of planning and research. Prior to the Ecovim dehydrators' arrival, the team held six to eight meetings to evaluate everything including equipment placement, manufacturer's warranty, and Fort Lee's repair capabilities (Mills 2014). The equipment manufacturer assisted in the equipment installation, provided training for 30 DFAC employees, teleconferenced with the Fort Lee team to address questions, and was responsive to issues with the equipment (Mills 2014).

The use of dehydrators at Fort Lee will serve as a model for other installations that are hoping to adopt these practices. Headquarters Installation Management Command (HQ IMCOM) funded the Engineer Research and Development Command – Construction Engineering Research Laboratory (ERDC-CERL) to evaluate the capability and optimum application of food service waste reduction and conversion at Fort Lee, VA. Likewise, ERDC-CERL is also determining how these initiatives can impact installation landfill disposal and cost, waste diversion, and future specifications for dining facility design and field feeding operations. In addition, ERDC-CERL is working in collaboration with the Virginia State University, which is currently researching the utilization of the residual biomass product as a potential soil amendment on crops or as animal feedstock.

Figure 7. Dehydrator systems at DFAC 3500, Fort Lee.

Figure 8. 650 lb capacity dehydrator at Fort Lee commissary.

Figure 9. Ecovim dehydrator at Fort Lee's Field Operations Training Branch (FOTB).

2. Hanscom AFB Commissary Dehydrator: In Spring 2014, the commissary at Hanscom AFB installed an Ecovim dehydrator, to process the more than one ton of food waste it produces each week. The dehydrator is used about every other day, and for every 650 lbs of input, there is an output of 80 lbs of dried biomass. Hanscom AFB Civil Engineering supplies waste bins. The organic waste is sent to a waste-to-energy facility through their waste services contractor ONOPA Services LLC[1]. Commissary employees are welcome to take any biomass output they want for their own personal use. An adjustment filter was needed to tone down the acidity of the pH, and a permit was required. The dehydrator was not receiving the correct voltage, and consequently, it was not getting hot enough to burn the residue inside the machine, causing an odor issue. Technicians fixed the issue and added a voltage booster. Ecovim sends personnel to the commissary to monitor the dehydrator every so often[1].

3. Tentynine Palms Dehydrator Pilot: In 2012, during a 64-day pilot test of the commissary's 250-pound capacity Ecovim Dehydrator, 3,100 lbs of food waste was reduced into 150 lbs of sterile dehydrated biomass and 310 gallons of condensate (Griffith-Onnen 2013; DeCA 2012). The Ecovim Dehydrators conserve water by reusing the condensate runoff to control humidity in the unit, thus not requiring a fresh-water con-

[1] L. Griffin, Personal Communication, 18 November 2014.

nection (USMC 2009). The dehydrators produce an acidic sterile dehydrated biomass, which can later be mitigated, and condensate with a good carbon-nitrogen ratio (Griffith-Onnen 2013). Imperial Western Product, the Twentynine Palms waste service contactor, removes one to one-and-a-half tons of finished dehydrator biomass from Twentynine Palms every three months. After removal, it is reprocessed into a feed additive for cattle by batching it with corn, bread, and grain and then re-cooking it[1].

4.3 Containerized in-vessel composting

Description: in-vessel composters are a high-tech form of composting that use carefully controlled mixing, aeration, temperature, and moisture to accelerate the natural decomposition process. Processing time varies from only 24 hours to 14 days. Upon completion, the compost produced should be tested, as further treatment may be needed before soil application (Griffith-Onnen 2013).

Location: in-vessel composters are often located outside due to potential odors; however, some models may be located indoors (U.S. EPA 2015; Griffith-Onnen 2013).

General Price Range: $10,000–$80,000 (Hamilton and Chiang 2014)

Benefits: in-vessel composting is most feasible when:

- Acquiring a permit for a technology is undesirable or unobtainable. In most cases, a permit is not required if the compost product will be applied within the installation. Prior to using as a soil amendment, testing of the compost may be required. Testing requirements vary by state and may consist of testing compost for physical, chemical, organic, and biological properties, as well as synthetic, organic compounds, and pathogens. The United States Composting Council (2014) and the McEntee Media Corporation (n.d.) provide a state-by-state summary of permits and other requirements for composting. Likewise, the United States Composting Council provides detailed test protocols for the composting industry (2010).
- Available water sources are varied in type (potable, rainwater, etc.)

[1] T. Garza of Imperial Western Product, Personal Communication, 21 May 2015.

- Liquid waste residue is not desired, or the risk of effluent exceeding maximum discharge limits is a concern
- Electricity is limited. In-Vessel composting uses a low to moderate amount of electricity (1.71kWh-62kWh per day) to process food waste (Griffith-Onnen 2013).
- High grade compost is desired as a product; however, the final product should be tested to see if it is ready for immediate use (Griffith-Onnen, 2013). Some states regulate holding time, 21 days being the average (U.S. EPA 2000).

Concerns: Installations should be aware that in-vessel composting:

- Processes waste within one day or over several weeks of entering the technology. Process time depends on the make and model of technology selected. Curing of compost is necessary and may take anywhere from several weeks to several months.
- Requires the addition of brown waste (i.e., wood chips) for a carbon source, and a mix of different feed materials (i.e., processing a large volume of one type of material results in an unbalanced compost product)
- Technologies vary in size, ranging "from small bins to tub grinders to large structures" (Griffith-Onnen 2013). Small systems can be located inside, while other larger systems may require large amounts of land to store waste, cure compost, and for equipment and truck movement. "The meteorology of a potential site (should be determined) so that odors can be adequately treated, diluted, and dispersed" (U.S. EPA 2000).
- Requires a moisture content range around 60% (Bonhotal 2011). Depending on unit and waste type, the in-vessel composter could use 50 gallons of water per day
- Requires a moderate to low level of maintenance (e.g., preparing the feedstock, filling the vessel, monitoring the PLC, and emptying the vessel) at a moderate cost of $61 to $534 per day (Griffith-Onnen 2013; U.S. EPA 2000).

4.3.1 Case studies

1. Fort Leonard Wood Food Waste Composting Demonstration: In Spring 2015, Fort Leonard Wood's Plans, Analysis and Integration Office (PAIO) sponsored ERDC-CERL as part of their Integrated Strategic Sustainability Planning (ISSP) to conduct a demonstration of an in-vessel composting system for the diversion of food waste from their

dining facilities. The equipment selected for this demonstration was a rotary drum composting system (Figure 10) that is commonly used in the agricultural industry. Rather than locating multiple smaller units at source locations, a single large unit, sized to accommodate waste available on a regular basis, was selected and mounted on a trailer to be pulled to each source location[1]. A larger unit was selected to reduce the manpower and transportation necessary to distribute wood chips to the unit(s) and enable food waste to be directly loaded into the in-vessel composter. Additionally, purchasing one larger unit was more economical than purchasing multiple smaller units. The rotary drum composting system has a capacity of six cubic yards, and was fed one to two cubic yards of food waste per day and two to four times as much yard waste. With a three-day retention period, the rotary drum composting system optimally produces two cubic yards of compost per day[1]. The 2015 testing of the in-vessel composter was successful. Using the in-vessel composter would yield a savings of $200 per ton in disposal costs for the three tons of organic waste diverted from the landfill every day, which results in an estimated, annual cost savings of $219,000[2]. Fort Leonard Wood is now considering whether to get a Part B Solid Waste permit from the State Department of Natural Resources, and to go through with site modifications such as installing concrete pads[2]. Meanwhile, the in-vessel composter is being used to compost landscaping waste, and the derived compost is being utilized for landscaping and gardening on-post[2].

[1] D. Gebhart, Personal Communication, 6 July 2015.

[2] D. Gebhart, Personal Communication, 18 August 2015.

Figure 10. In-vessel system similar to system Evaluated for Fort Leonard Wood.

2. Fort Bragg In-Vessel Food Waste Composting Demonstration: Fort Bragg, NC, successfully conducted a demonstration of three containerized, in-vessel composting systems to process food waste. The systems tested were the Engineered Compost System (ECS) shown in Figure 11. The ECS is capable of handling one to 50 tons of a mixture of food and wood waste. Currently, Fort Bragg has been feeding the systems commissary food waste (Figure 12) and wood chips that are produced on-post from trees and brush using a tub-grinder or via their waste service contract for processing wood pallets (Figures 13 and 14). Tree and brush wood chips were found to produce a better compost mixture[1]. The systems are fed by mixing the materials in a large tub where wood chips are transferred using a front-end loader. The food waste is conveniently lifted into the system using a crane as shown in Figure 14. After the materials are mixed in the tub, they are transferred to the containerized system for composting. The work required to feed and operate the systems requires approximately two to three government employees. Fort Bragg is now planning to purchase a fourth in-vessel composting system[2]. The compost is tested as required by Fort Bragg's

[1] A. Oxendine, Personal Communication, 14 July 2015.

[2] A. Oxendine, Personal Communication, 19 May 2015.

state permit. Eventually Fort Bragg will explore selling the compost to contractors who do landscaping on post[1].

Figure 11. ECS In-vessel system at Fort Bragg, NC.

[1] A. Oxendine, Personal Communication, 14 July 2015.

Figure 12. Food waste to be fed into the in-vessel-composting systems.

Figure 13. Wood chips to be mixed with food waste.

Figure 14. Food waste being fed into the in-vessel composting systems.

4.4 Worm-based composting (Vermicomposting)

Description: Vermicomposting, or worm-based composting, is a method of composting involving one to two pounds of worms per pound of food waste. Worms are generally kept in bins with the food waste and moist paper bedding, but they can also be kept in windrow piles. Red wigglers are the most common worms used in vermicomposting. Worms are expected to double in population size every 90 days if they are in a suitable environment. Vermicomposting compost is rich in nutrients, microbes, and worm mucus, which helps the soil retain moisture and nutrients. Industrial-size vermicomposting boxes with dimensions of five-feet wide, eight-feet long, and four-feet tall are designed for a daily capacity of 75 to 150 pounds per day of organic waste. These boxes can accommodate 40 to 100 pounds per day of food waste with the remainder of the organic waste comprised of bulking material and bedding (Gannett Fleming 2002).

Location: Vermicomposting operations should be located in a composting bin in a temperature -controlled building for year-round food waste processing. However, a vermicomposting bin can be located outside since worm eggs may be able to survive mild winters and repopulate composting bins once temperatures warm up (The Daily Journal 2013).

General Price Range: $20 per pound of worms, $100-$45,230 per worm bin/container depending on size and material (Hamilton and Chiang 2014; (Sustainable Agriculture Technologies, Inc. 2012a)

Benefits: Vermicomposting is most feasible when:

- Acquiring a permit for a technology is undesirable or unobtainable. In most cases, a permit is not required if the compost product will be applied within the installation. Compost testing may be required prior to use as a soil amendment. Testing requirements vary from state to state and may consist of evaluating compost for physical, chemical, organic, and biological properties, as well as synthetic organic compounds, and pathogens. The U.S. Composting Council (2014) and the McEntee Media Corporation (n.d.) provide a state-by-state summary of permits and other requirements for composting. Likewise, the U.S. Composting Council provides detailed test protocols for the composting industry (2010).
- A limited amount of land (outdoors) or space (indoors) is available; institutional worm bins of 5 ft by 6 ft by 4 ft can handle 45–55 pounds of food waste per day (Sustainable Agriculture Technologies, Inc. 2012b). The size of bin needed will vary depending on the volume of waste (Biernbaum 2013)
- Electricity is limited. Vermicomposting does not require electricity
- Water resources are limited, or available water sources are varied in type (e.g., potable, rainwater, etc.). Worms need a damp environment, but will drown in standing water (Sherman 1997)
- No-to-low amount of liquid waste residue is desired, or the risk of effluent to water quality is a concern
- Financial resources to maintain a food waste technology are low
- High-grade compost (vermicast), without a need for post-processing, is desired as a product. It should be noted, however, that vermicast does not qualify as a Class A product since the temperature of the compost never reaches 55° C (U.S. EPA 2002)
- Low maintenance of certain conditions (i.e., moisture, temperature, and type/consistency of organic matter) is feasible to prevent loss of worm population.

Concerns: Installations should be aware that vermicomposting:

- Processes waste in as short as five to six weeks, but more normally over four to six months. Processing time depends on the ratio of worms to waste (Biernbaum 2013).

4.4.1 Case studies

1. Wright-Patterson AFB Vermicomposting Program: At Wright-Patterson AFB's recycling center, fruit and vegetable waste from the

commissary is composted via vermicomposting (Theopolos 2013). In 2002, Wright-Patterson started the vermicomposting program with about 300,000 free worms, donated from Arnold Air Force Base, with expectations that the population would grow to 500,000 (Hannah 2002). The worms eat their weight in food waste every day; as of April 2015, this equated to one ton per month. Food scraps are ground and mixed with paper. Care for the worms entails feeding and spray misting them, which only takes one person one hour per day [1].

4.5 Summary of comparison of small-scale technologies

Below, Table 2 summarizes some of the benefits, concerns, and requirements for each of the four enumerated small-scale technologies, allowing for side-by-side comparison over twelve metrics.

Table 2. Small-scale food waste technology comparison.

	Digester	Dehydrator	In-Vessel Composter	Vermicomposting
Annual capacity for food waste	≤365 tons/year	≤365 tons/year	365-1,000+ tons/year	≤1,000 tons/year
Likelihood of a required permit	Moderate	Moderate	Low	Low
Location indoors or outdoors	Indoors	Indoors	Indoors or outdoors	Indoors or outdoors
Outdoor space requirement	N/A	N/A	40-3,000+ sq.ft.	≤3,000 sq.ft.
Water volume requirement	>100 gallons/day	No water required	50-100 gallons/day	<50 gallons/day
Water type requirement	Potable	No water required	Potable or non-potable	Potable or non-potable
Discharge of organic waste to sewer	Yes	No	No	No
Processing time requirement	One day	One day	Days to weeks	Weeks to months
Production of a useful/desirable product	No	No	Yes	Yes

[1] D. Dalton, Personal Communication, 8 April 2015.

Food waste(s) not acceptable for processing	Hard food waste (i.e., meat bones and coconuts,) and grease	Hard food waste (i.e., meat bones and coconuts)	Technology can process all food waste	Hard food waste (i.e., meat bones and coconuts), grease, dairy, citrus fruits, broccoli, and onions
Pre-Processing requirements	Removal of food packaging	Removal of food packaging	Removal of food packaging. Addition of equal amount brown waste (i.e., wood chips)	Removal of food packaging. Addition of shredded paper, corrugated cardboard, or straw
Post-Processing requirement to make use of residual material	Yes	Yes	No	No

5 Feasibility Study for the On-Post Selection of a Diversion Approach

There are important steps of a solid waste study that must be performed in order to identify the most effective on-post diversion strategy. By conducting a feasibility study, regulatory limitations, waste characterization, and return on investment (ROI) should be determined.

After a regulatory evaluation and a waste characterization are performed, the installation will better understand its alternatives. Not all available approaches will be applicable to every site since the circumstances of each installation are different. For instance, a full scale, on-post composting facility could work great for installation A, but not be feasible for installation B for a number of reasons (e.g., limited land availability).

After the applicable technologies are selected, installations should consider whether they would like to try a building-by-building approach (small-scale) or a centralized operation (installation wide-scale). Both cases have different and very specific logistical approaches, and the installation should determine whether they could handle the logistics of each. The installation should also determine the extent of food waste diversion. Would the installation only divert pre-consumer food waste, or would post-consumer food waste be included in the diversion as well?

When an installation is making the decision on which activities around post are suitable for inclusion in a food waste diversion initiative, certain aspects need to be considered. For each site, building, or activity, the following questions should be asked and answered:

- *Are the materials separated from the waste stream at the source?* In most cases, the answer is no. Usually, there will be some separation and classification of the materials needed. The cleaner the waste is from other materials, such as service items, the easier it is to separate and integrate to the composting feedstock. Also, oftentimes, regulatory requirements make source separation a requirement.
- *Separation is needed, but how much of a burden is it to separate?* Pre-consumer food waste is easier to separate as it can be controlled by staff in a specific area (e.g., in the kitchen), compared to post-

consumer food waste that has to be separated by multiple consumers eating at a given time. Aggressive education, signaling, and adequate food waste containers are needed if pursuing post-consumer separation.

- *Can enough materials be collected to support the composting operation?* For instance, yard waste or wood chips are needed as bulking materials. These materials may not be generated at a constant or adequate rate. Also, processing equipment (e.g., wood chipper) is needed to make it suitable for composting.
- *Are there other means to dispose of food waste that is currently used?* Are the waste generators willing to change current practices? For example, disposing of food waste into the garbage disposal may be a practice that some DFACs would not be willing to change as it affects their profitability and, in some cases, requires a contract modification.
- *Is the installation willing to switch to compostable materials (e.g., food trays, cups, cutlery) to help ease the food separation from the waste stream at dining facilities?* Composting materials are often more expensive. Selection should be done in a very careful matter since not all materials that are advertised as compostable truly are.
- *Is this facility contractor operated?* If so, what would it take for contracted personnel to adhere to changes necessary to support the food waste diversion? Are contract modifications needed? Would these modifications increase the contract costs?

All the alternatives being considered should be evaluated in a cost benefit analysis. Important items to evaluate in such an analysis are the costs of net labor, energy, and water inputs and outputs needed to support these initiatives as well as any health and safety concerns. In addition, savings in solid waste management and the benefits of uses of the final product should be documented. This data will provide a basis to develop a Return on Investment (ROI) analysis. An ROI will determine how many years it would take to pay off the investment. Depending on the individual circumstances of an installation, costs and savings will vary, resulting in differing ROIs for each installation. The more specific the information determined (i.e., solid waste contract costs per ton), the more accurate the ROI. Equation 1 below shows the general formula for an ROI. An example of a simple ROI can be found in Appendix C.

$$\text{ROI}=(\text{Capital Cost})/(\text{Annual Savings}-\text{Annual Costs}) \tag{1}$$

Capital costs are one-time costs associated with implementing a technology. Capital costs can include, but are not limited to, initial equipment costs, equipment installation costs, and costs to retrofit a space for equipment. Annual savings are yearly savings from reducing the volume of waste disposed and profits generated from implementing a technology. Annual savings can include, but are not limited to, savings from dumpster fees, transportation costs, tipping fees, and savings from the sale of technology products such as compost or its use on site, which reduces the need to purchase compost. Annual costs are yearly costs spent to continue the operation of a technology. Annual costs can include, but are not limited to, maintenance costs, additional water and energy costs incurred due to operation of the technology, costs for additional labor needed to operate the technology, and annual certifications, training, and permitting costs if applicable.

The final selection of a food diversion approach should be based on all the findings from the feasibility study. The ideal technology or approach selected should be the one that reflects the highest economic benefit while providing the maximum waste diversion possible.

6 Situational Based Flow Chart

Accompanying the information in this report is the Interactive Flowchart for U.S. Army Installation's Organic Waste Diversion, a spreadsheet-based model. The model can be accessed at http://dx.doi.org/10.21079/11681.dataset.001c. The model was developed to guide an installation new to organic waste diversion in selecting an organic waste management technology and practices that best meet the installation's specific capacities and preferences. It was designed to be accessible by anyone with the Microsoft Office Suite. The model is used by reading a numbered question under a section, selecting a response from the drop-down list under that question, and reading and following instructions in the "Recommendation" or "Next Step" cell to the right of the question if present, or otherwise proceeding to the following question. Each question uses a set of "if-then" logic to direct the user to information and resources based on their responses to each question. This same logic directs the user between sections as well as questions.

The model consists of eight sections:

Section 1

Section 1 of the flowchart explains that the Army's Net Zero Installations Policy is the driver behind diverting organic waste at army installations, and ensures the installation is prepared to begin taking steps toward net zero waste before going any further in the model.

Section 2

Section 2 of the flowchart includes donating non-perishable and unspoiled perishable food that is fit for consumption by people or by animals. Section 2 also acknowledges composting and rendering as other organic waste diversion options.

Section 3

Section 3 of the flowchart explains that there are on- and off-post options for diverting food waste from landfills, and directs the user to a section focused on one of those options.

Section 4

Section 4 of the flowchart describes, in more detail, options for off-post waste diversion, and methods used to transport the waste from the installation to the off-post entity.

Section 5

Section 5 of the flowchart explains that on-post diversion options can be large-scale or small-scale depending on the volume of food waste that the installation generates annually, and directs the user to a section focused on one of those options.

Section 6

Section 6 of the flowchart describes the labor required to operate large-scale technologies and methods of transporting waste from on- and off-post to the technology.

Section 7

Section 7 of the flowchart is a series of questions about the installation's capacities and preferences, which are relevant to the small-scale technologies that are listed in Section 4 of this report. The user's responses for each question helps to recommend the technology or technologies that best meet the installations capacities and preferences.

Section 8

Section 8 of the flowchart describes labor required to operate small-scale technologies and transport waste to the technology if it is not co-located with the technology already.

7 Conclusion

With the advent of the U.S. Army's Net Zero Initiative and projections of increased workload and declining manpower for installation environmental staff, installation personnel need practical guidance in meeting the challenges of food waste diversion. This report has aimed to provide that guidance and to illustrate and exemplify the many alternatives, technologies, and practices that can be applied to an installation depending on its needs and capabilities. Questions regarding the approaches, contracting language, and food waste management technologies referenced in this report, or otherwise regarding food waste diversion, can be directed to U.S. Army Environmental Command.

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Appendix A: Composting Facilities near Army Installations

Data tables for the "Composting Directory" of U.S. Army installations and nearby composting facilities can be found at http://dx.doi.org/10.21079/11681.dataset.001a. This directory primarily includes commercial composters, although some anaerobic biogas facilities and local farms are included as well. These facilities receive a wide range of compostable materials ranging from a selection of animal manures to food waste. By implementing a system for organic waste diversion off-post, an installation can realize savings in both capital and manpower resources.

The directory is alphabetized by the state and location of each installation. For each installation, the directory provides the name, distance in miles from the installation, and phone number for every composting facility within 60 miles (in some cases over 60 miles) of the installation. The composting facilities highlighted in purple are facilities that specifically expressed an interest in working with the Army. The directory also answers five key questions for installations interested in composting and aid them in selecting the composting facility that best fit their needs. The five questions asked of composting facility personnel included:

1. What type of waste streams does the facility accept?
2. What is the final product generated with the waste (i.e., compost, biogas, etc.)?
3. Will the facility pick-up waste from the installation, or must the installation deliver its waste to the facility?
4. Does the facility charge a tipping fee for accepting waste?
5. Does the facility have the capacity to accept an additional 3,000 tons to 7,000 tons per year of organic waste from a given installation?

Appendix B: Prison Facilities within 60 Miles of Army Installations

A list of prison facilities that are located within 60 miles of 24 Army installations can be found at http://dx.doi.org/10.21079/11681.dataset.001b. The use of inmate labor for support installation operations can either take place on-post or at the inmate prison facility. If inmates reside at an on-post prison facility or a nearby prison facility where it is economical to transport them to the installation, they can work directly at the installation. If it is not economical for an installation to transport inmates to the installation, or there are security reasons prohibiting inmates from working at the installation, it may be possible to deliver work to the inmates at the prison where they reside.

Appendix C: Return on Investment

The following tables elicit a simple ROI that was developed to consider the implementation of a dehydrator at a scenario Army installation's DFAC. Military installation costs and savings vary per location and depend on individual circumstances of the installation. This example ROI is designed to apply to one building on-post and one evaluated dehydrator model. Values for the food generated at the installation and the retrofit costs are roughly estimated.

Table 1. Food waste generated by scenario installation.

Installation Food Waste Generation		
Food waste generation:	300	tons/year
	5.77	tons/week
	0.82	tons/day
Average density of food waste*:	772	kg/m^3
	0.58	$tons/yd^3$

*The average density of food waste was interpolated from the EPA's Waste Materials Density Data table. The food waste density in table two is the median between the "medium" and "compacted" densities given for kitchen food waste (EPA Victoria n.d.).

Table 1, above, shows the food waste generated by the scenario installation on an annual and weekly basis, and an interpolated density for partially compacted kitchen food waste (EPA n.d.). Below, Table 2 shows the capacity of the dehydrator that the installation is considering in lbs/day, tons/day, tons/week, and tons/year, as well as the percentage reduction in volume that food waste entering the dehydrator undergoes.

Table 2. Dehydrator capacity and food waste reduction capability.

Dehydrator Information		
Capacity:	650	lbs/day
	0.33	tons/day
	2.28	tons/week
	118.30	tons/year
Percent reduction of food waste:	85	percent

Table 3. Estimated fees associated with waste disposal to landfills (with and without implementing a dehydrator).

Dumpster Rental and Pick-Up Fees			
	Without Dehydrator	With Dehydrator	
Cost for one 2yd^3 dumpster and pick-up (six day pick-	$104.00		per week
Volume of food waste produced:	1.42	0.94	yd^3/day
Number of dumpsters needed:	2.00	1.00	dumpster s
Cost for dumpsters and pick-up:	$208.00	$104.00	per week
Contractor Fees (Transportation, Landfill Maintenance, and Other)			
	Without Dehydrator	With Dehydrator	
Fees as percentage of dumpster cost++:	15		percent
Contractor fees:	$31.20	$15.60	per week
Tipping Fee			
Landfill tipping fee:	$65.00		per ton

+ The cost for the 2yd3 dumpsters is actually a monthly cost, but was transformed into a weekly cost to easily discern the number of dumpsters needed per week to collect waste (Rowlett n.d.).

++ Summation of several fees charged by the contractor as percentages of dumpster rental and pick-up fee[1] .

Table 3 shows the costs incurred by the scenario installation to rent dumpsters to hold the waste generated by the installation each week, and if a dehydrator is present, the dehydrated waste output from the dehydrator. If the installation does not have a dehydrator, the volume of food waste produced by the installation per week is simply:

[1] Rowlett, Customer Service, Personal Communication, 7 August 2014.

$$Volume\ of\ Food\ Waste\ per\ Day_{(Without\ Dehydrator)} = \frac{Food\ Waste\ Generated\ per\ Day}{Average\ Density\ of\ Food\ Waste}$$

$$Volume\ of\ Food\ Waste\ per\ Day_{(Without\ Dehydrator)} = \frac{\frac{0.82\ Tons}{Day}}{\frac{0.58\ Tons}{Yd^3}} = \frac{1.42\ yd^3}{Day}$$

If the installation does have a dehydrator, the volume of food waste produced by the installation per week is:

$$Volume\ of\ Food\ Waste\ per\ Day_{(Dehydrator)} = \frac{Daily\ Capacity\ of\ Dehydrator \times (1 - Percent\ Reduction\ in\ Volume\ of\ Waste)}{Average\ Density\ of\ Food\ Waste} + \frac{(Daily\ Food\ Wast\ Generated - Daily\ Capacity\ of\ Dehydrator)}{Average\ Density\ of\ Food\ Waste}$$

$$Volume\ of\ Food\ Waste\ per\ Day_{(Dehydrator)} = \frac{\frac{0.33\ Tons}{Day} \times (1 - 85\%)}{\frac{0.58\ Tons}{Yd^3}} + \frac{(\frac{0.82\ Tons}{Day} - \frac{0.33\ Tons}{Day})}{\frac{0.58\ Tons}{Yd^3}} = \frac{0.94\ yd^3}{Day}$$

The contractor fees shown in Table 3 include the charges for transportation of waste from the installation to a landfill, as well as other fees such as landfill maintenance fees. These fees are a percentage of the dumpster rental and pick-up cost and will vary by location. Contractor fees are calculated as shown below:

$$Constractor\ Fees = Dumpster\ Cost \times Fee\ Percentage$$

$$Contractor\ Fees_{(Without\ Dehydrator)} = \$208 \times 15\% = \$31.20$$
$$Contractor\ Fees_{(With\ Dehydrator)} = \$104 \times 15\% = \$15.60$$

In addition to the fees that the contractor charges, the landfill charges a tipping fee for every ton of waste the installation sends. Table 3 estimates the average landfill tipping fee as \$50 per ton of waste; however landfill tipping fees vary by location from roughly \$20 per ton to over \$100 per ton.

Table 4. Annual cost savings from implementing a dehydrator.

Costs to Landfill Waste		
	Without Dehydrator	**With Dehydrator**
Annual dumpster fees:	$10,816.00	$5,408.00
Annual contractor	$1,622.40	$811.20
Annual tipping fees:	$19,553.57	$12,999.54
Total annual cost:	**$31,991.97**	**$19,218.74**
Annual savings:	**$12,773.23**	

Table 4 shows the annual costs accrued by the installation for dumpster fees, contractor fees, and tipping fees, with and without the dehydrator. The summation of these annual fees is the total annual costs of the installation to landfill waste. The annual savings from using a dehydrator can be calculated using these numbers. Calculations for the annual dumpster fees, annual contractor fees, annual tipping fees, the total annual costs of landfilling waste with and without a dehydrator, and the annual cost saving of implementing a dehydrator are shown below.

$$Annual\ Dumpster\ Fees = \frac{Dumpster\ Cost}{Week} \times \frac{52\ Weeks}{Year}$$

$$Annual\ Dumpster\ Fees_{Without\ Dehydrator} = \frac{\$208}{Week} \times \frac{52\ Weeks}{Year} = \$10{,}816.00$$

$$Annual\ Dumpster\ Fees_{With\ Dehydrator} = \frac{\$104}{Week} \times \frac{52\ Weeks}{Year} = \$5{,}408.00$$

$$Annual\ Contactor\ Fees = \frac{Contractor\ Fees}{Week} \times \frac{52\ Weeks}{Year}$$

$$Annual\ Contractor\ Fees_{Without\ Dehydrator} = \frac{\$31.20}{Week} \times \frac{52\ Weeks}{Year}$$
$$= \$1{,}622.40$$

$$Annual\ Contractor\ Fees_{With\ Dehydrator} = \frac{\$15.60}{Week} \times \frac{52\ Weeks}{Year} = \$811.20$$

$$Annual\ Tipping\ Fees = \frac{Cubic\ Yards\ of\ Waste}{Day} \times Density\ of\ Food\ Waste \times \frac{365\ \text{Days}}{Year} \times \frac{Landfill\ Tipping\ Fee}{Ton}$$

$$Annual\ Tipping\ Fees_{Without\ Dehydrator} = \frac{1.42\ Yd^3}{Day} \times \frac{0.58\ Tons}{Yd^3} \times \frac{365\ Days}{Year} \times \frac{\$65.00}{Ton} = \$19{,}553.57$$

$$Annual\ Tipping\ Fees_{With\ Dehydrator} = \frac{0.94\ Yd^3}{Day} \times \frac{0.58\ Tons}{Yd^3} \times \frac{365\ Days}{Year} \times \frac{\$65.00}{Ton} = \$12{,}999.54$$

$$Total\ Annual\ Cost = Annual\ Dumpster\ Cost + Annual\ Contractor\ Cost + Annual\ Tipping\ Fees$$

$$Total\ Annual\ Cost_{Without\ Dehydrator} = \$10{,}816.00 + \$1{,}622.40 + \$19{,}553.57 = \$31{,}991.97$$

$$Total\ Annual\ Cost_{With\ Dehydrator} = \$5{,}408.00 + \$811.20 + \$12{,}999.54 = \$19{,}218.74$$

$$Annual\ Savings = Total\ Annual\ Cost_{Without\ Dehydrator} - Total\ Annual\ Cost_{With\ Dehydrator}$$

$$Annual\ Savings = \$31{,}991.97 - \$19{,}218.74 = \$12{,}773.23$$

Table 5. Total capital costs for dehydrator implementation.

Dehydrator Capital Costs	
Equipment cost:	$65,000.00
Equipment installation cost:	$1,500.00
Retrofit costs:	$8,500.00
Total capital costs:	**$75,000.00**

Table 5 presents one-time capital costs necessary for implementing the dehydrator. These include the cost of the technology, the cost of installing the technology, and the cost of retrofitting the existing facility so that the technology can be installed and operated. These costs will vary depending on the type of technology selected and the existing infrastructure at the site it is implemented.

Table 6 presents the annual costs to operate and maintain the dehydrator. Operating costs may include the costs of personnel to operate the technology, and maintenance costs may include cleanings and replacement parts of the technology.

Table 6. Annual operation and maintenance costs for technology.

Dehydrator Operation and Maintenance Cost	
Annual O&M costs:	**$1,500.00**

Table 7. Summary of costs and benefits for dehydrator at DFAC.

Cost Benefit Analysis		
Total Capital Costs:	$75,000.00	
Total Annual Savings:	$12,773.23	
Total Annual Costs:	$1,500.00	
ROI:	**6.65**	**years**

Table 7 presents the total costs (capital and annual) of the dehydrator, as well as the annual savings from implementing the dehydrator. From these costs and savings, an ROI can be calculated as shown below:

$$ROI^{**} = \frac{Capital\ Cost}{Annual\ Savings - Annual\ Costs} = \frac{\$75{,}000.00}{\$12{,}773.23 - \$1{,}500.00} = 6.65 \approx 7\ years$$

**This Return on Investment calculation does not include inflation or additional energy costs incurred due to the operation of the unit.

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14. ABSTRACT

Methods of organic waste diversion currently being employed by U.S. Army installations were reviewed to provide recommendations and case studies as well as identify best practices. As part of the Army's Net Zero Installation Strategy, it is essential that installations reduce the amount of solid waste they send to landfills. Food and other organic waste, such as yard trimmings and wood residuals, are a major component of the solid waste generated by installations that can be reduced, repurposed, or transformed. Both on-post and off-post diversion alternatives are discussed, and case studies from U.S. military installations are provided as examples. Wherever possible, examples of documentation language (e.g., contract statements, Memorandum of Agreements (MOAs)/Memorandum of Understandings [MOUs]) are provided for contractor support of diversion activities. The report identifies mature and available small-scale organic waste management technologies, and the associated benefits, concerns, and conditions for their successful use on an installation are examined. An excel-based decision tree accompanies the report to provide guidance for selecting technologies or practices that suit an installation's specific capacities and preferences. The analysis provided is applicable to any Army installation or other sizable organization in the early stages of considering how to divert organic waste from a landfill.

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Source reduction (Waste Management)	Organic wastes	Military bases
Net Zero	Food waste	Composting

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