

Massachusetts Clean Energy Center's Commonwealth Organics-to-Energy Program

Feasibility Study Report 2012-COTE-03

Feasibility Study of Biothermal Energy Recovery from
Composting of Food Waste, Manure and Landscape Debris
at Franklin Park Zoo, Boston, MA

Submitted by Commonwealth Zoological Corporation
in partnership with City Soil & Greenhouse, LLC

October 30, 2014



BIOENERGY FARM: ZOO NEW ENGLAND/ FRANKLIN PARK

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SCALE 1"=80'

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Executive Summary

The Commonwealth Zoological Corporation in partnership with City Soil & Greenhouse LLC assessed the feasibility of constructing a facility at the Franklin Park Zoo (the Zoo) for extracting energy from the aerobic digestion (composting) of manure, animal bedding and landscape organics from the Zoo and source-separated food and yard wastes generated in close proximity to the Zoo in Boston's Dorchester neighborhood.

Compost can generate between 1 and 2 MM BTU per ton as it decomposes. Compost heat recovery systems have been utilized for centuries to extend the growing season, using various means of enclosing and capturing the biothermal energy while conserving the nutrient value of manure and other organic materials as they compost. Over the past thirty years, systems of varying degrees of complexity, success and cost have been developed for application in experimental and conventional greenhouse structures and in other agricultural heating applications.

The project as presently designed is technically feasible. The material handling methods, equipment, site infrastructure and other components recommended fit the needs of the location, operating team and regulatory requirements. The approach described within this report was chosen after reviewing the range of practices, equipment and infrastructure on relevant institutional, commercial, municipal and agricultural composting sites.

For the Massachusetts Clean Energy Center (MCEC)-funded feasibility study at ZNE, two biothermal energy recovery systems have been identified to use in concert with a composting system for food waste from commercial and institutional generators, and manure and landscape organics from ZNE. A number of composting technologies and system configurations were evaluated for their suitability for this particular installation.

City Soil & Greenhouse determined that the best composting technology for the proposed site employs a two-phase highly aerobic digestion (composting) process. The first phase consists of rapid digestion (a three- to five-day cycle) in an aerated rotating drum to achieve high-energy yield rates, rapid material throughput, and volumetric reduction of the feedstock. This first phase will also assure reliable destruction of animal pathogens and potential human pathogens contained in the feedstock materials. Homogeneous mixing in the rotating drum provides a consistent and high temperature profile throughout the mix, resulting in reliable destruction of plant pathogens and weed seeds. Heat is evolved rapidly during this phase, driving off or consuming most of the odor-causing volatiles, which are removed under controlled conditions.

Hot, saturated and enriched compost exhaust can be directly used in heating greenhouse soil beds that double as biofilters. City Soil's Compost-Greenhouse system uses a biofilter to extract volatile and odorous compounds, supply heat to plants, and evenly distribute CO₂ into the growing space to boost crop production. The design developed for ZNE includes the use of Agrilab Technology's Isobar™ system that extracts heat from moisture-laden compost exhaust and transfers it to liquid that can be used in hydronic heating systems. The Agrilab system permits biothermal energy to be pumped through insulated pipes to heat buildings more than 300 feet from the source. Heat is efficiently recovered from the compost process exhaust in a two-stage system. In the first stage, saturated hot exhaust collected from the in-vessel composting system is directed through two-stage heat transfer technology. The processed air that is exhausted from the Isobar™ is fed into City Soil's Compost-Greenhouse system where a biofilter extracts volatiles, holds heat, and evenly distributes CO₂ into the growing space.

The second phase of this aerobic digestion process receives the partially composted materials from the first phase (rotating drum). The material is placed in enclosed, aerated 'static piles,' where air is drawn through the pile from the bottom. Biothermal heat is recovered, exhaust air is scrubbed of odors, and CO₂ is recaptured in a greenhouse-enclosed biofilter adjacent to the composting system. The cycle time of this second phase is 20-30 days, during which energy is extracted at a lower rate per ton, but from much greater mass over a longer period of time.

An optional third phase continues to utilize the heat and CO₂ that are released as materials passively 'cure' over a 90 to 120 day timeframe. This last composting stage further reduces the volume and moisture content of the material, concentrates the nutrients, and lowers the cost of screening the material. It is then ready for use at the Zoo, or for export in bulk and bagged forms. Worms can also be added in this phase to accelerate the composting process and improve the quality and value of the end product. This phase can be housed in an inexpensive 'high tunnel' greenhouse covering adjacent to the primary composting building.

Greenhouse Gas emissions are mitigated by using compost-generated heat as a replacement for natural gas as the heat source in existing and expanded greenhouse space, and for space heating and domestic hot water use in nearby buildings. Harmful emissions are also mitigated by through the energy-efficient conversion of organic materials into soil amendments. The alternative, namely transporting heavy organic material significant distances for processing, requires diesel fuel expenditure and intensive equipment usage. This system would serve local generators and haulers and have capacity to divert at least 3,600 tons per year of food waste from landfill or incineration.

Thermal energy is transferred to a 10,000 gallon insulated water tank via re-circulated loop. The system as designed is estimated to recover approximately 685,000 kWh per year from the bioconversion of 5,400 tons, (approximately 'wet' 15 tons per day), of organic feedstock processed per year. Energy generated by this system will be used at ZNE's Franklin Park Zoo for space-heating, domestic hot water, and material drying. The greenhouses heated and enriched by the compost will produce crops that can be used for consumption by the animals at the Zoo, for plantings in the Zoo landscape and exhibits and, sold to supplement the operation. Annually, the operation will produce between 2,000-2,500 cubic yards of high-quality compost and vermicompost for use on the Zoo grounds and sold to support the operation. This material will be suitable for application to soils used to grow food for human consumption, and can be marketed as such. The system would have an estimated capital cost of \$1.3 million. The facility would generate operating revenues and avoided costs of \$436,000 annually. After annual operating costs of \$296,000, the project would result in an operating gain of \$140,000, with a calculated internal rate of return of 17.1%.

The facility's financial viability would be based on a combination of revenues from sales of products and management services (tip fees) for organic materials processing, and avoided costs presently incurred by ZNE. Avoided costs to ZNE for energy, waste disposal, horticultural products, labor, and animal food coupled with revenues from tipping fees and product sales could make the operation self-sustaining, depending on the cost of capital. The operation would be more cost-effective if its throughput were doubled with the addition of a second rotary drum composter. Designing the facility to process 30 TPD would afford a significant economy of scale with only a moderate increase in the cost of equipment, labor and operations. It could fit on the footprint available for the project that has been identified as suitable for the 15 TPD facility in this study.

Background

City Soil & Greenhouse (CSG) has been providing custom soil, compost, and four-season 'grow-how' to urban land stewards for 25 years. CSG supplies Boston's community gardens and urban farms that produce crops on vacant lots, rooftops, and in local greenhouses. CSG operates compost sites for the City's Public Works Department at Mass Audubon's Boston Nature Center in Mattapan, and rents a parcel of state owned land from Zoo New England (ZNE) on the Zoo Overflow Parking lot across the street.

Over the past 35 years, Bruce Fulford of CSG has developed a series of projects that combine composting systems with biothermal energy recovery. In 1980 Fulford established the Biothermal Energy Center in Portland ME, and developed research-scale hydronic heat recovery systems with manures and crop residues. He designed and installed a solar greenhouse at a school in Rindge, New Hampshire that featured an integrated composting system for dairy manure and bedding, which supplemented the daytime solar heating system and added CO₂ to boost crop production. In 1982 Fulford completed a month-long applied study in Belgium of a method of biothermal energy recovery and anaerobic digestion systems developed by noted French compost innovator Jean Pain. From 1983-1987 he designed and led a team in the construction, monitoring, and evaluation of a compost-heating and CO₂ -recovery greenhouse system at the New Alchemy Institute in Falmouth, MA. This facility established the first research and publicly accessible demonstration of biothermal energy in the United States. It provided critical data and acted as a working demonstration of the value and principles of compost heat capture, biofiltration, and CO₂ harvesting. It utilized off-the-shelf components to monitor and control the collection of energy-rich exhaust gases for producing a wide range of food crops for staff consumption, commercial sales, and to germinate seedlings for the 4-acre market garden.

In 1999, City Soil & Greenhouse designed and constructed a similar compost-heated greenhouse at ReVision House Urban Farm in Dorchester, MA. On both of these pioneering biothermal systems, City Soil engineered, installed, or supervised installation of all system hardware and performed and/or supervised the management of the system and all data collection practices on the project. In both installations, organic waste feedstocks included food waste, crop residues, manure and bedding, aquaculture mortalities, and yard wastes. The technology for integrating composting with greenhouse heat production proved to be successful; heat was effectively transferred from compost to compost-enriched soil/biofilter beds, CO₂ levels were elevated and documented, and a variety of crops thrived. Additional research was funded through a USDA-SARE grant to evaluate the implementation of composting-greenhouse technology on farms in Massachusetts and Vermont. Data collection was moderate, but again demonstrated that biological thermal energy and optimal CO₂ concentrations could be achieved with compost systems integrated with greenhouse production.

The USDA-SARE study highlighted the fact that 'real-world' application of the technology must be employed at the appropriate scale and be readily integrated with common farm equipment and practices, or be significantly better than standard operating procedures to warrant the capital investment. The adoption of new technologies and practices for energy production, agriculture, and organic waste management will only be broadly adopted when such technologies can prove to be cost effective, reliable, and require little additional labor. This applies to farms, or at municipal, commercial, and institutional composting operations such as ZNE.

The USDA-SARE research focused on aerated static pile composting (ASP) systems integrated with greenhouses, which were installed on three farm sites. City Soil also provided USDA-funded technical

assistance to Diamond Hill Farm's compost heating project in Sheldon VT, a project launched by Brian Jerose, the CEO of WasteNot Resources and Agrilab Technologies. The team developed and deployed an innovative application of ASP composting coupled with a liquid-to-gas-phase heat exchanger and a closed loop hydronic system to capture and utilize heat from the compost exhaust vapor.

The Agrilab Isobar° technology is in part based on fundamental research and publications by Fulford, BioThermal Associates, and New Alchemy Institute in Falmouth MA between 1981- 1987, from Jean Pain's work, and other scientific literature. The patent developed by Joseph Ouellette includes the innovative use of Isobar° heat exchangers to optimize renewable thermal energy capture from composting systems. The Agrilab Isobar° system extracts heat and removes water vapor from the compost exhaust stream; the heat in hydronic form can be used for space heating, or to heat liquids - such as an insulated bulk tank to store hot water or to pre-heat milk for pasteurization or replacement formula on a dairy farm.

Most malodorous gases are not removed with the Isobar° system, and exhaust vented from the heat exchanger module requires further treatment through filtration or dilution if it contains concentrations of odorous off-gases from the composting process.

1. Feedstock Quantification and Characterization

Zoo New England on-site organic residuals

Off-site local food waste generators

The Commonwealth's Solid Waste Master Plan developed by the Massachusetts DEP¹ set a goal of building capacity for an estimated 350,000 tons annually by 2020. In 2012, MDEP created RecyclingWorks,² with the Center for EcoTechnology to facilitate diversion, separation, and collection of food waste for transport to composting and AD facilities and other reuse. There are now more than 1,400 businesses and institutions in the Commonwealth that have reported that they are using some collection service for source-separated organics (SSO)'s. The ZNE site can become an integral part of an emerging system, thanks to its strategic location close to major points and clusters of food waste generation.

The greater Boston area generates the highest concentration of post-consumer food scraps in New England, and also hosts numerous institutions and commercial food processors, supermarkets, and import/transportation facilities that generate pre-consumer food residuals. Local and regional haulers are already collecting a significant percentage of readily separated food waste, and generators seeking local recycling opportunities are demanding urban processing destinations.

MassDEP compiled a list of Massachusetts food waste generators, most recently updated in 2011. Based on this data, the generators affected by the Food Waste Ban in Greater Boston area (within range of the ZNE facility, roughly from Quincy to Malden, from Boston to Newton), generate over 50,117 tons of food scraps per year (TPY).³ City Soil has been in contact with private commercial haulers that, in total, presently collect more than 50 TPD within a 5-mile radius of the proposed ZNE site, that have expressed strong interest in bringing SSO's to a well-managed composting site. There are many hauling companies with the ability to haul organics, including Mass Hauling, E.O.M.S., Casella, Waste Management, Save That Stuff, Capitol, Republic, E.L. Harvey, Renewable Waste Solutions, and CERO. Between these companies, and foreseeably others as the market expands, much of this SSO waste will be collected and transported to composting sites and/or anaerobic digesters that are being developed.

Rather than collection, however, the issue is processing capacity close to the point of generation. There are ten composting facilities between 15 and 45 miles from downtown Boston, with a combined processing capacity of 49,275 tons per year.⁴ Since these facilities are processing materials from nearby communities, there will be a need for additional processing capacity closer to Boston. The urban ZNE site would provide a convenient and cost-saving (fuel, labor, maintenance) location for haulers to drop their loads close to the point of generation.

¹ Massachusetts Department of Environmental Protection Organics Subcommittee Meeting, 1 Winter St. , Boston MA Feb 24, 2014

² Personal communication, Lorenzo Macaluso, Center for Ecotechnology
Food Waste Generators: <http://www.mass.gov/eea/docs/dep/recycle/priorities/foodgen.pdf>

³ Cambridge Organics Report:
<http://www.cambridgema.gov/theworks/ourservices/recyclingandtrash/faqrecyclingandrubbish/compostingquestions/compostpilot/feasibilitystudy.asp>

⁴ Composting Facilities: <http://www.mass.gov/eea/docs/dep/recycle/reduce/06-thru-l/fcdcmpst.pdf>

There are a number of institutions that could be directly served by the ZNE site. Within a three-mile radius of the site, major generators that will need to implement diversion to comply with the upcoming food waste ban include the Shattuck Hospital (102 TPY), the Hebrew Rehabilitation Center (348 TPY), Beth Israel Deaconess Medical Center (312 TPY), and the Connolly Center/DOC Pre-Pre-release Center (roughly 25 TPY combined). Across the river, Cambridge is about to begin its yearlong organics curbside pick-up program, projected to collect 104 TPY. Cambridge DPW included the ZNE site in its feasibility study as a viable place to bring their material. There are many colleges and universities that have expressed interest in coupling their diversion programs (generating a combined 8,374 TPY) with local processing for promotional and educational purposes.

Some haulers are contracting with pig farmers, some haul to peri-urban composting facilities; the closest are in Saugus at Rocky Hill Farm (utilizing a rotary drum system) and the Town of Needham, (using a loader-turned windrow system). A number of haulers presently take materials from Boston to Brick Ends Farm (windrow composting) in Ipswich, some haul to Marlboro and tip at the WeCare (rotary drum) facility. Additional separated collection is being or will be captured for diversion to composting facilities to comply with the food waste disposal ban that went into effect on Oct. 1, 2014.

CERO, (the Cooperative for Energy, Recycling and Organics), a community-owned hauling start up working to serve businesses in Dorchester, Roxbury and Mattapan, is relying on City Soil or another local site to bring their organics for processing. Bootstrap Compost collects residential scraps from over 630 area homes and nearly three-dozen businesses, including Trillium Brewery, the Nature Conservancy, and Taza Chocolate. CERO will be collecting from grocery stores and restaurants in Roxbury, Dorchester, and Mattapan. Renewable Waste Solutions works with a number of businesses across Boston, and provides hauling services for the Greenovate Boston compost pilot. The ZNE site could also serve as an accessible destination for food waste diverted from multiple upcoming city of Boston school cafeteria pilot composting programs.

Table 1: Feedstock Sources			
Feedstock	Sources	Quantity (Tons per year)	% Solids
Pre- and post-consumer food waste	<ul style="list-style-type: none"> • Shattuck Hospital, Forest Hills • Department of Youth Services, Connolly Ctr. • Department of Corrections Pre-release Ctr., (Jamaica Plain) • UMass Biolab Cafeteria, Mattapan • Haley House restaurant & Bakery, Roxbury • City Fresh Food restaurant, Roxbury • Whole Foods Grocery, Jamaica Plain • Whole Foods Grocery, Dedham • Bootstrap Compost - Boston • CERO – America’s Food Basket • Brookline Public Schools • Boston Public Schools 	≥ 5000	40%
Postconsumer food waste (from animals and visitors)	On-site	50	50%
Vegetative crop residue	On-site	50	50%
Leaves, Deciduous	On-site	40	75%
Herbivore manure and bedding	On-site: collected loose in bins, segregated from carnivore manure and quarantined manure.	260	70%
Combined Feedstock	Combined	≥5400	45% Weighted Average

For a tangible example, Haley House, a bakery and restaurant in Boston’s Lower Roxbury neighborhood, generates about 500 pounds of food waste weekly, and has been separating and diverting SSO’s to several informal composting destinations for three years. Haley House is just one of hundreds of restaurants in Boston that generate materials that can be processed at the ZNE facility. Haley House and a rapidly growing number of restaurants and other modest volume generators welcome and would direct their food waste to a local, permitted, and professionally managed facility even though they will not be affected by the first level of the anticipated enforcement of the food waste ban.

Feedstock Type	Percent by weight (%)	Tons/Month	Yd³/Month	Density (Lbs/Yd³)
Food Waste Commingled with Cardboard and Paper	84%	355	700	1015
Manure and Bedding Mix	10%	42	115	750
Wood Chips	4%	15	45	675
Leaves / Yard Waste	2%	10	45	450
Total Mixed Feedstock	100%	422	905	940

Feedstock assessment

The materials to be composted at the ZNE BioEnergy Farm have been composted at the site previously by City Soil core staff. The materials streams have not changed significantly since 1998, with the exception that more SSO's are available locally that are not commingled with cardboard.

Food waste commingled with cardboard from the Haymarket was delivered to the site in compactor trucks by Boston Public Works, along with dining hall food scraps from Harvard University, and pre-consumer food waste from the Stop & Shop Distribution Center in Boston's Hyde Park-Readville location. These materials were routinely processed on the site along with animal bedding waste (ABW) from local biological laboratories, zoo manure and bedding, leaves and wood chips from Franklin Park, the Boston Housing Authority, and from commercial landscapers.

Bulk density

Manure and bedding delivered from the Zoo by its hauler to the rented compost site parcel had a bulk density of 600-800 pounds per cubic yard. The moisture content and weight of the material is largely a function of weather conditions and frequency between collections; at present the materials are stored in open dumpsters and subjected to rainfall.

Nutrient concentrations in feedstocks

Lab analyses of the blended manure and bedding were not performed at this time, as they would not be representative of the conditions and qualities that would be delivered to the composting facility. Additionally, under present storage conditions, as much as one week can elapse between collections. During this time a significant fraction of the ammonia-N can be lost through volatilization, and in extreme rainfall, loss of potassium and nitrogen can occur through leaching.

Seasonal fluctuations in volumes and organic waste stream

In the summer, manure volumes are reduced since the animals spend more time outdoors and less manure and bedding are collected. Seasonal spikes in volume of materials resulting from fall and springtime leaf collection, and following storm events, are common and must either be exported or managed on-site.

Representative samples of food waste from post-consumer collections by Bootstrap Compost show the materials to have an average bulk density of 1,100 pounds per cubic yard. Food scraps recently collected by another local hauler from the Lincoln School in Brookline weighed 780 lbs per cubic yard.

2. Assessment of Host Site

Site Survey – Existing Conditions



Figure 1: A landscape architect rendering of the Franklin Park area with proposed composting building and greenhouse at center. The golf course is shown in the foreground. Trees shown in light green are in irreversible decline or dead, including most of those clustered around the proposed bioenergy farm location. This aerial view is towards the northwest. *Source: KZLA (Kyle Zick Landscape Architects)*

Topography and Surface Conditions

The proposed site (Option #1) for this project is a rectangular parcel of land bounded to the north by Glen Lane, a service road located on the Franklin Park Zoo property, and to the south by a wooded embankment and swale bordering Circuit Drive. The rectangular plot identified as the primary location suited to a 30 TPD or 15 TPD enclosed composting facility is 25,000 square feet in area; 100 feet deep by 250 feet wide. The land is sparsely wooded with mature oak trees that are healthy, dying and dead. Topographic relief does not exceed 6 feet on the proposed site and most of the surface is level or gently sloped.

Large volumes of blast-rock puddingstone excavated from previous site construction have been applied to most of the area, graded, and compacted to form a hard, stable surface. Extensive site work and grading should not be required. The site is located in a service area for the zoo and is not open to the general public. It is accessed from Glen Lane via a service entrance. The road is accessible from both ends of the Zoo, but due to security issues the west end gate is seldom used. A motorized gate provides access to Glen Lane at the east end of the site behind the CRC (Community Resource Center) and associated cluster of office buildings. This entrance would be used for routine deliveries of compostable materials (truckloads of food waste, leaves, woodchips) from off-site sources.



Figure 2: Aerial photo indicating approximate footprint of available sites

The site access is adequate for service by delivery vehicles and trucks for materials, or for emergency services. The traffic associated with this scale compost site operation would not impact the public or change the typical service use of this drive by employees and contractors. Glen Lane is approximately 32' wide at most points, and it is 40' wide at the point across from the entrance to the proposed 25,000 SF site. At its widest point, Glen Lane is 58' wide, 8' east of the existing 27' x 84' greenhouse. Glen Lane's southern boundary is a dry-stacked stone retaining wall of Roxbury puddingstone that varies from 3.5' to 5' in height, running almost ½ mile along the length of the Zoo's property; the wall serves as a loading dock for three dumpsters positioned along its length. There are three separate, dedicated 30 cubic yard dumpsters for: 1) manure and bedding; 2) leaves and other horticultural debris; and 3) bagged trash and manure from carnivorous animals. Glen Lane is also used for storage of materials, equipment, and parking for Zoo staff cars, trucks, trailers, and several senescent vehicles. There are a series of landscape material bays on Glen Lane's southern side, demarcated by concrete 'washout blocks' that hold gravel, sand, stone, compost, mulch, and road salt in separate sections. The top of the wall is at grade with a 100' to 180' wide strip of land between Glen Lane and the southern fenced boundary of the ZNE property, which is primarily forested with mature oak trees.



Figure 3: Topographic Plan View of Site showing footprint of 30 CY Facility Option

Utility Locations and Capacities

City Soil's Bruce Fulford and David Fulford met on site on February 23, 2013 with Zoo New England Facilities Manager Steve Mathes. Mr. Mathes identified all utilities and access points for electrical power, water, gas, and sewer lines. An additional site visit in May 2014 with Agrilab's Brian Jerose confirmed the suitability of the utility interconnections for Agrilab IsoBar[®] recovery and hydronic heat circulating system.

- **Natural gas:**

Natural gas service of adequate capacity is routed along the south side of Glen Lane, adjacent to the proposed site. A 3" line T's off the main. An alternative would be to install a natural gas fired generator of sufficient size to supply emergency backup for the blowers, the compost drum, and greenhouse fans and blowers.

- **Electricity:**

Single phase 240 Volt electrical service supplies a greenhouse on Glen Lane across from the proposed site. There is a 100-Ampere breaker panel in the head house. There is sufficient electrical supply to power the 5 horsepower motor that drives the rotary drum, as well as fans, blowers, lighting, and pumps that are used in the Bioenergy Farm complex. If it is insufficient, additional electrical line will

need to be brought in from other side of the Zoo or from Circuit Drive. Three-phase electrical service is available at the RainForest Exhibit and is junctioned on Seaver Street.

- **Water:**

A hydrant that T's off of a 1" water line of potable water is installed 8' east of the northeast corner of the 27' x 84' Nexus greenhouse. The 1" water line is presently tapped to run a hose to the two adjacent existing greenhouses on Glen Lane.

- **Fire suppression:**

Fire Hydrants are located at the head of Glen Lane (off of Circuit Drive, behind the CRC/Zoo Main office building) and at the Service Yard.

- **Sewer connection:**

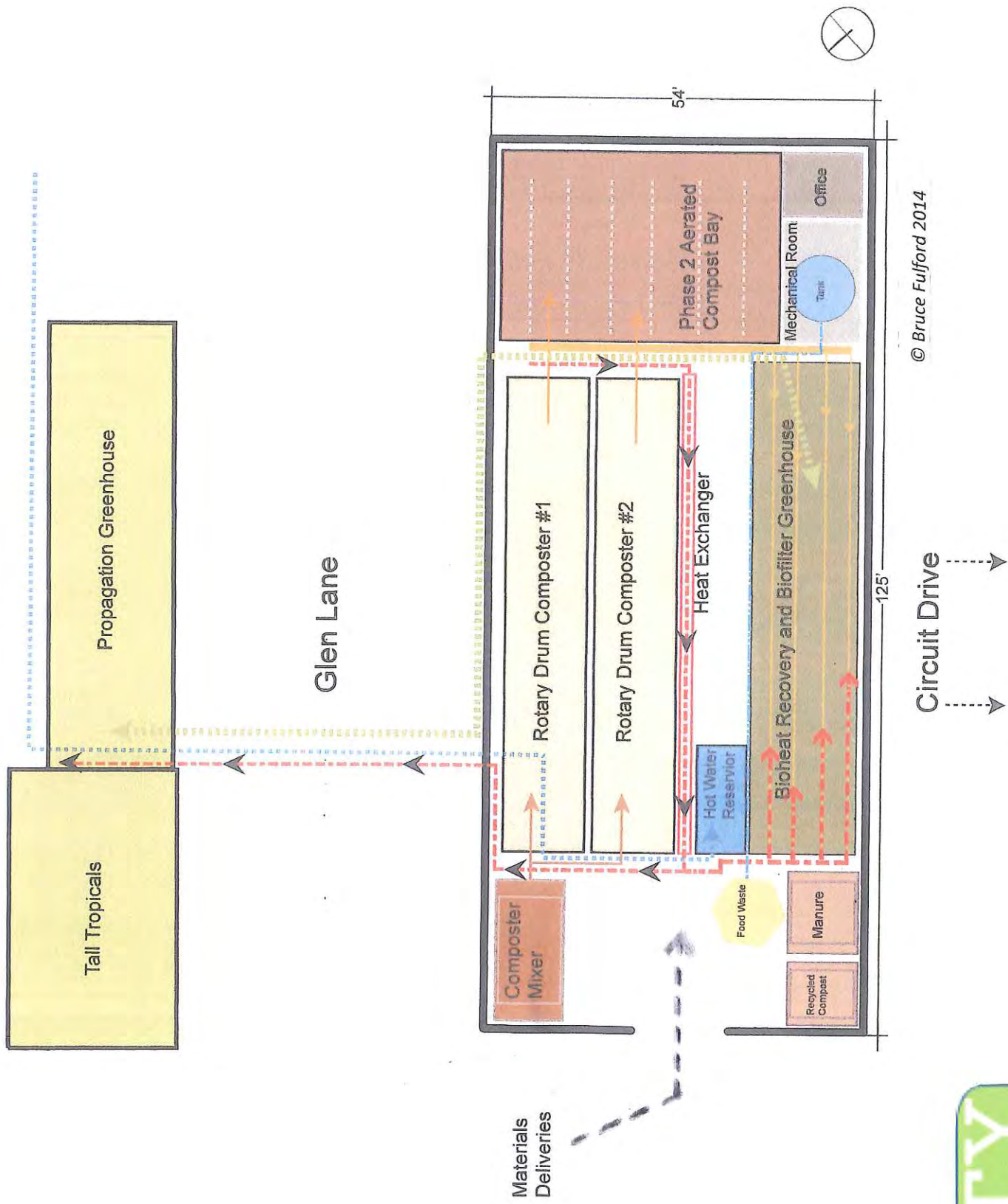
The closest connection to Boston Water & Sewer service is at the existing Public Restroom building, noted on the site plan.

- **Storm Drains**

There are two storm drains that serve the site and drainage of Glen Lane; they are both located along the base of the dry stack stone retaining wall along the southern side of Glen Lane, and feed into two separate 21" OD drain pipes that pitch to the south and cross underneath Circuit Drive. They connect to a larger 28" line underneath the golf course that drains to Scarborough Pond. Storm Drain #1 is at elevation 132.1 across from the access road that leads upslope to the restrooms, the gift shop, and the Kangaroo/emu barn. Storm Drain # 2 is located at elevation 130.4, which is 40' to the west of the access road leading north to Birds World. The manure collection dumpster is presently located almost on top of the drain grate.

Current Use of Available Space

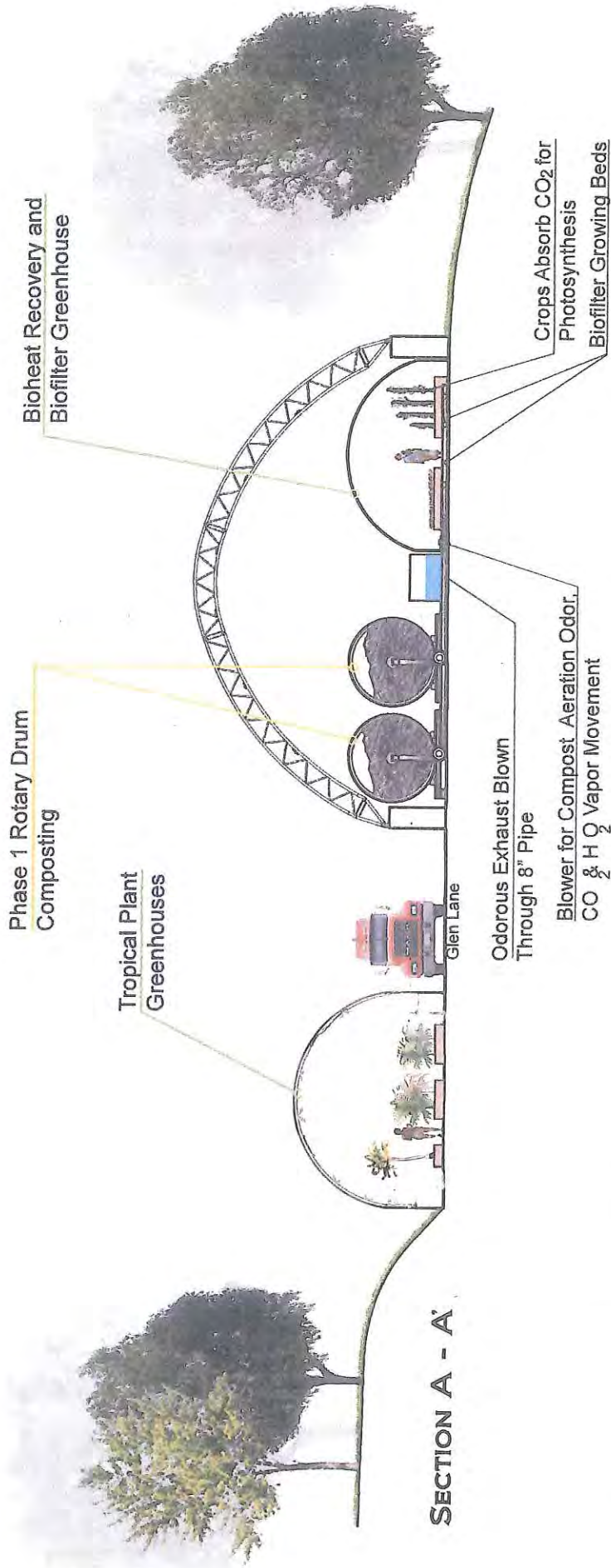
The proposed project site is currently used for equipment storage and as a staging area for landscaping and maintenance materials, supplies, and for storage of equipment and out-of-circulation vehicles. These items occupy approximately 30 percent of the usable area, but could be re-organized to make more efficient use of the available space without sacrificing access or functionality. The site has two distinct areas that merit consideration as sites for composting operations with heat recovery and interlinked greenhouse production. These areas straddle Glen Lane; a bituminous paved service road that connects the east and west ends of the Zoo. The Bioenergy Farm would eliminate two roll-off dumpsters that are presently stored on Glen Lane, and establish space-efficient and organized portion of the area to store useful equipment and materials.



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Figure 4: Composting and thermal energy capture activities are enclosed within a 125' x 54' structure. This site plan illustrates the location of equipment and uses of space within the proposed structure, with arrows indicating the flow of feedstock and compost through the facility.





LEGEND



Energy Use

Compost Processing/
Heat Production



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Figure 5: Section view of 30 ton per day twin-drum composting operation connected to greenhouses on Glen Lane

Figure 6: Plan view rendering of ZNE Greenhouse, Glen Lane and Composting Barn



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SCALE 1"=80'

3. Compatibility with Zoo Operations and Adjacent Community

a) Community Engagement Plan for the Integrated Composting and Bioenergy Facility at Franklin Park Zoo

Developing community support for a facility that manages putrescible materials is a prerequisite to siting and is paramount importance in sustaining the long-term operation and its potential for future expansion. Broad based support secured in advance of facility construction and startup is the most critical of success factors. The legacy of mismanagement of two local composting facilities has affected the immediate community around the compost sites -most notably their accompanying odor problems. Low quality compost and mulch products have been distributed more broadly through the gardening community and to local landscapers and in uses on civic projects, such as tree mulch along American Legion Highway. These issues have required remediation as a first measure in developing receptivity - and establishing credibility required to add medium to large scale composting of food waste in this community.

City Soil has operated the City of Boston's yard waste composting site on American Legion Highway in Mattapan since December 2012, and is contracted to manage the site through June 2019. City Soil has worked for more than 20 years in the community where the proposed bioenergy farm would be located. Zoo New England has earned the loyal support and respect of the host community for its extensive outreach, education, service and employment opportunities that it provides to local residents. ZNE and City Soil have forged strong relationships with community leadership, non-profit organizations, philanthropic donors, business leaders, and elected representatives.

Community meetings, public tours of City Soil compost facilities

As a primary means of building trust and engaging with the host City Soil has conducted a series of meetings and site tours of the adjacent composting facilities that it manages on the City of Boston composting site and on the Zoo's Overflow Parking Lot. These tours have provided more than 150 people who are part of the immediate and expanded community opportunity to inspect, ask questions, and get a first-hand understanding of the composting process.

A public tour of City Soil's compost operations at the City Of Boston's Yard waste Composting Site was attended by 27 registrants on April 21 2014; the tour was organized by the Boston Natural Areas Network, as part of their increasing focus on composting and partnering with City Soil to improve quality and access to compost for the urban garden community. City Soil president Bruce Fulford hosted a two-hour workshop question/answer format and discussion that included planned expansion into food waste composting, vermicomposting, heat recovery and integrated greenhouse facilities.

City Soil staffers Everett Hoffman and Chesapeake First taught a weekend workshop at Zoo New England on April 12, 2014. The workshop was attended by 17 middle school students who learned fundamental principles of composting, and the role of responsible organic waste management at ZNE and within the community.

City Soil toured the composting sites on May 3, 2014 with Urban Farm Institute's Executive Director Pat Spence, a lifelong local resident of Mattapan, and Mass Audubon Boston Nature Center Advisory Board Member. She has noted the high degree of odors associated with the poorly managed sites over the

past 7 years and is a strong supporter of improved management of the composting facilities in the community.

City Soil hosted a tour at the Boston Public Works compost site on September 24, 2014 that was attended by the USDA- Natural Resource Conservation Services Assistant State Conservationist, Terron Hillsman, NRCS Regional Conservationist Dan Lenthall, and Suffolk County Conservation District's Matthew Goode, Jamiese Martin and Betty Toney.

In the past 2 years City Soil has submitted proposals to MDAR, to DCR, and to the City of Boston for composting projects and integrated agricultural and environmental operations in this neighborhood. More than 15 letters of support were written and submitted by community members and local organizations for these proposals- all of the proposals addressed expanded composting capacity in this neighborhood. City Soil has convened multi-stakeholder projects and attended and addressed meetings that engage local community members and organizations. City Soil partners with the City of Boston's Greenovate Program to manage Boston's new food waste collection, education and outreach pilot program at farmers markets in Roslindale, Ashmont-Peabody, and Dudley Square.

<http://greenovateboston.org/news/compostbos-brings-exciting-changes-to-the-citys-waste-reduction-efforts>.

Other avenues of community outreach have been building broad-based support from local residents, influential political leadership and stakeholders in the urban agriculture, park stewardship, environmental justice and community. Many of the contacts and discussions have taken place in informal settings; this type of outreach is an effective means of building trust and support for siting and operating facilities that serve a broader community and clientele than the abutting neighborhood.

City Soil has frequent contact with leadership and membership of the Clark-Cooper Community Garden. City Soil has recently worked closely with ZNE ally Christine Poff, director of the Franklin Park Coalition, met with Emerald Necklace Conservancy the Ray Oladapo-Johnson and Ferris Donham of the Emerald Necklace Conservancy, and is involved in ongoing discussions with key department heads and senior staff. These include Brian Swett, Boston's Chief of Environment and Energy Services, and his top staff in Environment Department; Commissioner Nancy Girard, Director of Energy Policy and Programs Brad Swing and Director of Energy Finance Joe Larusso, Parks Department Commissioner Chris Cook, and Superintendent Bernie Lynch. City Soil also has met with Health and Human Services Chief Felix Arroyo Jr., Chief of Economic Development Planning John Barros, and BRA Senior Architect for Sustainable Planning John Dalzell, and Commissioner of Inspectional Services Bryan Glascock, and Boston Water and Sewer Commission Chief Engineer John Sullivan and Executive Director Charlie Jewell.

The departments within Inspectional Services, and the Boston Public Health Commission have jurisdiction over the construction permitting and operations of the facility – and Energy and Environment Department is actively seeking out and supporting ecological innovation, and houses the City's Greenovate program. City Soil also met with BRA's John Dalzell and with Edith Murnane, head of Boston's Office of Food Policy, to discuss development of the Bioenergy Farm and opportunities for siting, permitting, and financial assistance and partnership with the City of Boston.

One critical part of the study is a systematic effort to assess and develop community acceptance and support for the Facility. The neighbors of the Zoo have had a mixed history with facilities that have managed organic materials in the area. During 2012, two publicly-owned yard waste composting facilities located in the area were mismanaged by previous private operators, resulting in fugitive odors,

adverse impacts on surface water, and concerns with poor compost quality. Although the private operators of both sites were ultimately evicted from these sites, the community remains concerned as the result of adverse experience with these operations. Local concerns have been reinforced by negative publicity in the local and regional press, and by exchanges of information among local residents through direct and internet-based social networks. For a new composting facility to be successful, existing community concerns needed to be addressed and credibility established with local stakeholders as a pre-condition to implementation.

In this context, City Soil prepared a Community Engagement Plan to guide the process for addressing local concerns and developing community support for the Facility. The Plan involved the following steps:

1. Engage key community stake-holders and identify their concerns.
2. Develop responses to demonstrate how each concern will be addressed, and how the community will continue to be involved, throughout the development, construction and operation of the Facility.
3. Communicate the responses to the stake-holders and to the community at large.
4. Evaluate whether community concerns have been sufficiently addressed for the development process to be completed successfully.

Community Stakeholders and Concerns

The following groups of stakeholders were identified by researching the housing complexes and institutions that abut the project site at ZNE determining the governmental organizations that are involved with managing organic wastes and finding alternatives to landfilling these wastes, and contacting community organizations that promote environmental stewardship generally and the practice of composting and the use of compost specifically.

- Individual abutters/neighborhood organizations: Residential abutters live in the Olmsted Green and Hearth Elder Housing Complexes 1& II, and are represented by community group coordinators. The chief concerns of these residents are odor, noise, and appearance of the publically visible part of the compost sites, and access to and transportation of good quality compost to their garden sites.
- Community organizations: These include Boston Natural Areas Network (BNAN), Clark-Cooper Community Gardens, and Massachusetts Audubon Society - Boston Nature Center, the Urban Farm Institute, and ReVision Urban Farm which are generally favorably disposed toward the practice of composting. Their concerns revolve around ensuring that the site is properly managed for nuisance problems of odor and noise, and in developing a safe and reliable source of high-quality, locally-produced compost and other soil amendments.
- Governmental organizations: These include the Boston Parks & Recreation Dept., Boston City Councilors and Mass. State Representatives and Senators, Boston Public Health Commission, and Boston Conservation Commission. The governmental department heads, their staff, and politicians generally want assurance that the site will be managed in a responsible manner and provide good quality compost and make it available to local residents and small businesses. They want to know

whether the project will generate jobs, and help achieve broad environmental goals set forth by their administrations and constituents.

- Institutional abutters -- Institutional abutters include William J. Devine Golf Course (aka Franklin Park Golf Course) is managed by the Boston Parks Department and their contractors. This is the most critical of the properties that are adjacent to the Zoo because of the heavy use by a wide range of visitors. The Golf Course clubhouse is used for private meetings and special events, and is less than 1500 feet from the composting site. The greens and well-used jogging trail are within 200' feet at the closest point. Public parking for the Zoo is less than 700 feet from the proposed composting site.

Responses to concerns

To be responsive to stakeholder concerns, City Soil will take the actions outlined below:

Proactive management of nuisance conditions:

- Odor, vermin flies, and leachate are nuisance conditions and environmental impacts that must be prevented and their potential sources managed as part of the design and the operational plan. They have been clearly addressed in the community engagement phase of this project to date and will continue to be in future venues for public discussion. Concerns about odors are the community impact that most frequently delays or prevents siting of new facilities and results in the closure or limited capacity at composting operations. Odor mitigation measures will be incorporated into the facility design at every point where odors can be released. Operations will employ Standard Operating Procedures that would be developed to prevent the release of odors beyond the footprint of the site that can emanate from multiple sources, including:
 - food waste collection vehicles
 - feedstock receiving building
 - pre-processing
 - blending
 - loading composting system
 - compost exhaust biofiltration
 - secondary composting (curing) area
- Loads of food waste will be emptied by haulers in an enclosed receiving and mixing bay that is connected to treatment systems for odorous air and liquids that can accompany food waste and manures when they are delivered. The air from the receiving bay is exhausted through a biofilter before venting. The impermeable interior of the bay can be pressure-washed down daily to a tight tank that captures liquid rinsate. The odor-producing particles and soluble food waste will be recycled and composted in the enclosed system.
- The choice of processing equipment and compost 'recipe formulation' will be tailored to ensure rapid and thorough destruction of putrescible materials.
- All exhaust gases will be captured and scrubbed with an oversized biofilter, contained in a greenhouse enclosure.

- A backup odor control system will be available on-demand to insure air quality outside the facility in the event that the primary biofilter, air handling system, or other odor control components need to be serviced.

Operational problems at composting facilities commonly arise at facilities that are poorly designed, ill-equipped, and understaffed or managed by inexperienced or poorly trained operators. Equally important, where operators have short-term site tenure and few ties to the community, there is little incentive for the operator to make substantial investment in a facility that is not quickly amortized.

- **Team Competence**

ZNE's proposed facility benefits from the precedent of developing one of the first successful composting of food waste and manure facilities in the Massachusetts, in 1994. The same operator (CSG's Bruce Fulford) with new partners and staff, invest in, develop and manage a new facility. City Soil's team are among the most experienced composting professionals in the country and have been called to troubleshoot problematic composting operations throughout New England. CSG has consulted with MDEP, MDAR, EOEEA, NYSERDA and EPA and the USDA on a wide range of composting and organics-to-energy projects. City Soil & Greenhouse has developed technology options, site plans, operating protocols, community engagement programs and operator trainings for numerous commercial, municipal institutional and agricultural composting sites.

City Soil's industrial process mechanical and electrical specialist David Fulford has worked for more than 30 years in Johnson & Johnson's NORAMCO pharmaceutical facilities. He has been responsible for more than 70 projects that include production process redesign, managing construction, worker health and safety, mitigating community air quality impacts, and compliance with local, state and federal environmental regulations and reporting requirements.

Brian Jerosse has been a professional composter for more than 20 years and has extensive experience in biothermal recovery systems and in composting manures and other feedstocks used for bioenergy production. He has hands-on experience working with most of the feedstock materials that would be composted in this setting and is actively working on several systems where greenhouse integrations are being proposed. Agrilab is in discussions with the Cincinnati Zoo regarding a project at their facility.

Zoo New England Project Development Process

ZNE's resourceful staff has developed extremely popular world-class educational exhibits to their Dorchester neighborhood that have been designed, implemented and operated on lean budgets. ZNE uses a team approach in evaluating, planning, fundraising and implementing new projects. ZNE has methodically approached the opportunity to work with CSG in a new composting and bioenergy initiative, and vetted the concept internally and with key advisors and board members.

Contractual mechanisms

Operating and management contracts that incentivize sufficient commitment of capital and human resources toward facility design and management are critical to successful long-term operation. The contractual structure of ZNE's proposed facility would be a long-term partnership between the Zoo and City Soil & Greenhouse LLC, a private, locally owned and operated firm. The potential for revenue sharing from sales of products developed specifically from this project have been discussed and may afford a strong incentive to both parties to collaborate on marketing.

Appropriate scale

The proposed composting and bioenergy facility is scaled to manage a modest quantity of material—about one truckload daily of food scraps, plus the Zoo's landscape waste and manure and bedding. This relatively modest scale would deliver significant proof-of-concept value, with limited risk. If operational, financial, or design shortcomings are experienced on a 15 to 30 ton per day facility, the negative impacts can be much more swiftly and economically remedied than at 150 tons per day.

Commitment to process locally-sourced feedstocks to reduce greenhouse gas emissions: City Soil is developing relationships with local organics generators including Boston Parks and Recreation Dept. (BPRD) to compost their manure and leaves into compost and mulch products that can be used on high visibility landscape plantings such as Columbia Rd. in Dorchester, and in erosion and stormwater management projects including the Daisy Field on the Arborway in Jamaica Plain.

Boston-based specialized collection companies, including Save that Stuff, Bootstrap Compost, and CERO, seek a local destination to responsibly manage their compostable food scraps and supermarket organics. These companies engage with community residents, institutions and small businesses that engage their services because they are locally based and share commitment to community and the environment. Other local, regional and national private hauling companies provide source separated collection services and are interested in local processing options.

Nearby institutional generators of food waste in the local community could have their food scraps composted and converted to bioenergy in the proposed facility. These include the Shattuck Hospital, the Dimock Community Health Center, The Hebrew Rehabilitation Center, the VA Hospitals in Jamaica Plain and West Roxbury, Roxbury Community College, the DYS Connolly Center, and the DOC Pre-Release Center are some of the dozens of institutions based in the local community

Credibility - Responsibility to stakeholders

City Soil has a track record of managing composting and related projects within a 2-mile radius of the Zoo that demonstrate its commitment to being a responsible operator. Boston Public Works yard waste composting site: In November 2012, City Soil was awarded a Boston Public Works contract for operational responsibilities at Boston's only large-scale composting site, which is located on the grounds of Mass. Audubon Society's Boston Nature Center, ½ mile from the Zoo. The compost produced from the City's yard waste is delivered to community gardens including the Clark-Cooper Community Gardens, which gardens on more than 4 acres of land within the Mass. Audubon/BNC landholding. Zoo composting operation: From 1994 to 1997, City Soil president Bruce Fulford – then CEO of Greenleaf Composting - developed and managed a 2-acre composting operation at the Zoo for landscape debris, animal bedding and manure, post-consumer food waste from Harvard University and pre-consumer food waste from Stop & Shop and from Boston's Haymarket.

Transparency – Responsibility to the Zoo, local permitting authorities (ISD, BRA), Massachusetts DEP, Composting Stakeholders

The project is by design a very public process intended to set a standard and template for community engagement in siting bioenergy facilities for organics. This feasibility study is an important step in a multi-year process that has engaged state, local, and federal regulatory community and agencies charged with the responsibility of safeguarding air, water, and community quality of life, solid waste recycling, and developing renewable energy resources. Massachusetts DEP's recently promulgated streamlined solid waste regulations, the Solid Waste Master Plan, and Green Communities Act and the

Mayor's Climate Change and Urban Agriculture initiatives need working examples of well-run organics facilities.

ZNE and CSG have close working relationships with their respective nationally-based professional organizations (Association of Zoos and Aquariums, and the US Compost Council) that advocate and support the successful implementation of ground-breaking environmental projects with strong benefit to and involvement in the local community.

General benefits of the Project – demonstration value, resource management value, economic support for the Zoo, jobs, neighborhood benefits:

Demonstration value of retail & educational site: In May 2013, City Soil opened a public retail and customer education site on the parking lot leased from the Zoo to sell compost, soil amendments, and sustainable landscape products and to provide short-term composting of yard and food wastes. The site has helped to establish a clientele and revenue stream for the products that would be produced from ZNE organics at a future 10 to 30 ton per day facility along the lines of the proposed project. This site has also provided locally-based landscapers with disposal capacity for leaves, brush, grass clippings, wood chips and other landscape organics.

Forging multi-dimensional partnerships with near-by Commonwealth of Massachusetts institutions: City Soil will also actively develop working relationships with DOC and the Dept. of Youth Services as their nearby facilities are 2/3 mile from the proposed ZNE site and are large generators of a steady supply of food waste that could be source-separated and composted along with the animal manure and bedding. City Soil has met with top officials of the Mass. Dept. of Corrections (Former Commissioner Luis Sullivan, Deputy Commissioner Paul DiPaolo, Regional Director Tom Dickhaut, and Boston Pre-Release Superintendent Tanja Gray) regarding integrating members of the community presently incarcerated at the Boston Pre-Release Center into productive work with composting and an integrated heat recovery greenhouse project. City Soil has also discussed this initiative with Governor Michael Dukakis, Ferris Donham and Peter Barber - members of the Emerald Necklace Conservancy board. Ms. Donham has run the horticulture program at the Boston Pre-Release Center for 10 years.

Benefits to Zoo New England: The project has the potential to benefit a favorite community institution with lowered energy and disposal costs and revenue-sharing with City Soil from sales of compost, mulches, and related products. This project also will help the Zoo implement best management practices and programming consistent with its local, regional and global environmental education mission.

Communicate the responses in meetings with stakeholders

City Soil's approach to community engagement is to inform stakeholders in host communities in order to build support and trust. City Soil and ZNE identified primary contacts in the host neighborhoods and the greater Boston community and contacted them prior to and during the MCEC feasibility study. City Soil conducted over fifty meetings with stakeholders in the process of building support in this neighborhood for an expanded composting program that includes food waste.

These contacts are listed in the report Appendices.

Stakeholders

The coordination of stakeholders and jurisdictions would be managed with assistance from the Boston Architectural College, the Metropolitan Area Planning Council and/or other qualified project manager.

Sales and Marketing

The current and intended point of sale and distribution for these products is a portion of the Zoo Overflow Parking Lot that has been rented by City Soil. Starting in In May 2013 CSG began to develop a market outlet for the compost that would increasingly be generated by a City Soil/Zoo New England based composting operation. This site has market advantages of high visibility, excellent access from Morton Street and American Legion Highway, off-street paved parking, and close proximity to diverse and vibrant market sectors of home gardeners, commercial growers, community gardeners, and landscapers. Retail markets for City Soil & Greenhouse and Zoo New England based products have been established in this critical startup season; compost, soil blends, and mulches made from urban landscape organics and Zoo manure have been used in the 2014 growing season in high-profile projects throughout Boston and its suburbs by clients including Boston Natural Areas Network, Green City Growers, the Fenway Garden Society, The Trust for Public Lands, Mass Audubon, City Growers, and the Urban Farm Institute. If City Soil's lease on the Zoo Overflow Parking Lot is not extended beyond Dec. 31, 2014, City Soil has relationships with several of the nurseries along the American Legion Highway corridor and would enter into a retail arrangement with one of them.

Product profile

The products that are being manufactured from Boston's urban forest this season include screened leaf compost, high-grade screened leaf mulch, and custom blended soils and growing media for rooftop and raised bed gardens. These products are being sold and distributed to high-profile customers including The Food Project, Mass Audubon's Boston Nature Center, Green City Growers, City Growers, Boston Natural Areas Network, the Urban Farm Institute, and to landscapers and gardeners in and around Boston. Sales this season to date have distributed City Soil's product line to projects in all of Boston's neighborhoods and to Somerville, Quincy, Newton, Brookline, Barnstable, Wellesley, and Waltham.

New products marketed this year have included a vermi-compost and activated biochar/compost blend; City Soil's first client for this mix was the Food Project's greenhouse operation at the Dudley Street Neighborhood Initiative in Roxbury. The product is being used in production of greenhouse tomatoes.

Permitting

On-site composting of the materials generated by the Zoo, as is already being practiced under the stewardship of ZNE's director of horticulture Harry Liggett, fall within the regulatory exemption accorded Zoo's under DEP's new permitting process for organic waste diversion and composting.

A permit to compost post-consumer food waste or other source separated organics that are imported to the site from other sources will need to be secured through a self-certification process under the Mass DEP General Permit process.

The Zoo already has been composting leaves in a low technology approach, and food waste and manures on a small poured concrete composting pad on part of the proposed composting site that would be contained within the Zoo grounds.

Food waste composting: Pilot phase project to build community receptivity

The Zoo Overflow Parking Lot composting site has been permitted under the new Massachusetts General Permit category for composting facilities, and has been certified with the Massachusetts DEP and the City of Boston's Public Health Commission. This permits the use of the Zoo Overflow Parking Lot site for composting leaves and grass clippings, food waste and manures. Wood and brush may also be processed on the site with no additional permitting requirements.

(See permit in Appendix A)

This site has also been used by City Soil for demonstration purposes to showcase best management practices for handling food waste, and has accepted source-separated vegetative crop residue from South Boston's Higher Ground Farm, <http://higher-ground-farm.com> and post-consumer food waste from Bootstrap Compost. <http://bootstrapcompost.com>. These materials were blended with clean leaves collected from commercial landscapers, and have been composted with manure and bedding from Zoo New England on a trial basis. Finished product has been used in developing the Harold Street Farm, Boston's first urban farm constructed under the City of Boston's new Urban Agriculture Zoning Ordinance. Product was screened, sampled, and tested by an independent lab prior to approval by the Boston Public Health Commission for use in the project. City Soil is discussing the processing of cocoa bean hulls from Tazo Chocolate and other source separated organics with Charlestown-based hauler Save That Stuff <http://www.savethatstuff.com>. CERO (Cooperative Energy Recycling & Organics) <http://www.cero.coop> commenced their food scrap collection service with America's Food Basket grocery stores in October, 2014 and plan to bring source-separated materials to the site for composting.

City Soil is using this space to build the commercial and community-based market for the compost it creates from source-separated organic residuals from ZNE and other local sources. CSG will soon include the ZNE manure on a regular basis in the mass balance of materials.

MDAR-funded Food Waste Demonstration Project at Zoo Overflow Parking Lot

The Suffolk County Conservation District and City Soil were awarded \$35,500 for a grant proposal submitted on January 3, 2014 to the Massachusetts Department of Agricultural Resources. Matching contributions of \$61,695 brought the total project value to \$97,165.

This project was to demonstrate best practices for making and using the compost made from the four major sources of clean organics in the Greater Boston area, as identified in this report. The system includes an integrated biofilter-greenhouse system, similar in design but smaller than proposed in this report as the Phase 2 and Phase 3 composting components of the ZNE facility. Construction of the project was slated to be complete by June 30, 2014.

City Soil had leased the westernmost portion of the Overflow Parking Lot from ZNE starting May 1, 2013 to implement demonstration and educational activities, and to sell compost, mulch, and other landscape products to support these programs. The startup of the project was delayed when City Soil's lease from ZNE for the most strategically desirable and functional portion of the Zoo Overflow Parking Lot was contested by neighboring business Landscape Express.

Discussions with the ZNE and the DCR were followed by a series of meetings that City Soil and ZNE had with DCR, MDAR, the Suffolk County Conservation District, and local community groups. City Soil garnered strong support for its composting infrastructure development from the immediate community - and from a broad based network of urban agriculture and composting advocates that extends beyond state lines. City Soil and key advisors, including MIT Professor of Urban Studies Mel King met with

Secretary of Energy and Environmental Affairs Secretary Rick Sullivan, and Deputy Secretary Maeve Vallely Bartlett and key staff on May 6, 2014.

Follow up with Rick Sullivan's replacement as newly-appointed Maeve Vallely Bartlett proved unsuccessful in coming to an agreement permitting City Soil to remain on the portion of the site that it first leased, and DCR nullified ZNE's contract with City Soil for the contested portion of the parking lot; in the interest of preserving the option to develop the MDAR supported project and move forward with community programming, marketing and product development and sales, City Soil removed its materials and equipment to an uncontested portion of the site.

City Soil and ZNE plan to extend the current lease Zoo Overflow Parking Lot; City Soil and the Suffolk County Conservation District were notified on Oct.2, 2014 that they have been awarded \$69,879 to design and build a demonstration compost-heated greenhouse, and the proposed location of the Zoo Overflow Parking Lot. City Soil applied for MDAR funds, again, with the Suffolk County Conservation District as the fiscal agent and partner on the project. This round of funding afforded more resources and time to implement the project. The implementation of the project on the site will provide an important local proof of concept at a modest scale that strengthens the case for investing more permanent and capital-intensive initiative proposed for the Zoo.

Boston is hosting the East Coast BioCycle Conference on Organics, Energy and Sustainability in October 2015. MDAR Commissioner Greg Watson has expressed to DCR his strong support for the City Soil – SCCD initiative to implement the demonstration project on the site. The MDAR and match-funded demonstration project will provide an invaluable demonstration of an integrated community-based composting and bioenergy facility that is convenient to Boston. It will be included on the programmed tours that are featured elements of BioCycle conferences.

This demonstration project is a key strategic step in establishing community support for a larger scale and more capital-intensive facility that could be developed at ZNE with a longer lead-time, or if more practical, at the Zoo Overflow Parking Lot. The MDAR project provides important linkage and adds tremendous value to a facility established on the ZNE 'main campus.' The Zoo Overflow Parking Lot site would afford more accessible operation and a ready commercial retail outlet for end products where most of Boston's centralized composting is already taking place.

The facility could be established on State-owned land that has been under the Zoo's care and custody for 20 years, and be located close to two state-owned buildings that use hot water year round. Both the DYS Connolly Center and the Department of Corrections Boston Pre-Release facilities are close enough to the composting facility to be supplied with hydronic heat captured with an Agrilab system.

(See site plan map, Appendix F)

4. Technology Review of Appropriate Systems

Aerobic Composting Systems

There are a number of distinct approaches to composting the source-separated organic (SSO) fraction of the municipal solid waste stream. Historically, windrow composting and static pile composting have been viewed as the simplest and least costly approaches to processing municipal organics. That perception still applies to centralized composting of leaf and yard waste. However, when considering the SSO fraction, neither of these is the best option for a number of reasons.

For facilities servicing urban and suburban collection routes, it is most cost-effective to locate processing operations as close to the feedstock source as possible. This requires that processing take place in and around urban settings where suitable sites are few and the cost of land is at a premium, limiting the available footprint of installations. Neighboring businesses and housing are in close proximity to potential operating sites; therefore, any composting process or design must be evaluated considering the following criteria:

- Minimize space requirement
- Minimize vehicular traffic impact
- Optimize throughput and process energy recovery to yield positive project economics and fulfill processing contract obligations
- Produce a consistently high quality compost product
- Maximize control of public health and nuisance factors – particularly odor, rodents, flies, and noise and operate in compliance with federal, state, and local regulations.

Containerized Module

Containerized composting modules may be thought of as static piles enclosed in sealed vessels. There are more than a dozen types of enclosed and in-vessel composting systems that can be used to: 1) completely contain the process of composting odorous materials; 2) prevent access to attractive materials by birds, rats, and flies, and 3) foster hygienic composting. Boxes, bins, bays, and barrel-type composting systems have been developed over the past 30 years that offer varying features suited to differing sites, operational requirements, and raw material inputs. Some are batch loaded, some are 'continuous feed' systems, and all are more expensive than open windrow systems. These recent developments are, however, increasingly being adopted where environmental control of the composting process is a necessary investment to ensure the effective management of the process in sensitive locations. Most are supported by some pre-processing equipment and equipped with odor controls if located near public settings or abutting property owners.

These systems can be fitted with aeration manifolds and/or hydronic loops (water pipes). The aeration manifolds consist of ductwork moving exhaust vapor and air to heat exchange units and biofiltration systems for odor control. The hydronic loop can be used to preheat the contents, extract process heat, or both, depending on user requirements. Containerized systems have the advantage of being highly portable, allowing flexible process scheduling. Most are designed to be compatible with RORO trucks so that hauling and dumping are simplified. They are expensive for their capacity and require more handling than most other systems but they are a good fit to operations that need a high degree of flexibility.

Aerated Static Pile

Static pile composting is achieved by blending an appropriate feedstock mix and piling it to a suitable height, in an appropriate location. Aerobic bacteria proceed to decompose the feedstock. The pile may be covered, enclosed, or placed in the open. Aeration is achieved by drawing air through the pile by means of a negative pressure plenum or manifold system located under the pile. The technology is well established and has good potential for energy recovery using simple hydronic loops. The capital costs associated with these systems are moderate compared to in-vessel agitated aerobic systems, but substantially higher than turned windrow composting. Hydronic loop systems require a large investment in enclosed space if they are to be operated in a setting where pest and odor management are crucial to a successful operation. Additionally, such systems must be carefully monitored and controlled during decomposition to avoid moisture and temperature extremes that can halt the oxidation process by causing the aerobic bacterial population to crash. Poor monitoring can thus result in process delays, odor problems, or even fires. Installing automated control and data-logging equipment best mitigates these factors, and also increases throughput, minimizes operational risk, and reduces labor costs. The tradeoff is that these systems are capital intensive and require operators with a more technical skill set.

Agitated Bay

Agitated bay composting systems consist of a linear bay or bays in which the feedstock is placed and periodically agitated mechanically to introduce oxygen, additional feedstock, or water as required by the process. The bays are constructed of parallel containment walls and are generally open at the top. The agitating equipment is mounted on a carriage that spans the width of the bay. The carriage may be rail mounted or use guide wheels to ensure proper alignment as it is driven or pulled down the length of the bay. There are many bay agitation systems commercially available today, some of which agitate using horizontal rotating drums, flails, or chains, while others rely on vertically oriented, carriage-mounted augers. In some systems, the composted material can be moved through the bay and out the back end during the process of agitation, and fresh stock can be added to the front end of the bay. This simplifies material handling. Agitated bay systems are most commonly utilized in composting operations designed for biosolids and poultry manure management, and less commonly in food waste composting facilities.

Agitated bay systems offer high throughput and good process control. However, equipment, capital, maintenance, and operating costs are high. Enclosed agitated bay process equipment and the accompanying containment structures are typically taller, require a larger footprint, and are more concrete-intensive than aerated static pile systems. They can be adapted for energy recovery, but the heat exchange systems must be carefully designed and maintained to avoid the risk of mechanical damage or reduced operating efficacy.



Figure 7: Rotating Drum (Ecodrum)



Figure 8: Rocky Hill's custom-made Rotary Drum

Rotary Drum

Rotating drum composters have been in use in Europe and Japan for 50 years and in the US for approximately 40 years. Composting drum installations in Massachusetts have been operating continuously for decades. They are used to compost a wide variety of organic materials including mixed solid waste, manures, biosolids (sewage sludge), farm animal mortalities, and food processing wastes. The track record of drum composters – the core technology – is extensive and considered by many authorities to be among the most reliable when completely contained rapid processing on a compact footprint is desired.



Figure 9: Twin Ecodrum



Figure 10: Ecodrum with air handling system

Rotating drum composting units consist of a cylindrical drum set horizontally on rollers and equipped with a drive mechanism that rotates the drum axially. The drum is usually fitted with internal baffles that move the stock to the discharge end as fresh feedstock is added at the charging end, and the drum is often mounted at a small angle relative to the horizontal plane to promote good agitation. This also allows any liquid to be collected and drained from one end to facilitate cleaning. Air is drawn through the drum to maintain aerobic digestion, remove moisture, and regulate process temperature. Rotating drum composters turn slowly to blend materials while exposing their contents to the environments maintained within. Rotating drum systems easily produce consistently high temperatures that assure the destruction of weed seeds, roots, rhizomes, and animal, human, and plant pathogens. These systems have few moving parts, are simple to operate, and when properly engineered, installed, and maintained, can provide decades of virtually trouble-free service.

The high temperatures and mechanical agitation inside the drum composter rapidly transform odor-producing organic compounds, known as putrescibles, which are contained in food waste and manures, into a material with little objectionable odor. When the materials are discharged from the drum composter after three to five days, they have been thermally sterilized by prolonged exposure to temperatures in excess of 55° C, in a regimen that is known as the Process to Further Reduce Pathogens (PFRP). The set of requirements for time and high temperature conditions to be maintained in drum composting systems were developed by the USDA during research in the 1960's and 1970's. This research assured end-users of the product that sewage sludge could be safely composted and land applied to cropland, and private and public landscapes such as golf courses, and has been used for more than 40 years to guide composters in the design and operation of safe composting facilities.

Advantages of drum systems include low cost of ownership, simple construction using impermanent infrastructure, lower liquid fuel consumption from windrow handling and turning equipment, and full enclosure for excellent control of vermin and vectors. Drawbacks include substantial costs for electrical power consumption and high capital cost. Due to their rapid process cycle and heat release, large, expensive heat exchangers are needed to effectively recover that energy. However, with such systems, nearly half of the recoverable energy in a given mass of feedstock can be harvested in just three to five days. They achieve volumetric reductions of more than 60 percent during that time, making them a logical choice for applications where secondary processing requires stockpiling product for an extended time.

Rotary drums have primarily been used for composting materials that are closely analogous to the feedstocks that would be processed at the ZNE facility; most have been used for composting food waste, manure, woodchips, municipal solid waste (MSW), and biosolids with bulking agents. There are at least six vendors that are actively marketing drum composters of varying sizes to US customers. Rotary drums are differentiated from one another by the materials used to construct the drum unit, the speed at which they are designed to rotate, the drive mechanisms, and the loading and discharge systems. Almost all drums are used in concert with a secondary composting process that deploys mechanical aeration via turning or blower-forced aeration, which is utilized after the feedstock is removed from the drum.

Rotary drum composters from four separate manufacturers are deployed in Massachusetts. One of Massachusetts' longest-running composting operations uses two 90' long x 12' diameter rotary drums to compost biosolids, MSW, and source-separated food waste. The Marlboro facility treats odors using an enclosed 30,000 square foot biofilter. The town and the facility operators (WeCare Organics) have developed successful community engagement protocols and practices during 20 years of operation as a public-private partnership.

Based on technical assistance provided by City Soil & Greenhouse, LLC and rotary drum specialist and associate Robert Spencer, Rocky Hill Farm in Saugus MA constructed its own 15 ton per day (TPD) rotary drum composter in 2010, and fabricated a second unit during 2012 and 2013. The drums are used for processing food waste brought to the site by commercial composters, which is blended as needed with bulking agents. The drums were selected as the most effective technology to contain odor and limit access by vectors, while requiring modest labor and processing food wastes in a setting that had experienced regulatory and community pressure. The Mass DEP and USEPA funded the initial technical assistance, and construction costs for the first drum were sourced from the Recycling Loan Fund.

Rotary drum composters are also in use at Mass Natural Fertilizer Co. in Westminister Massachusetts, (manufactured by BW Organics), and on Nantucket, where two drums were installed for composting the island's MSW stream. The Nantucket facility has experienced significant problems associated with their hardware, which have been attributed to design flaws in simple but critical wear parts that resulted in very costly repairs to the main drum.

Biothermal Energy Extraction Systems

Compost Pile to Hydronic Heat Recovery

In hydronic heat recovery systems, a liquid (usually water or water/glycol solution) is circulated through a heat exchanger that recovers process-generated heat directly from the pile. Utilizing the same heat

recovery mechanism as above, heated liquid is pumped to another heat exchanger that releases the heat at the point of use or in a thermally insulated hot water reservoir. These systems were advanced in the 1970's by French forester and agricultural technologist Jean Pain, and are most effective when deployed with wood chips and composting piles that can passively compost in place for months without turning. The heat exchange loop is often made up of lengths of plastic tubing laid inside, underneath, or on top of, or inside of the pile. There is better thermal transfer when the loop is laid under the pile, as temperatures are usually higher there, whereas placement on top results in a lower chance of damaging the tube during material handling. The drawbacks to this system are two-fold: The heat exchange loop is subject to damage; and it interferes with material handling activities and is therefore not suited for use with turning equipment. The advantage is that it is a low-cost way to harvest energy from static pile systems. More sophisticated systems have been built using Pex tubing. These systems are not well suited to the materials and throughput needs of the site at ZNE, but could be applied to wood chips harvested in the urban forest. For the purposes of this project, with the emphasis on food residuals processing and safe and effective manure management, this approach has been ruled out.

Direct Exhaust Air to Biofilter Greenhouse System

City Soil & Greenhouse's *Greenfilter*TM is a biofilter and biothermally-heated growing bed. It is designed for easy installation and periodic recycling on-site, or for export as enriched, composted mulch. This system scrubs odors from composting food waste contained in a rotating drum composter. An electrically powered variable speed blower draws water vapor, surplus heat, and CO₂ out of the sealed drum and forces it through biofilter growing beds contained in the greenhouse. Water vapor condenses in the growing beds, while odors are filtered by the moist soil and are converted by bacteria into plant nutrients. CO₂ is absorbed by plants through stomates on the undersides of leaves, boosting photosynthesis and plant growth.

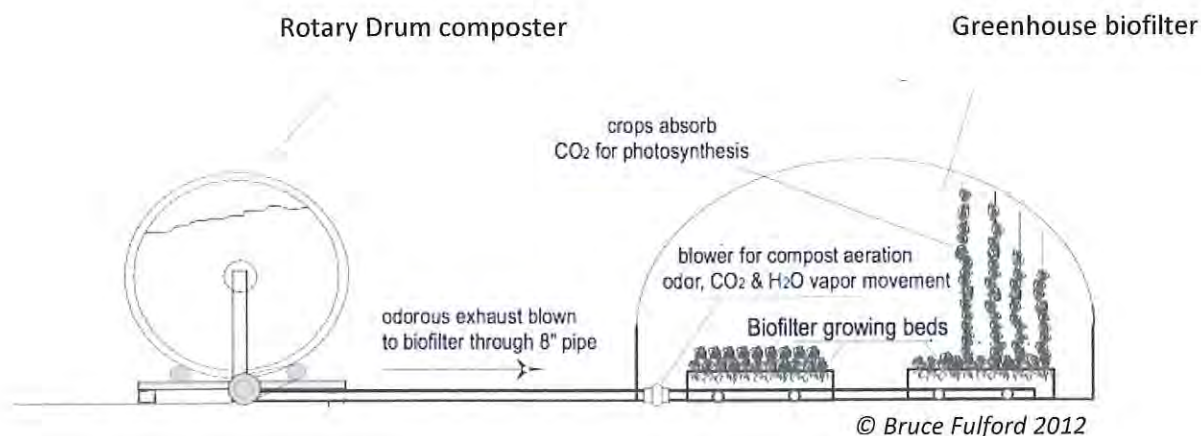


Figure 11: City Soil's Greenfilter: system

These systems direct the air drawn from an aerated static pile or in-vessel system into a plenum beneath a biofilter inside a greenhouse, and are application-specific for greenhouses. The system provides CO₂ to the greenhouse crop, and the crop is planted directly in the biofilter. The biofilter transforms ammonia, a common form of nitrogen found in manure, into nitrate. The air is saturated with moisture which, when properly managed can be used by transpiring plants as condensate. The plants (with some help from the bacteria in the biofilter) take up nitrogen, which stimulates rapid plant growth. The biofilter organisms that transform odors do not thrive at temperatures in excess of 110^o F. Crops in the biofilter planting bed typically grow best at soil temperatures under 85^o F. Most aeration system exhaust temperatures range from 110^o F to 160^o F, and these systems must therefore regulate temperature or use post-exchanger exhaust. Engineered operational controls that track CO₂ levels to optimize plant production and trigger ventilation to ensure greenhouse workplace safety are included in the system.

Exhaust to Hydronic Heat Recovery

In exhaust to hydronic heat recovery systems, a liquid (usually water or water/glycol solution) is circulated through a heat exchanger that recovers process-generated heat from the air stream and transfers the heat by conduction to a circulated liquid. The heated liquid is pumped to another heat exchanger that releases the heat at the point of use or in a thermally insulated hot water reservoir. These systems are simple and robust if the exchanger is constructed from materials that are compatible with the hot, corrosive, saturated air stream, and sized appropriately for efficient recovery. The exchangers are quite expensive in comparison to the simple in-pile tubing collectors for hydronic recovery systems, but require little maintenance beyond periodic cleaning. They are well suited for any system in which air is drawn through the pile or otherwise extracted from an enclosed or in-vessel system.

Closed Loop Phase Change System

Closed-loop phase change systems represent the current state of the art in heat recovery from composting operations. These systems are significantly more efficient than hydronic systems in terms of heat transfer between the process source and a heat reservoir. The reason for this efficiency is that the heat transfer medium maintains a fixed temperature while absorbing heat energy to change from a liquid to a gas. The gas migrates to the cool end of the system where it releases the heat and re-condenses into a liquid that flows back to the process heat source where the cycle begins again. Heat transfer is driven by the difference in temperature between the body losing heat and the body gaining heat. The rate at which heat is transferred between the two is directly proportional to the temperature difference between them. Over time in hydronic systems, the temperature of the heat transfer fluid approaches that of the process, causing the efficiency of the heat transfer to decrease as the fluid heats. On the other hand, the temperature of the phase change heat transfer medium remains stable at the low boiling point of the heat transfer medium. The process air exchanger and water exchanger are adjacent to one another, eliminating the need for piping between the two and the associated heat loss.

The Agrilab Isobar[®] is the exclusive proprietary system of this type that is being marketed in the US at this time. It has been selected for this application for its capacity to improve critical biofilter performance by pulling heat from a saturated exhaust stream before it is biofiltered, and because it supplies hydronic heat that can be transported greater distances more cost effectively than large diameter air handling pipes.

This technology is currently utilized at livestock farms in NY, VT and NH. The use of this system at the University of New Hampshire Organic Research Dairy Farm is described in an article accessible through link <http://www.biocycle.net/2014/02/21/heat-recovery-from-compost/>.

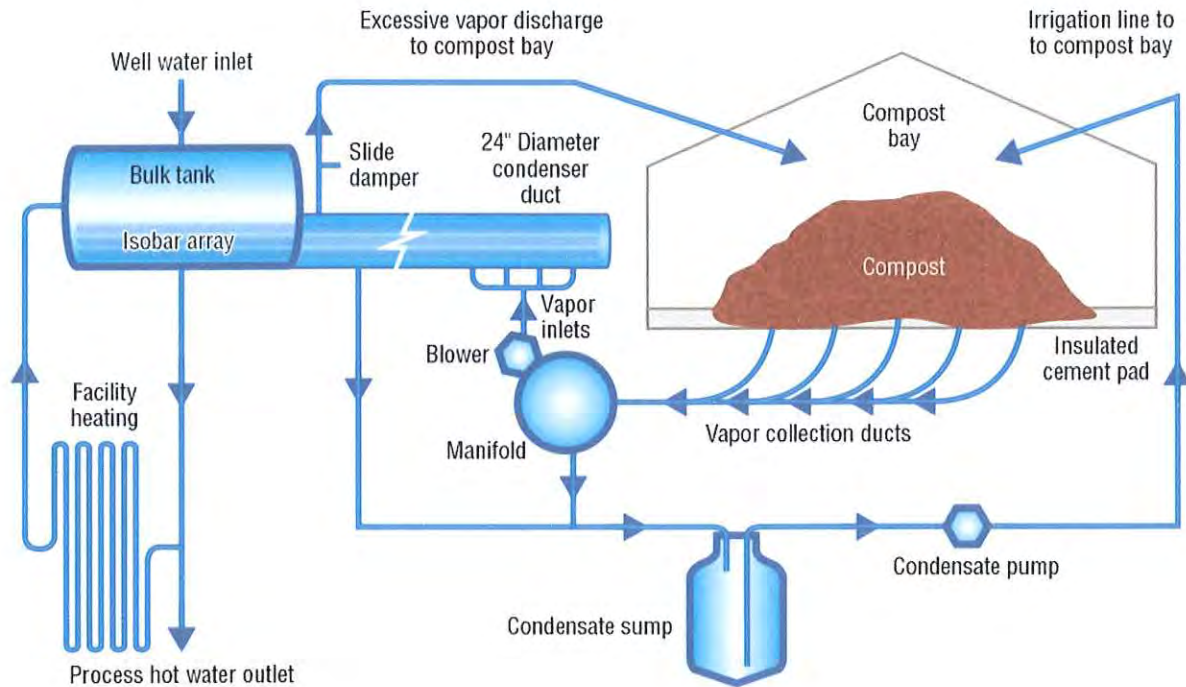
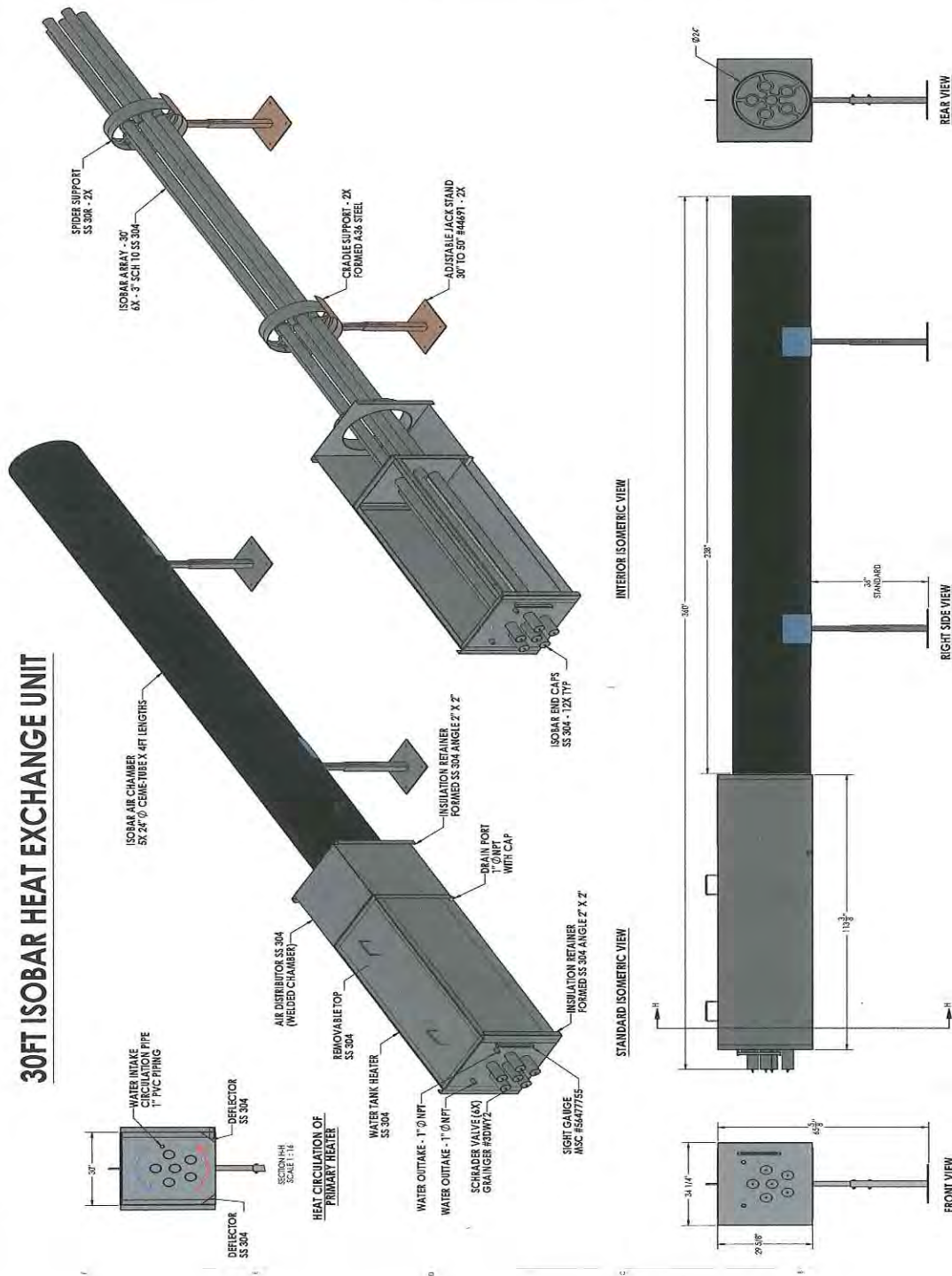


Figure 12: Agrilab Isobar® Heat Exchange System



Figure 13: Isobar® Heat Pipes at Farm Compost Site in New York State

30FT ISOBAR HEAT EXCHANGE UNIT



FILED IN: 10/17/12
 PROJECT: 30 ISOBAR HEAT EXCHANGE UNIT
 DRAWING NO: D 840953
 SCALE: 1/8" = 1'-0"
 SHEET: 1 OF 2

MATERIALS: SS 304, HDPE, PVC, A36
 WATER TANK MAX VOL: 289.5 GAL
 WATER TANK SIZE: 30" X 30" X 84"
 AIR DISTRIBUTOR SIZE: 30" X 30" X 30"

Figure 14: Dimensions of Isobar® Heat Exchange Unit on Farm Compost Site in NH

5. System Selection Criteria and Specifications

The current recommendations for equipment, facilities and operating plan incorporate the review of the available technologies to manage organic residuals and generate renewable thermal energy. This section will describe the conceptual design and evaluation criteria applied to the available alternatives.

The following criteria have been used to select the components of the ZNE facility composting system:

- Generate Threshold Energy Yield Identified by the OTE Program
- Divert minimum of 10 Tons/Day Pre- and Post-Consumer Food Waste from Landfill
- Fit Available Space
- Provide Ability to Monitor and Log Critical Process Parameters
- Ability to Reliably Achieve Regulatory Compliance
- Compatible with Current Use of Site
- Low Net Power Consumption
- Operate With Zero Negative Impact to Abutters
- Capacity of Process Uninterrupted Supply of Local Feedstock
- Create High-Value Product(s)
- Accept Herbivore Manure and Bedding from ZNE
- Accept Leaves and Brush from ZNE
- Process Wood Chips as Bulking Agent
- Support 24/7 Process with 8/5 Operators (2)
- Operate at 97% Process Uptime

Description of selected systems: BW Organics Rotary Drum Composter

BW Organics is the vendor of rotary drum compost technology that has the most extensive track record in serving the US market. In the past 23 years they have placed more than 300 units of varying sizes worldwide. BW's Installation locations range from the Galapagos Islands, to Glacier Bay National Park in Alaska, a dairy farm in Washington State, a turkey processor in New York State, and a prison in Georgia. Over the last 7 years, an increasing number of the units have been used to compost food waste at correctional facilities, colleges, and industrial cafeterias. BW Organics drums have been installed for composting food waste at the following institutions: Warren Wilson College, Swananoa North Carolina; Lincoln University, Jefferson City Missouri; Maharishi School, Fairfield Iowa; University of North Carolina, Greensboro North Carolina; Michigan State University, Grand Rapids Michigan; Montclair State University, Montclair New Jersey; Brown Creek Correctional Institution, Polkton North Carolina; South Central Correctional Center, Licking Missouri; Northeast Correctional Center, Bowling Green Missouri; and Toyota Motor Manufacturing, Georgetown Kentucky.

The company has seven differently sized compost vessels, constructed of steel plate and ranging in processing capacity from 0.33 cubic yards (CY) per day to 32 CY per day. Model 1050, their largest model, is 10 feet in diameter and 50 feet long.

One of the greatest design features of these drums is their modest electrical requirement. The drums are cradled at both ends with a special plastic liner that offers minimal resistance as a motorized drive chain turns the unit. Most of the units are chain driven; a five horsepower, 230-volt motor and gear are

used to drive the Model 1050. The large size and weight of the chains on the larger drums make them difficult to repair if they break; an alternative power option is to utilize four direct-drive motors and gears with four support rollers. Each of the four motors can range from one to six horsepower, depending on the size of the drum and optimal turning speed. The drums operate continuously but can be timed for intermittent turning.

The Franklin Park Zoo installation would recirculate pre-warmed process air and fresh air into the drum, provide oxygen, and remove moisture. Most units come with a burping check valve that allows exhaust air to escape when the vent is rotated above the mass of waste in the drum, but closes when it is below the waste so that material does not spill out.

Most BW Organics (BWO) installations to date have not incorporated biofiltering; exhaust air from the drum would need to be piped to a biofilter through an additional swivel pipefitting at either the feed end or discharge end of the drum.

A BWO installation to process 30 TPD of blended organics would use two model 1050 rotary drum composter units. One model 1050 rotary drum can process about 15 TPD, or 32 CY per day. Current pricing for a new model 1050 BWO Drum and associated equipment is approximately \$275,000; This includes a mixer, loading belt conveyor and horizontal screw to charge the drum, a discharge belt conveyor and elbow for loading a truck or hopper, the electrical control panel, freight, and installation. Additional model 1050 rotary drums, conveyor extension kits for each conveyor, plus freight and installation, are about \$170,000 apiece excluding freight and installation costs.



Figure 15: Twin mixer/feed systems with BW 1050 drums in pole barn process 30 TPD

Rotary drums would be installed on a level concrete slab or other appropriate stabilized surface. The appropriate area dimensions of a single drum pad are 60 feet by 24 feet – totaling approximately 1,440 square feet (SF). Single-phase electrical service could be used for each rotary drum and accessory conveyors. The power for an 80 to 100 horsepower electric grinder would need to be three-phase. In-feed mixing and discharge could add to the footprint because these functions should be enclosed; the drums would not need to be, but if the drums are enclosed and/or insulated, the biothermal heat that they radiate can more effectively be captured and used. Primary activities inside the containment facility include preheating inbound material, producing greenhouse crops, workspace heating, and drying down the end product. Heat supplied to adjacent buildings would be in hydronic form and pumped through

buried insulated pipes to buildings in closest proximity to the new facility. The biothermal energy could also be used to reduce moisture in finished compost stored in a covered bunker prior to export, thereby reducing the weight (and resulting transport costs) of the finished compost.

We must note that the ZNE composting site could host a less capital-intensive process than the rotary drum-based system that we ultimately recommend in this report. An enclosed aerated static pile (ASP) facility should not be ruled out as an option, but would not provide the throughput on a compact footprint or as effective and rapid pathogen destruction as the rotating drum technology. It would make use of multipurpose mobile equipment, (a front end loader), could utilize existing topography to its advantage, (with some modifications), and may require less capital investment to become functional than a rotary drum. An ASP system could be effectively managed, generate a similar quantity of bioenergy, and process close to the same tonnage as a drum-based 2-stage system. However, it would require a larger footprint and would not afford the same level of thermal control provided by the drum composter, in concert with the ASP as a secondary phase. ASP systems are essentially open-sourced, having been developed first by the USDA in the late 1960's, and are used worldwide for reliable processing of a wide range of organics. There are many vendors and engineering services that supply designs, control packages, aeration components, and combinations of off-the shelf components and open source or proprietary software.

Both the ASP systems and rotary drum systems require some pre-processing of the food residuals to remove physical contaminants, and the process is accelerated by particle size reduction via coarse shredding prior to incorporation into the primary composting stage. For both of the technologies there are successful exceptions in practice to these operational steps; these are typically in settings on larger sites, or with different feedstocks, and where there is more flexibility to remove contaminants after the materials have been composted.

The logistics of bringing a large (10 x 50') drum composter to the ZNE site, off-loading, and installing it require advance planning and special permits, and a crane with an 80 ton capacity or an alternative means of off-loading and positioning the drum in its final destination.

A 15-ton per day single drum facility and supporting hardware, including biofiltration, working surfaces, enclosures and mobile supporting equipment, is projected to cost \$1.3 million. Capital costs for a two-drum facility designed to process 30 wet tons per day, are projected to be between \$1.6 and \$1.8 million. The actual costs for each of the facility sizes materials and facilities specifications developed from a fully engineered and permitted design for the enclosing structure and surrounding site work at will depend the cost of capital, labor rates and construction markup at the time of construction.

Description of Process: Conceptual Design

The following site plan illustrates one configuration of a 15 TPD facility that includes one rotary drum composter and supporting equipment, contained in a structure positioned to the north side of Glen Lane. This facility would be new construction and dedicated to the operation of the composting and thermal energy recovery processes. The ZNE facility will be designed to process 5,400 tons of feedstock per year at the rate of 15 tons per day. The composting process considered in this study is optimized for a high-energy extraction rate and throughput on a small physical footprint. To generate a high quality end product, fully utilize the energy potential of the feedstock, and to meet the user requirements; the process must be carried out in two distinct phases. Approximately half of the available heat content in each ton of feedstock is recovered in each of the two process phases.

Phase 1:

Zoo manure, local food scraps and urban leaf and yard waste will be delivered to the facility via zoo staff and contracted haulers. All materials will be tipped within the enclosure on to a concrete floor, using an entrance at the west end of the building. Material handling at the facility begins once loads are tipped on to the receiving floor. Load inspection is followed by feedstock shredding, mixing and loading into the rotary drum. Air is drawn through the digester to supply oxygen to the aerobic bacteria on which the process relies, and to remove excess generated heat. Energy recovery during Phase 1 begins when the pre-processed feedstock is loaded with a skid-steer or small articulating loader into the rotating drum digester and microbial activity begins to generate heat. The hot (130°F – 150°F), saturated air is exhausted from the drum and drawn via ductwork through a high efficiency Isobar™ phase change heat exchanger, where heat is recovered through a water jacket and transferred via insulated piping to a large insulated water tank for storage and use. After passing through the Isobar™ exchanger, the cooled air is passed through a greenhouse biofilter to capture moisture and volatile plant nutrients, and to further scrub odors. The air delivered to the biofilter is still quite warm (90°F – 100°F) and saturated, and it heats and humidifies the airspace in the greenhouse.

The **Phase 1** composting process reduces the volume of the originally charged feedstock by approximately 50% during the 3-4 day process cycle. The resulting material is more finely blended and drier than the unprocessed feedstock. Rapid decomposition of feedstocks with adequate oxygen supply will remove most of the putrescibles, so there is little potential for negative odor. Retention time in the drum for the feedstock would be approximately 72 hours with the discharged material then being aerated during a second, longer phase.

Phase 2:

Energy recovery during phase 2 begins when the feedstock processed in Phase 1 is removed from the drum digester and placed in an aerated static pile via a stacking conveyor. Air is drawn under negative pressure (vacuum) through the pile via a manifold and ductwork array in the floor. This air circulation process provides oxygen to the composting bacteria and transports heat out of the pile for recovery and use. The air may be used in conjunction with a biofilter for direct space heating of a greenhouse or processing areas, or it can be recovered through a hydronic loop and stored as in the Phase 1 scenario. Heat is evolved at a lower rate (BTU/hour/per cubic yard) in the aerated static pile than in the drum digester, and more area is available for heat transfer, so the rate of thermal energy capture diminishes during the Phase 2 composting.

Phase 3:

Screening or other high-grading with separation technology would directly follow Phase 2, to reclaim bulking agent, and to remove film plastics, glass, and inert contaminants. Composted materials may be exported in bulk, for off-site screening if warranted, or screened and used on site, as well as exported (marketed) in bulk or in bagged forms.

Phase 4:

This phase is optional vermicomposting, which could be performed on some or all of the materials that are generated from Phase 1 or Phase 2, then be followed by (or completely bypass) curing in a covered bunker or drying and bagging.

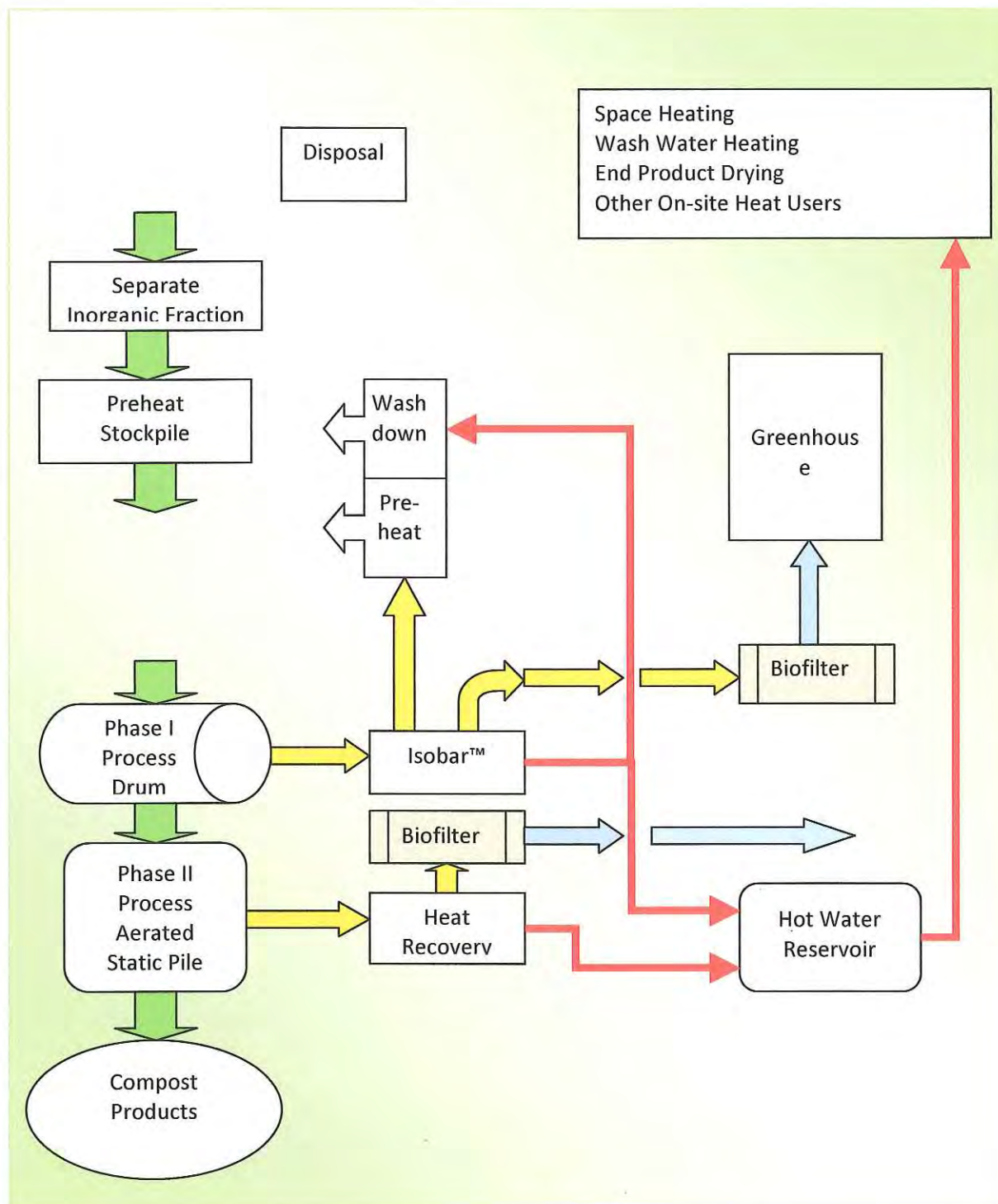


Figure 16: Compost Feedstock to Energy Recovery Process Flow

Mass and Energy Balances

Phase 1

The drum digester capacity is 96 cubic yards, which is assumed to equal 45 tons of the blend of feedstock identified in this report. The Phase 1 process cycle takes three days and can be allowed to run for five or more days. For best throughput, one third (32 cubic yards) of the digester contents are discharged each day and fresh feedstock is introduced at the front end.

Energy recovery as measured at the liquid outlet of the Isobar[®] averages $\geq 1,000$ BTU per ton per hour at a process air temperature of 140°F. This is equal to 394,200,000 BTU/Year recovered from the exhaust stream from a single Rotary Drum digester. Converting from BTU to Kilowatt Hours (kWh) (1 kWh = 3412 BTU) translates to a yield of 115,529 kWh/Year of recoverable energy from the primary phase. During peak heat generation, the Isobar[®] can deliver in excess of 2,000 BTU per hour per ton. If drum digester technology is used, the composting process is optimized for rapid heat generation at the beginning of the cycle; thus the actual energy yield will be greater and may be as high as 200,000 kWh annually from a 15 TPD system. For purposes of this study; however, we are using the lower expected energy recovery rate as the basis for projected energy recovery values.

Phase 2

The partially composted material is discharged from the drum and placed in enclosed aerated static pile (ASP) where it will continue to compost for approximately 60 days. The pile is maintained at a volume of approximately 450 cubic yards (225 tons), representing 30 days of output from Phase 1. Older material is removed and trucked off site or elsewhere on the ZNE site for curing, as new material from the Phase 1 process is added to the ASP. The ASP continues to generate heat recoverable at the rate of 1,000 BTU per hour per ton, for a total of 225,000 BTU per hour or an annual yield of 1,944,000,000 BTU. Converting to kilowatt-hours yields, the Phase 2 process generates an annual recoverable energy output of 569,730 kWh.

Under these assumptions, the combined Phase 1 and Phase 2 composting of 5,400 tons per year of feedstock recovers the usable heat equivalent of 685,259 kWh per year. This energy will be used on site primarily for space heating and domestic hot water.

A tertiary phase that would recover additional energy value would take place during curing and/or vermicomposting. After the composted material is removed from the ASP bins, it continues to generate modest quantities of heat. The curing materials can be placed into a third phase in the main Bioenergy Farm building, removed from the building by dump truck and placed in a high-tunnel greenhouse, or placed in uniform flat topped piles or in a block. Plastic Row covers can be placed atop curing compost to utilize the root-zone heating value for crops year-round. In the summer, this approach would not utilize the heat, but the CO₂ enrichment could be expected to produce a 20 to 50% increase in yields of crops over conventional cropping while requiring minimal irrigation.

The crops produced in the BioEnergy Farm would be fed to the Zoo animals, and/or could be marketed as part of a revenue-generating business to support the operation and ZNE. An economic value has not yet been assigned for the crops for zoo animals or other uses.

Feedstock Processing Requirements

Removal of non-compostable inputs (plastics, elastomers, metals) will be performed in an enclosed space equipped with appropriate ventilation and odor control measures. This operation will involve

manual inspection of feedstock prior to shredding, and removal of any visible trash using a hooked trash fork. Particle size reduction and feedstock blending will be accomplished by loading carbonaceous and nitrogenous feedstock at an approximate ratio of $\geq 25:1$ carbon to nitrogen into the mixer and running the mixer for several minutes. For best performance, the mixed feedstock will be brought to a temperature of 100 to 135°F in an enclosed container or sealed bay prior to charging into the drum. Heat recovered from the composting process will be used to pre-heat each 15-ton charge prior to shredding and blending.

A two or three day supply of containerized feedstock will be stored to allow 5-day/week operations and provide for periodic maintenance of the rotary drum digester, whether planned or unplanned. Pre-heating can be accomplished in the same containers if they are fitted with hydronic loops of adequate size. The containers used for this purpose would be a walled bay with wash-down walls and floor drain to tight tank, inside the tipping and mixing area. Alternatively, a sealed and insulated compactor unit could be staged outside of the preprocessing building and preheated with hydronic circulation from the Isobar system or thermal storage tank.

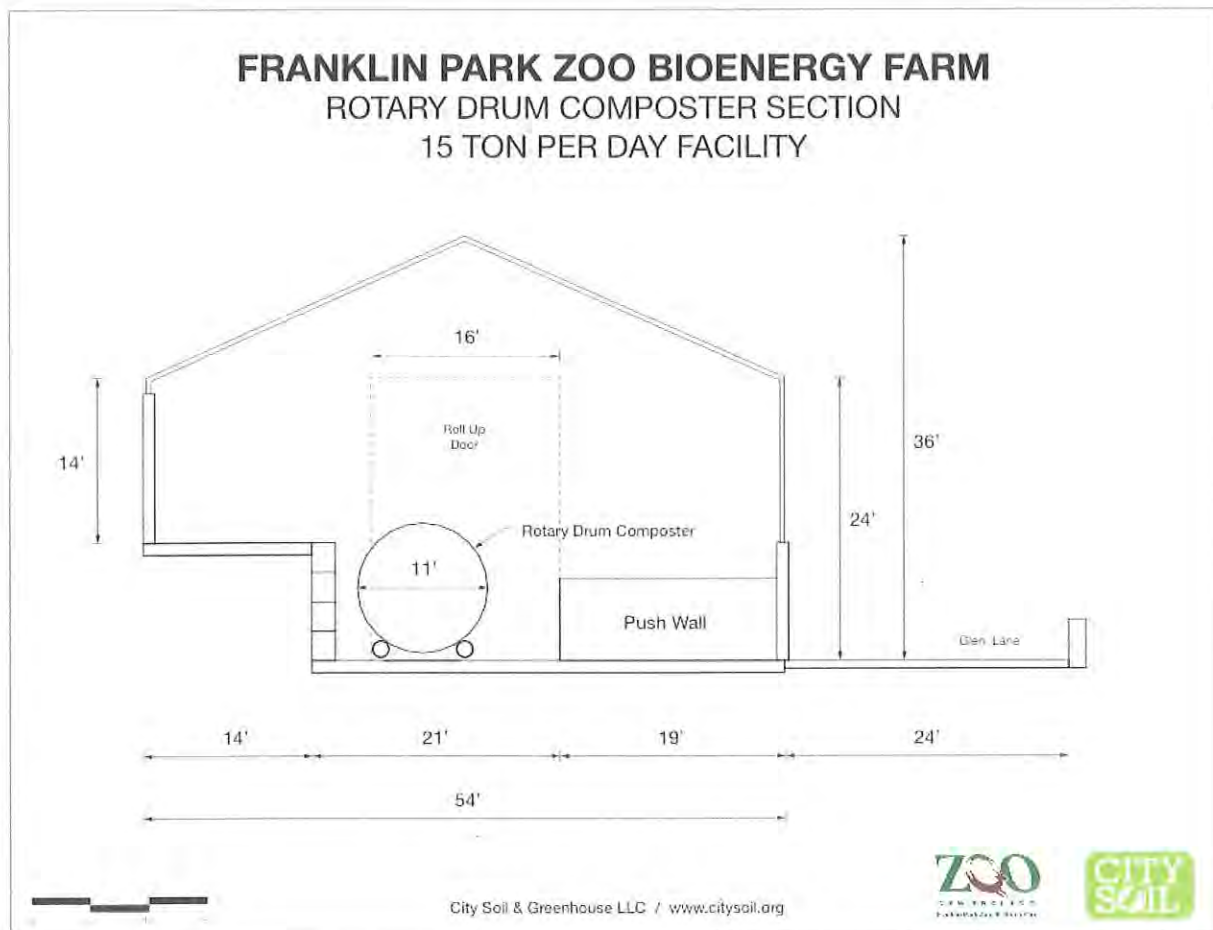


Figure 17: Details for rotary drum and material receiving and charging area

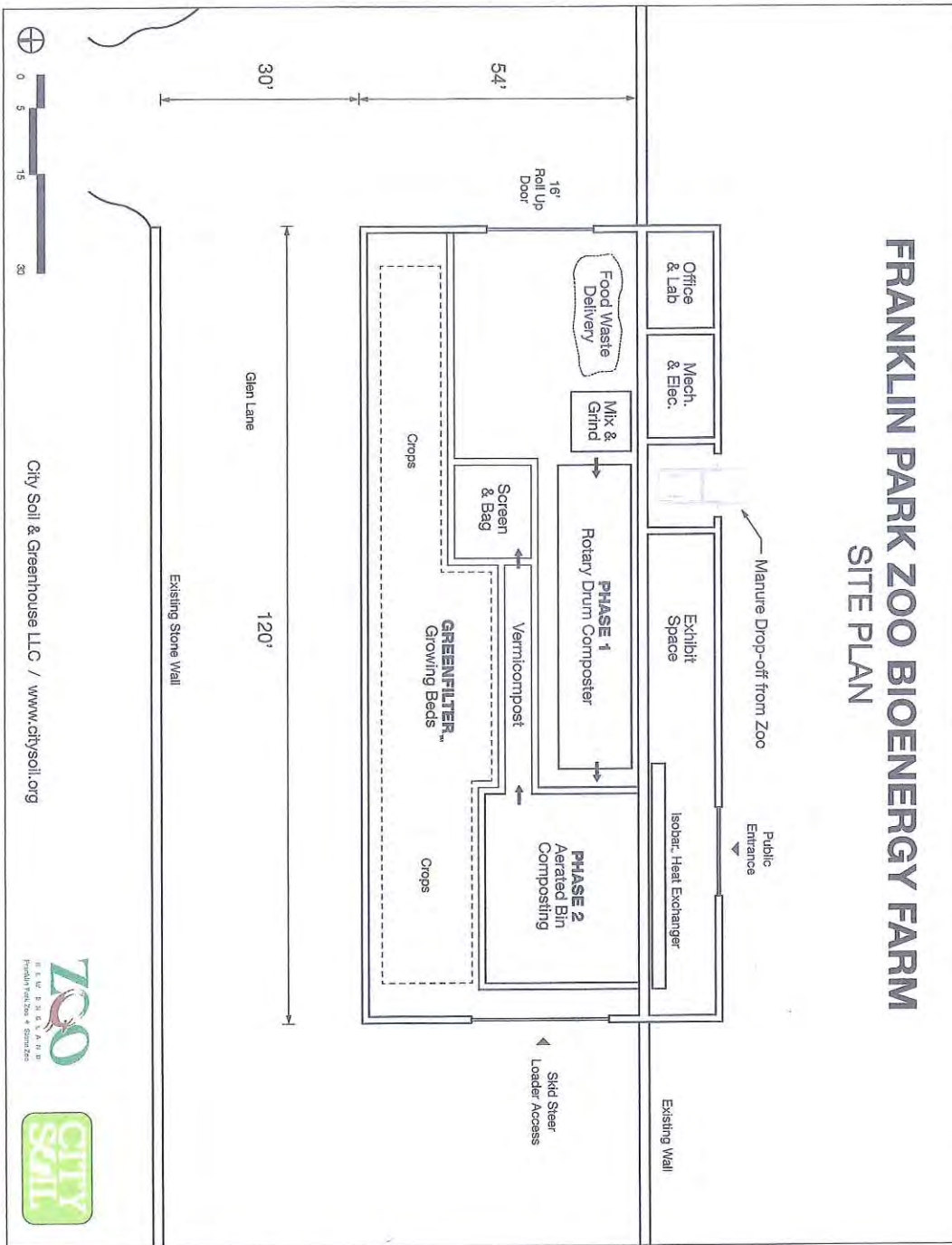


Figure 18 Site Plan for 15 Ton Per Day facility situated on Glen Lane

Structures

The bioenergy facility will consist of three contiguous structures and a biofilter. Exhaust from the Isobar® heat exchanger ranges from 90 to 110°F and carries water, CO₂, and some ammonia and other trace off-gases from the composting process, into the biofilter where it heats the greenhouse and feeds the plants.

Zone 1 houses the materials-receiving (tipping) and inspection area, Phase 1 composting process equipment, an electrical room, and the facility office and washroom. It is an insulated steel-framed structure. The tipping floor contains heating coils that utilize some of the captured process heat.

Zone 2 is an uninsulated steel-framed enclosure: this could be a pre-engineered fabric structure, pole barn, or greenhouse with bay doors that serves to contain the Phase 2 composting process. The composting bay has 6-ft high push-rated walls of reinforced concrete. The insulated floor is load-rated to support loading equipment traffic. The floor is channeled front-to-back at regular intervals. The channels are keyed-in during construction, and hold the static pile aeration manifold and thermal transfer loops, which are protected by flush-mounted cover plates. The channel covers are perforated at intervals to permit uniform aeration.

Existing Greenhouses at ZNE consist of two pre-engineered structures on the north side of Glen Lane. The largest greenhouse is a standard 28' x 80' steel box-beam framed 'Nexus' model with a double layer inflated polyethylene film glazing. The greenhouse was donated to the Zoo, disassembled at one site and re-erected on site in 1995 by ZNE staff and crew that now work with City Soil. A new 32' x 36' double poly-glazed structure was just erected by ZNE (fall and winter 2013/2014). Both of these greenhouses occupy a proposed location for, or are immediately adjacent to, locations where the BioEnergy Farm's main composting and biofiltration structure would be located. They could both be left in place and connected to the proposed compost building via insulated ductwork and hydronic heating and return lines. Either or both could be moved and effectively retrofitted as part of a site reconfiguration; the older of the greenhouses (84' x 27' Nexus) is sorely in need of new glazing, end walls, and a south sidewall, and could most readily be moved to another location on the site or elevated if needed.

System Component Arrangement

The building's internal layout, the connected materials handling and energy transport functions are designed to facilitate material flow by keeping input and output locations close together, which also reduces conveyance costs. Linear sequential processing is highly efficient. System components and buildings have been grouped closely to minimize the length of piping and wiring runs and to minimize energy loss. The thermal storage tank is placed centrally with the same energy conservation goals in mind.

Zones 1 and 2 are separated to prevent re-inoculation of Phase 2 product through exposure to untreated feedstock. The process is designed to destroy any pathogens in Phase 1.

Land in urban and suburban areas is at a premium and not usually available in large parcels. These are the best locations to compost desirable food waste feedstock because the supply is plentiful and the supply chain is geographically short. This configuration maximizes throughput on a small footprint.

BioFilter

The concentration and chemical composition of the air stream that contains odorous compounds will have a significant influence on biofilter size and performance requirements. Building and fire protection codes commonly require that industrial buildings provide 6 to 12 air changes per hour. Minimizing the quantity of treated air is a key design objective. More compact composting buildings, shorter runs for large diameter pipe, and simplified ductwork will save capital and maintenance costs while simultaneously improving operational efficiency. Shared walls with the enclosed composting enclosure can decrease capital and space heating costs.

Average specifications for biofilters used in the US composting industry are 1 ft²/ 5 CFM and 4-8 feet of filter media depth. Many biofilters range from 5 to 10 feet in depth, using a blend of coarse, fibrous, woody materials as large as 6." Biofilters at the 10' depth using carefully selected filter media and managed pH, moisture, and temperature, are able to process more than 10 CFM/SF of most odorous compounds. Process exhaust with high ammonia concentrations may need to be pretreated by sparging and aqueous absorption, pH modification of feedstock materials prior to composting, or addition of biochar to the filter media for effective removal. Several patented biofilter systems with highly compact footprints have been used to effectively scrub process air from composting facilities.

Placing a roof over the biofilter helps control moisture in wet weather. Fogging or sparging the biofilter exhaust at a single point provides additional reduction of odor causing volatiles if biofilter size is limited. The conceptual design produced for this study includes the filter cover to produce consistent results, but does not rely on sparging, because other equally effective controls exist that do not require large volumes of water.

The Main Biofilter scrubs odor-causing molecules from the process exhaust. It consists of a one-to-many manifold buried in a large (3536 Ft²), deep (8 Ft.) pile of coarsely milled wood covered by a thin layer of compost. It provides a substrate for bacteria to grow on. As exhaust is forced through the pile, bacteria colonizing the wood surface release enzymes that break the odor molecules apart, rendering the exhaust air odorless or nearly so. The conceptual design calls for the biofilter to be contained in a greenhouse enclosure, which will serve two functions. The covering prevents excessive rain or snowfall from saturating the biofilter media and reducing performance, and also provides a useful growing space that will capitalize on the heat, CO₂, water vapor, and gaseous nitrogen compounds generated from the composting process.

Impervious surfaces

Composting 15 tons per day requires development of new hardscape that protects stormwater, which must be managed through low impact design measures built into the site. Building roofs, pads, and paving create impervious cover. Since rain does not get absorbed through it, this diverted water must be managed so that soils or leachate are not washed into waterways. Stormwater will be harvesting for re-use from gutters on buildings and roofs, and diversion to infiltration swales at the perimeter of the site when these are filled.

Table 3: Building Dimensions and Impervious Cover			
Item	Dimensions (Ft)	Area (Ft²)	
Building 1 Roof	56 x 100	5600	
Building 2 Roof	34 x 66	2244	
Greenhouse Pad	28 x 80	2240	
Biofilter Roof	34 x 104	3536	
Building 2 Apron	20 x 80	1600	
Hot Tank / Conveyor Pad	22 x 34	748	
Driveway	30 x 120	3600	
Total Impervious Cover		19,568 Ft²	0.449 Acres

Biofilter Review

As described previously a biofilter is one of several components used in composting processes to capture, filter and treat exhaust odors. Neighbor complaints have indeed led to closure of a number of compost sites nationally and a biofilter is one several tools to address this risk. One of the advantages of in-vessel composting systems and composting within buildings is the ability to capture and treat the exhaust air from the composting process and the receiving area where fresh feedstocks are delivered to the site. Building and fire protection codes require that industrial buildings have 8 to 12 air changes each hour, so fresh air is of necessity pulled into the building, which dilutes the compost odors. This air can be directed to a biofilter for biological treatment of odors, rather than being dispelled directly outdoors where the odors might impact the surrounding area. Biofilters have been shown to remove 95 to 97 percent of odors associated with composting, and are used successfully throughout the world. One of many examples in Massachusetts is a large and effective biofilter at the City of Marlborough's solid waste/biosolids composting facility. It is enclosed in a 30,000 square foot building and treats up to 120,000 cubic feet per minute (CFM) of exhaust air from two large rotary compost vessels and three buildings.

For the enclosed receiving area building described above, there would be 42,000 cubic feet of air to treat per air-change. At 12 air changes per hour approximately 8,400 CFM of air would require treatment. The exhaust air from a rotary drum might add another 1,600 CFM, for a total of 10,000 CFM for treatment. A biofilter to treat 10,000 CFM would occupy approximately 2,100 square feet at a depth of 4-6 feet of media. In this ZNE proposal, multiple biofilters would be used to best manage the variation in air volumes and associated moisture, temperature and other exhaust characteristics. Directly supporting growing and heating space loads will be matched with odor reduction demands.

Biofilters associated with compost and anaerobic digestion (AD) facilities are normally both fixed capital costs and ongoing operating expenses, as they require periodic replacement. Capital costs for biofilters can range from less than \$20 to more than \$50 per square foot, depending on many variables. Reported O & M costs for agricultural biofilters range from \$3-\$5/1000 CFM/year. The lifespan of organic biofilter

media typically ranges from 2 years to more than 5 years. A conventional biofilter for the ZNE facility could cost between \$42,000 and \$100,000 to construct.

The concentration and chemical composition of the odorous airstream will have a significant influence on the biofilter sizing and performance requirements. Minimizing the quantity of air treated is a key design objective. More compact composting buildings, shorter distances required for costly large diameter pipe, and simplified ductwork will provide savings on capital cost and maintenance. Shared wall(s) with the enclosed composting enclosure can decrease capital costs.

Industry averages used to calculate the size of biofilters used in the US composting industry are commonly in the 1 square foot of biofilter surface area per 5 CFM of odorous air, and range between 4-8 feet of biofilter media depth.

Biofilters in use at the European Kompogas Anaerobic Digester plants and at Organic Waste Systems (OWS) AD facilities inspected by City Soil in 2010 ranged from 5' to 10' in depth, and utilized a blend largely comprised of coarse fibrous woody materials, with particles as large as 6" minus. Biofilters deploying a 10' depth use carefully selected filter media and managed pH, moisture, and temperatures, and the biofilter media might be able to process more than 10 CFM per SF of most odorous compounds. High ammonia concentrations may need to be pretreated via sparging or through pH modification of feedstock prior to composting for effective ammonia removal.

Several patented biofilter systems with much more compact footprints have been used to scrub process air from composting and anaerobic digestion (AD) facilities. Biofilters sized at less than 1.67 percent of the volume of air treated have been used in European composting plants with reported removal rates of 97 percent or greater, for hydrogen sulfide, Dimethyl Disulfide, dimethyl sulfide and mercaptans. These and other notoriously odorous compounds can be produced from spoiled food, and planning for their removal is critical to the success of a facility that will process such materials. Using this smaller footprint formula, 500 cubic feet (18.5 cubic yards) of biofilter media can treat 30,000 cubic feet per minute (cfm) of odorous air.

The aforementioned biofiltration systems are effective, and costly. The emerging 'greenfilter' technology that will be utilized at the ZNE facility provides similar results at a competitive cost. Shallow-bed biofilters with plants, or greenfilters, have demonstrated the efficacy of scrubbing odors from, dispersing, and beneficially utilizing heat while sequestering some of the CO₂ released from the composting process. A greenfilter establishes an economic value for harvesting the otherwise wasted byproducts of the composting process. The ZNE/City Soil Bioenergy Farm will be designed to readily recycle the biofilter media and use it as a finished product. The Revision House greenhouses deployed two separate 'greenfilters' to capture hot compost vapor exhaust and maintain frost-free growing beds of leafy greens and other vegetables in Dorchester. A USDA SARE grant helped vegetable growers in Vermont and Massachusetts evaluate and refine practices for this compost heat and CO₂ utilization method.

City Soil & Greenhouse has integrated a variety of greenhouse styles and sizes with shallow-bed biofilters treating process gases from composting animal manures, leaves, and food wastes. Shallow-bed biofilters capped with a layer of soil have proven effective at supporting growth year-round, and economically recycling water vapor and ammonia released from composting manures.

Enclosing the biofilter with a fabric enclosure or poly-film greenhouse shell affords optimum control of biofilter moisture in all weather conditions and added odor control insurance. This design would also permit sparging (fogging with a mist) to remove of the exhaust from the biofilter at a concentrated point for additional wash-down of odorous air, and/or recirculation of the exhaust air back to the biofilter if necessary.

Capital costs of greenhouse or fabric structures, installed, for a biofilter enclosure range from \$6 to \$20+/SF. City Soil recently received a price quote from a Massachusetts vendor for a high-quality recycled glasshouse measuring 120' x 54' with 14' sidewalls, and glazed with tempered glass at \$20/SF installed. Low cost 'hoop-house' style film-glazed greenhouses can be erected for less than \$6/SF.

6. Energy Use Profiles and Values

This section describes the historical energy consumption for heating various buildings at ZNE. Natural gas measured in therms or 100,000 BTU equivalents is tracked for a list of structures shown below in Table 4. The cost per therm is shown as \$1.319 using January 2014 values. This report identifies seven existing or proposed buildings at ZNE that are within 250 feet of the proposed composting facility/BioEnergy Farm. This distance was an arbitrary but reasonable radius for burying and connecting new insulated water lines to deliver hot water and cold water return lines.

The seven existing buildings are projected to consume \$17,000 per year of energy using natural gas (see Table 5: 2012 Energy use by building within 250' of composting facility). The table shows monthly and annual consumption figures. The authors project that a minimum of \$15,000 year of energy savings could be realized upon integrating the biothermal energy. This assumes that during peak heating demand (extreme cold weather events) some supplemental natural gas heating would be required.

There are additional buildings within 1000' of the proposed composting unit that also consume energy for heating including the aviary building, zoo restrooms and other animal housing. Should thermal energy generation at the composting facility exceed the demands of the composting process buildings and the closer cluster of zoo buildings, extending hot water distribution lines can be considered in more detail. This could also apply to an integration of solar thermal collectors for this site.

The current scenario described by the authors may generate \$48,800 of thermal energy from the active composting process (based on January 2014 natural gas costs). The combined rotary drum and aerated static pile processes with an average 15 tons per day of inputs can yield 16.5 MMBTU/day of thermal energy when integrated with the heat exchange units and practices described. See Table 4: Compost Energy Value of 15 TPD facility.

	16.5 MMBTU/day combined heat generated
	165 Equivalent Therms gas required to generate -Therms/day gas
\$	217.86 Equivalent energy cost/day
	224 Days/year active heat utilization
\$	48,800.10 projected annual value gas equivalent

Table 4: Compost Energy Value of 15 ton per day facility

The following table shows gas usage of buildings within 300 feet of the composting facility.

Table 5: Zoo New England FY '12 Gas Usage

FY '12	Stone Zoo	TF	Zebra	Brooder	Meet Barn	ECO	Ed	Gift	Giraffe	Green-house	Kang	Lion	Little Critter	Out rest	tree kang	Service yard	CZ Barn	Birds World	Giddy-up	CRC
July	167	0	0	0	0	6	6	0	131	44	0	69	0	0	0	131	26	0	252	0
Aug.	74	0	0	0	0	7	6	0	157	82	0	74	0	0	0	130	29	0	259	0
Sept.	273	0	0	2	0	15	7	1	149	135	0	59	0	0	7	170	25	0	117	0
Oct.	1,493	3,442	3	14	1	37	25	21	419	270	0	10	0	0	32	621	27	543	350	66
Nov.	3,885	8,820	58	52	63	131	81	128	668	806	12	0	37	0	94	2,896	191	2706	368	555
Dec.	4,862	10,732	102	55	50	134	106	162	831	852	28	0	89	0	119	3,217	355	2787	317	633
Jan.	8,275	14,519	189	179	50	212	146	240	1,022	1,148	74	0	64	0	186	3,345	738	4013	346	1015
Feb.	6,500	11,204	143	113	38	149	127	196	797	1,030	72	0	11	0	161	3,185	394	3316	309	751
March	5,358	8,979	76	59	50	100	79	106	635	751	32	0	15	0	87	3,356	235	2302	266	515
April	3,421	7,637	39	82	21	95	62	74	571	716	11	29	8	0	79	2,616	145	2370	308	226
May	1,889	4,347	4	23	5	28	22	24	197	452	0	70	7	0	29	2,331	128	2065	359	163
June	639	949	0	0	4	21	11	8	177	243	0	48	4	0	10	1,011	111	884	286	156
Total	36,836	70,629	614	579	282	935	678	960	5,754	6,529	229	359	235	0	804	23,009	2,404	20,986	3,537	4,080
	Franklin Park Zoo			142,603																
	Stone Zoo			36,836																
	Grand Total			179,439																

7. Projected Monthly Biothermal Heat Production from Available Feedstocks

This section describes the renewable thermal energy yields on a total theoretical basis as well as projections on the portion that can be economically captured and utilized at ZNE. The 15 tons per day (TPD) projections are shown for this round. (See Table X: Weights, Volumes and Residence Times for 15 TPD scenario.) The authors recognize a 30 TPD scenario should also be considered to assess the value of additional biothermal heat production, and the implications for material handling, capital costs and operations. This may ultimately be recommended as a Phase II expansion of a working compost site.

Table Title: **Bioenergy Materials assumptions**

15	Tons processed/day
32	Cubic yards/day
0.47	Compost feedstock - Cu Yards per ton
45.0	Drum tonnage total capacity
96.0	Drum volume filled
3	Residence time in drum, days
72	Residence time in drum, hours
60	Residence time in Phase 2 ASP, days
1440	Residence time in Phase 2 ASP, hours
63	Days of Active Composting

Table 6: Weights, Volumes and Residence Times for 15 TPD scenario

The calculations for the biothermal energy yields used figures from both academic research and documentation of existing commercial and municipal composting facilities (Themelis, 2006). Further factoring of the recoverable portions of that energy were made by evaluating performance of existing facilities using the Isobar® Heat Exchange Unit, and assigning a predicted efficiency for this site and its proposed practices. An additional factor was applied to the efficiency of utilizing the generated BTUs for various existing and proposed facilities. See Table 7: Compost Energy Assumptions and Projected Values.

Biothermal heating calculations

Compost Heat Produced		
Drum	15	Tons processed/day
ASP	945	Tons Active Compost (Phase 2 feedstock-cumulative tons)
	7660	BTU/lb dry weight
	5362000	BTU/ wet ton theoretical yield
	2681000	BTU/Ton/conservative projected total yield @ 50% theoretical
	2010750	BTU/Ton/total recoverable yield @ 75% conservative projected total yield
	31916.7	BTU recovered heat generated per day/ton active compost
	478750.0	BTU Heat generated /day/15 tons (32 cy)
	4.8	Therm/day Heat generated from each 15 ton load
	1329.9	Heat recovered, average, BTU per hour/ton
	16.5	MMBTU/day combined heat generated
	165.2	Equivalent Therms gas required to generate -Therms/day gas
	\$217.86	Equivalent energy cost/day
	224	Days/year active heat utilization
	\$48,800.10	projected annual value gas equivalent

Table 7: Compost Energy Assumptions and Projected Values

The total potential of biothermal heating just in Boston is significant and helps place the modest scale of the proposed facility in context. To achieve such a disruptive shift in energy generation and consumption, early stage successful examples are important to advance adoption of innovative practices. The ZNE proposal presents a powerful example for composting and sustainable resource management practices in a setting uniquely capable of also providing public and other stakeholder education. See Table 9: Biothermal heating calculation and CO₂ implications.

Table 8: CO₂ offsets from compost heat recovery	
50,000	cy leaves, wood chips annual yield in Boston
1,000,000	BTU per cubic yard, produced from compost heat
50,000,000,000	BTU produced annually
1035	BTU/cu ft heat yield from gas
48,309,179	Equivalent cubic feet (CCF) of gas required to produce same heat value
483,092	CCF gas to produce equivalent heat
1.035	Therms/100 cubic feet (CCF)
500,000	Total therms generated
1.319	\$/therm pricing Jan. 2014
\$659,500	Annual \$ value of biothermal heat, if captured
12	lbs CO ₂ generated per CCF (EPA)
5,797,101	Total lbs CO ₂ lost during LNG combustion
2,898.55	tons CO ₂ annually avoided, Fracking and Line losses not accounted for

Table 9: Boston area biothermal heating calculations and CO₂ implications	
	Assuming that one acre of greenhouse uses approximately 100,000 ccf natural gas annually
2400	Greenhouse size
4,400	CCF/season
1.83	CCF/sf
43,560	1 acre (square feet)
79860	CCF/year per acre
958320	CO ₂ /acre per year
4	Acres projected
3833280	#'s CO ₂ avoided annually heating cost
	CO ₂ absorbed by crops in greenhouse
40	tons per acre/year
80000	lbs/acre/year
320000	4 acres CO ₂ uptake

References:

25 x 96' greenhouse in MA uses 4,400 CCF/season

Umass <http://extension.umass.edu/floriculture/fact-sheets/corn—home-grown-heat-source>

8. Permitting

Permits and Regulatory Approvals

ZNE has statutory authority to use the land within its boundaries for purposes that support its core environmental conservation and educational mission. It is zoned as parkland. All construction activities need to conform to state and City building codes. The specific portions of the site identified in this proposal and the activities on them have been used at least intermittently, for similar purposes, since 1995. The zoo is presently composting food waste, manure, and landscape materials from on-site sources. Containerized handling of these materials occurs on site by contracted operators with heavy equipment, and the zoo is also operating greenhouse production space.

The Zoo at Franklin Park was one of, if not the first, urban food waste composting facility in Massachusetts. Food waste diversion for composting in Boston was pioneered at Zoo New England (the Franklin Park Zoo); in 1994, FPZ (now ZNE) in partnership with Greenleaf Composting, which was co-founded by City Soil's president Bruce Fulford, secured a demonstration permit through MDEP that established the precedent for capturing pre-consumer food waste from Stop & Shop, and post-consumer food waste and lab animal bedding waste (ABW) from Harvard University Dining services.

Between 1994 and 1997, the food waste/manure/yard waste-composting site at Franklin Park Zoo operated under a Demonstration Permit from the Department of Environmental Protection. Although this permit has expired, DEP's new streamlined compost regulations afford permit-by-rule status for this scale of facility, which would fall under the General Permit classification. Such classification would allow on-site composting of Zoo manure with leaves in quantities of up to 30 tons per day, and 105 tons weekly of food waste that meets the criteria set forth in the revised 310 CMR 16.00. Under the new General Permit, the project would need to file an annual report with MDEP by Feb 15th every year after it becomes operational. If the ZNE composting and bioenergy operation markets agricultural products generated from the facility and becomes, by definition under 61A an agricultural unit, then the composting facility could qualify for an agricultural exemption under the Department of Agricultural Resources revised composting regulations, which are expected to be finalized by the time this project would become operational. If this were the case, the operation would be assessed an annual fee and need to comply with annual reporting requirements.

Massachusetts is implementing a ban on food waste disposal for generators that produce more than 1 ton of food waste weekly, which took effect on Oct. 1 2014. Permitting of facilities for organics recycling has been streamlined to facilitate development of additional handling capacity close to points of generation. In anticipation of the ban and to further the ZNE/City Soil relationship, and also to build the business opportunity, City Soil prepared and submitted to Mass DEP and Boston Public Health Commission on October 15, 2013 a certification for general composting facility at the Zoo Overflow Parking Lot (Appendix A). This important step established a legal commercial and institutional composting facility on land under the care and custody of ZNE for accepting pre-consumer and post-consumer food waste, leaves, yard debris, and woodchips from commercial landscapers and arborists, in addition to Zoo New England's manure and bedding.

The proposed site occupies a topographic high point that drains in all directions. Most of the surface consists of highly compacted stony fill that is up to six feet deep. The fill was compacted using heavy equipment at the time of placement and is essentially impervious. Most of the site drains to the west

and then follows the service access to a storm drain on Glen Lane. Some water flows down a wooded slope at the southern perimeter and then into a storm water drain on the north side of Circuit Drive. There is little evidence of erosion, though the ground at the access point is not vegetated and has been disturbed by truck and equipment traffic.

Regulatory Requirements

Federal Food Safety Modernization Act PL 111-353 Biological Soil Amendments: Subpart F

Under the act and its proposed rules, only compost products that meet standards for specific pathogen and contaminant loading may be applied to land used to grow human foodstuffs. High quality compost meeting these standards sells at significantly higher price than product that does not. The proposed process is designed to produce conditions that consistently produce pathogen kills that exceed these standards. The process does so by ensuring uniform heating at controlled temperatures for a specific time, and the process may be validated under a testing program. The applicable section of the code is included in Appendix B to this report.

The US Composting Council's Seal of Testing Assurance Program ('STA') is a compost testing, labeling and information disclosure program designed to give producers, consumers and regulators the information to get the maximum benefit from the use of compost. The program was created in 2000 and is the consensus of many of the leading compost research scientists in the United States. No other compost testing program provided this type of information to compost producers or buyers.

The Test Method for the Examination of Composting and Compost (TMECC) provides detailed protocols for the composting industry to verify the physical, chemical, and biological condition of composting feedstocks, material in process and compost products at the point of sale.

Material testing is needed to verify product safety and market claims. TMECC provides protocols to sample, monitor, and analyze materials at all stages of the composting process, i.e., prior to, during and after composting to help maintain process control, verify product attributes, assure worker safety, and to avoid degradation of the environment in and around the composting facility.

Use of standard methods and protocols for sampling, analysis, reporting, and interpretation of test results will promote production and marketing of quality composts that meet a core set of analytical standards. The methods and protocols in the TMECC form the basis for the U.S. Composting Council's grant from the US Environmental Protection Agency to develop a Seal of Testing Assurance (STA) for the commercial composting industry in the United States. Also, the Compost Analysis Proficiency Testing program (CAP) was initiated through collaboration with managers of North American Proficiency Testing (NAPT) to provide the Compost Laboratory Analysis Industry with an inter-laboratory QC program, to develop reference materials, and to measure the performance and reliability of TMECC analytical methods.

9. Financial Analysis of Proposed Options

Capital and Operating Costs for the facility are detailed in the business proforma.

Pro Forma Operating Assumptions and Projections

The accompanying financial projections model revenues and operating costs of a bioenergy farm at Zoo New England's Franklin Park Zoo. These figures are based on a stable facility supporting a 15 ton per day processing capacity over a ten-year period. It assumes capital costs of \$1.3 million, with \$600,000 from grants.

The facility is projected to generate Year 1 revenue of \$436,327 on costs of \$295,855. The resulting operating gain of \$140,472 covers required debt service of \$66,252 at a ratio of 2.12 times in Year 1. As modeled, the facility generates a 17.1% IRR.

The facility will produce compost, heat and crops with a combined value of \$219,151. The amount of compost generated is estimated to be 30% of the incoming tonnage of feedstock, resulting in 3,499 yards of compost that can be sold at \$35/yard for sales of \$122,448. The facility will generate 12,896 therms of energy at a value of \$17,925, based on \$1.39/therm. This amount of thermal energy is sufficient to heat nearby buildings. Crops grown in the attached greenhouse will yield an annual value per square foot of \$8.50, for total value of \$78,778. No financial value is allocated in this analysis for renewable energy credits (RECs), carbon offset value, or other environmental benefits of this facility.

Capital Expense

The \$1.3 million projected capital expense for the facility breaks down as follows:

Item	Cost
Buildings	\$452,942
Equipment	\$682,020
Greenhouse (new construction)	\$96,100
Greenhouse (improvements to existing)	\$24,024
Electrical and mechanical controls	\$44,500
Total	\$1,299,586
Rounded	\$1,300,000

Building costs are modeled at \$452,942 for the structures that contain the following functions: feedstock receiving and pre-processing, rotary drum turning, and secondary composting. Building costs include architectural and engineering fees, and a 15% contingency cost allowance.

Equipment costs of \$682,020 include delivered and installed costs for a helical mixer/shredder, conveyers, one rotary drum composter, a skid steer loader or small articulating front-end loader, blowers, fans, pumps, heat exchangers, lighting, irrigation and fire protection.

Capital cost for 40' containerized Isobar unit (CIU) – are \$89,500 – however the CIU is lease eligible and has a full 5-year warranty. Monthly leasing costs for the Isobar are estimated at \$1,700, financed by a leasing company that has been sourced by Agrilab LLC. Capital cost for fixed 40' Isobar unit including all

comparable connections, controls, and components is estimated at \$79,000. This is not lease-eligible, and has 5-year warranty on Isobar unit only – components depend on manufacturer.

Greenhouse costs include \$96,100 for new greenhouse construction and modifications and improvements to existing ZNE greenhouse of \$24,024.

Controls are estimated at \$44,500.

Feedstock Materials

Feedstock includes 1) food waste, 2) yard waste, and 3) manure mixed with bedding. Feedstock quantities are based on operationally feasible ratios of food waste imported to the Zoo site in one truckload daily, mixed with yard waste (leaves, woodchips, horticultural waste) and zoo manure/bedding at the rate that it is presently generated on site. Quantities are described in tons for purposes of comparing value relative to current disposal costs commonly billed on a weight basis. The throughput capacity of the composting system is based on the volumetric limits of the materials handling equipment; appropriate conversions of feedstock tonnage to volume to have been made in the feedstock supply, avoided disposal costs, and end product assumptions.

End Products

Compost

The finished compost is assumed to be 30% by weight of the feedstock materials, with a bulk density of 2.13 cubic yards per ton. It is used on site, and also marketed through wholesale and retail channels to support operational costs of the facility.

Thermal Energy

Thermal energy is the quantity generated from the 15 tons per day of feedstock and used by existing buildings at ZNE within 300 feet of the point of generation (the composting system).

Crops

Food crops, foliage and horticultural products grown in the heated greenhouse space generate revenue to the business or provide value to ZNE through avoided expenses. Crop area is quantified as square feet, and includes existing greenhouse space on Glen Lane and new space constructed in the Bioenergy Farm build-out.

Waste Product

Waste products from the composting process are assumed at 2% of the feedstock by weight, and consist of non-recyclable trash and screener rejects removed before or after composting. Waste products are disposed of via landfilling off-site at commercial rates.

Tip Fees, Prices and Costs

Tip Fees & Avoided Disposal Costs

Estimates for disposal and collected fees or costs avoided are based on the low end of current rates in the immediate market. Projected rates are equivalent or less than what is paid at this time by ZNE for disposal of manure and yard waste, and the present market rate for source separated food waste disposed of locally by commercial haulers operating in Boston. The model assumes a 3% annual increase in disposal costs for all materials.

Food waste is supplied by haulers bringing outside pre-consumer and post-consumer organics to the Zoo, with tip fees of \$45/ton. Yard waste and manure are generated at the Zoo, with an avoided disposal cost of \$20/ton for yard waste and \$30/ton for manure. Year 1 revenues from food waste are \$180,675 based on 4015 tons/year at \$45/ton, assuming 11 tons/day for 7 days/week. Yard waste avoided disposal costs are \$14,600 based on 730 tons/year at \$20/ton, assuming an average of 2 tons/day. Avoided disposal costs for manure are \$21,900 based on 730 tons/year at \$30/ton at 2 tons/day. Total revenue from tip fees and avoided disposal costs is \$217,175.

Pricing on product sales

Compost pricing is modeled at \$35 per cubic yard; this pricing represents a blend of wholesale and retail rates for screened compost and vermicompost products used at ZNE, or sold in bulk, bagged or other containerized form. Pricing is consistent with current market rates for compost sold by City Soil in the Boston market.

Thermal energy is priced based on the cost of natural gas used to heat the existing greenhouses and adjacent buildings and the new bioenergy farm main processing building and integrated greenhouse. The value of energy is estimated to increase 3% annually.

Crop prices are modeled at \$8.50 per square foot per year, based on low to moderate annual revenues for greenhouse crops. Crops produced in the facility can be sold to support the costs of operation, used at ZNE to propagate and overwinter plants in exhibits, and to supply food to zoo animals.

Expenses

Expenses for operations and overhead include labor, contractors, electricity, water and sewer, equipment fuel and fluids, maintenance, repair, replacement of components and wear parts, routine maintenance of structures, and independent lab testing of products generated by the facility. Expenses are projected to rise 3% annually.

Labor Costs are \$130,000 annually for two FTE employees at an average rate of \$25/ hour; this will provide for one FTE employee at \$30/hour and one at \$20/hour, on payroll 40 hours/week, 52 weeks annually. Payroll taxes are modeled at 26% of annual hourly wages. Personnel will be responsible for receiving and processing all feedstock, monitoring and routine maintenance of energy transfer systems, and managing the greenhouse and crop production portion of the Bioenergy Farm. The facility is designed to operate 24/7 year round, even when not staffed. Payroll taxes are assumed at 26%.

Technical assistance and management services provided by City Soil are \$40,000 annually and cover the oversight of facility operations and performance, coordination and tracking of all deliveries of inbound and outbound materials, supervising on-site labor, permit compliance, reporting, product marketing and sales, and facility and operations troubleshooting.

Costs for plumbing, mechanical, and electrical contractors and lab work associated with the operation of the facility are assumed at \$20,000 in Year 1; these professional fees include the provision of specialized tools for the respective tasks associated with the required work.

Utilities and equipment fuel costs are projected at \$24,000 in Year 1. Electricity is used for the rotary drum composter, conveyors, blowers for compost aeration and biofiltration, pumps that circulate fluids for heating, irrigation and wash-down, lighting, and to operate automated controls. Electricity used to

operate the composting facility, energy recovery and connected greenhouse facility is estimated as follows.

Itemized Cost of Electricity used in facility operations

Key assumptions					
Operating # Days per year	350				
Cost per kWh (\$/kWH)	\$0.15				
Electrical Use Detail					
	HP	KW	Hrs/day	Cost /day	Annual
Grinder/mixer	100	74.6	0.5	\$5.60	\$1,958.25
Conveyers	2	1.49	4	\$0.90	\$313.32
Composting Drum	5	3.73	24	\$13.43	\$4,699.80
Aeration blowers for curing compost	8	5.97	12	\$10.74	\$3,759.84
Biofilter Blower	2	1.49	24	\$5.37	\$1,879.92
Greenhouse ventilation	1	0.75	6	\$4.48	\$895.20
Greenhouse circulation fans/inflation	0.5	0.37	24	\$1.34	\$469.98
Lighting		0.10	12	\$0.18	\$63.00
Circulating Pumps	0.2	0.1492	24	\$7.83	\$1,723.26
Total	118.5	88.401		\$41.85	\$15,762.57
1) Assumes 15 days downtime for holidays and equipment maintenance 2) No predictive assumptions are made for escalating costs of electrical power 3) Aggregated power use estimates based on conceptual facility design, but not based on an engineered facility plan					

Fuel is used by the loader. Water purchased from Boston Water and Sewer Commission is used for pressure washing compost process equipment, for greenhouse irrigation, washing produce, and sanitation.

Maintenance costs are estimated at \$40,000 in Year 1, and include the repair, replacement and normal maintenance of equipment and facilities; these include all wear parts in fixed and mobile equipment, electrical and mechanical components and the bioenergy farm building. Over the 10-year period covered by the pro forma, no major component replacement is anticipated.

Maintenance cost for the Agrilab Isobar system (average estimate over 10 year cycle) - \$1,250/year – wear items include fans, controls, sensors, and upkeep of doors, vents, paint, and couplings and other connections. Annual operating cost estimate for the Isobar unit is \$1,200, for electricity to operate blower and circulating pumps.

Financing

The 15 TPD Bioenergy Facility will be financed as follows: \$600,000 from grants, \$560,000 from loans, and \$140,000 from equity investment in the facility development. The loan will be repaid over 10 years at a rate of 3.5%.

The significant level of grant funding (46.2%) assumed in this model reflects the amount of support that City Soil and ZNE believe could be raised from philanthropic sources that are not already tapped to fund other Zoo priorities. Grant support is also anticipated from mission-aligned state sources, including MCEC, Mass DEP, and MDAR, and key institutional stakeholders and foundations. For the debt financed portion of the project (43.1%), this model assumes that low-interest loans would be obtained from sources that include Recycling Loan Fund, SBA loans, impact investors, environmentally-oriented funds, and Industrial Development Bonds. Equity financing of 10.8% would be raised from investors in clean/sustainable technology development and project-based portfolios.

An alternative financial projection assuming no grant funding shows an IRR of 2.6% and annual debt service of \$123,048, with a coverage ratio of 1.14 in Year 1. This model assumes that 80% of the project cost would be debt financed at 3.5% interest rate over 10 years, coupled with 20% equity investment.

These two pro forma illustrate the high degree of variability in financial performance resulting from different capital investment structures; both show better than break-even results even without monetizing environmental benefits and credits that could be applied to the operation.

Doubling the throughput of the facility by adding a second rotary drum and expanding the footprint of the site would substantially improve the economics of the operation. The fixed capital and operational costs for most of the building, equipment and labor to operate the facility distributed over a 30 ton per day facility would afford an economy of scale, but has not been modeled in this study.

City Soil & Greenhouse LLC
Pro forma operating projections for Zoo New England Bioenergy Farm - with subsidy

Printed	10/9/2014	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantities											
Feedstocks	Unit										
Food waste	ton	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015
Yard waste	ton	730	730	730	730	730	730	730	730	730	730
Manure/bedding	ton	730	730	730	730	730	730	730	730	730	730
Total		5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475
End product											
Compost product as % of feedstock (tons)		1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643
Compost product (yards) (2.13 yds/ton)		3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499
Thermal energy (Therms)		12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896
Crops	SF	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268
Waste product											
Screened residuals as percent of feedstock		110	110	110	110	110	110	110	110	110	110
Tons to be landfilled annually											
Tip Fees, Prices and Costs											
Tip fees per ton		\$ 45.00	\$ 46.35	\$ 47.74	\$ 49.17	\$ 50.65	\$ 52.17	\$ 53.73	\$ 55.34	\$ 57.00	\$ 58.71
Food waste											
Yard waste		\$ 20.00	\$ 20.60	\$ 21.22	\$ 21.85	\$ 22.51	\$ 23.19	\$ 23.88	\$ 24.60	\$ 25.34	\$ 26.10
Manure		\$ 30.00	\$ 30.90	\$ 31.83	\$ 32.78	\$ 33.77	\$ 34.78	\$ 35.82	\$ 36.90	\$ 38.00	\$ 39.14
Avoided disposal costs per ton											
Compost (per yard)		\$ 35.00	\$ 36.05	\$ 37.13	\$ 38.25	\$ 39.39	\$ 40.57	\$ 41.79	\$ 43.05	\$ 44.34	\$ 45.67
Thermal energy (\$/therm)		\$ 1.39	\$ 1.43	\$ 1.47	\$ 1.52	\$ 1.56	\$ 1.61	\$ 1.66	\$ 1.71	\$ 1.76	\$ 1.81
Crop yield value per SF per year		\$ 8.50	\$ 8.83	\$ 9.37	\$ 9.84	\$ 10.33	\$ 10.85	\$ 11.39	\$ 11.96	\$ 12.56	\$ 13.19
RECS		\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
Costs		\$ 90.00	\$ 92.70	\$ 95.48	\$ 98.35	\$ 101.30	\$ 104.33	\$ 107.45	\$ 110.69	\$ 114.01	\$ 117.43
Residuals haul+disposal											
Revenues and values											
Tip fees and avoided disposal costs		\$ 180,675	\$ 186,095	\$ 191,678	\$ 197,428	\$ 203,351	\$ 209,452	\$ 216,735	\$ 224,207	\$ 232,874	\$ 241,740
Food waste: tip fee revenue		\$ 14,600	\$ 15,038	\$ 15,489	\$ 15,954	\$ 16,432	\$ 16,925	\$ 17,433	\$ 17,956	\$ 18,495	\$ 19,050
Yard waste: avoided disposal cost		\$ 21,900	\$ 22,567	\$ 23,234	\$ 23,931	\$ 24,649	\$ 25,388	\$ 26,160	\$ 26,934	\$ 27,742	\$ 28,575
Manure: avoided disposal cost		\$ 122,448	\$ 126,122	\$ 129,905	\$ 133,803	\$ 137,817	\$ 141,951	\$ 146,210	\$ 150,596	\$ 155,114	\$ 159,767
Product sales		\$ 17,925	\$ 18,463	\$ 19,017	\$ 19,588	\$ 20,175	\$ 20,780	\$ 21,404	\$ 22,046	\$ 22,707	\$ 23,386
Compost sales @ \$35/yd		\$ 78,778	\$ 82,717	\$ 86,853	\$ 91,195	\$ 95,755	\$ 100,543	\$ 105,570	\$ 110,849	\$ 116,391	\$ 122,211
Thermal energy sales (value)		\$ 436,327	\$ 450,992	\$ 466,176	\$ 481,899	\$ 498,179	\$ 515,040	\$ 532,502	\$ 550,589	\$ 569,323	\$ 588,731
Crops for Zoo use/sales											
Total		\$ 436,327	\$ 450,992	\$ 466,176	\$ 481,899	\$ 498,179	\$ 515,040	\$ 532,502	\$ 550,589	\$ 569,323	\$ 588,731
Expenses											
Operations											
Technical assistance & management (City Soil)		\$ 40,000	\$ 41,200	\$ 42,436	\$ 43,709	\$ 45,020	\$ 46,371	\$ 47,762	\$ 49,185	\$ 50,671	\$ 52,191
Operating Labor Cost		\$ 130,000	\$ 133,900	\$ 137,917	\$ 142,055	\$ 146,316	\$ 150,706	\$ 155,227	\$ 159,884	\$ 164,660	\$ 169,621
Maintenance costs		\$ 40,000	\$ 41,200	\$ 42,436	\$ 43,709	\$ 45,020	\$ 46,371	\$ 47,762	\$ 49,185	\$ 50,671	\$ 52,191
Contractors (plumbing, mechanical, electrical)		\$ 20,000	\$ 20,600	\$ 21,218	\$ 21,855	\$ 22,510	\$ 23,185	\$ 23,881	\$ 24,597	\$ 25,335	\$ 26,095
Utilities and equipment fuel costs		\$ 24,000	\$ 24,720	\$ 25,462	\$ 26,225	\$ 27,012	\$ 27,823	\$ 28,657	\$ 29,517	\$ 30,402	\$ 31,315
Custom Screening		\$ 5,000	\$ 5,150	\$ 5,305	\$ 5,464	\$ 5,628	\$ 5,796	\$ 5,970	\$ 6,149	\$ 6,334	\$ 6,524
Residue disposal		\$ 9,855	\$ 10,151	\$ 10,455	\$ 10,769	\$ 11,092	\$ 11,425	\$ 11,767	\$ 12,120	\$ 12,484	\$ 12,859
Overhead		\$ 20,000	\$ 20,600	\$ 21,218	\$ 21,855	\$ 22,510	\$ 23,185	\$ 23,881	\$ 24,597	\$ 25,335	\$ 26,095
Insurance		\$ 2,000	\$ 2,060	\$ 2,122	\$ 2,185	\$ 2,251	\$ 2,319	\$ 2,388	\$ 2,460	\$ 2,534	\$ 2,610
Property taxes		\$ 5,000	\$ 5,150	\$ 5,305	\$ 5,464	\$ 5,628	\$ 5,796	\$ 5,970	\$ 6,149	\$ 6,334	\$ 6,524
Admin and General		\$ 285,855	\$ 304,731	\$ 313,873	\$ 323,289	\$ 332,987	\$ 342,977	\$ 353,266	\$ 363,864	\$ 374,760	\$ 386,024
Total		\$ 140,472	\$ 146,262	\$ 152,304	\$ 158,610	\$ 165,192	\$ 172,063	\$ 179,236	\$ 186,724	\$ 194,543	\$ 202,707
Operating Gain		\$ (1,044)	\$ (5,270)	\$ (10,128)	\$ (14,711)	\$ (19,019)	\$ (23,021)	\$ (26,734)	\$ (30,135)	\$ (33,214)	\$ (35,976)
Capital cost		\$ (1,300,000)									
Grants, offsets, intangibles		\$ 600,000									
*Cash flow		\$ (700,000)	\$ 130,214	\$ 136,004	\$ 142,046	\$ 148,352	\$ 154,934	\$ 161,805	\$ 168,978	\$ 176,466	\$ 184,285
Cumulative cash flow											
IRR		17.1%									
Operating Gain		\$ 140,472	\$ 146,262	\$ 152,304	\$ 158,610	\$ 165,192	\$ 172,063	\$ 179,236	\$ 186,724	\$ 194,543	\$ 202,707
Debt service	\$560,000 @3.5% for 10 yrs is \$5621/mo.	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252	\$ 66,252
Debt service coverage ratio		2.12	2.21	2.30	2.39	2.49	2.60	2.71	2.82	2.94	3.06
Rate		3.5%									
Term (yrs)		10									
Monthly debt service		\$ 5,521									
Financed cos	100.0%	\$ 66,252									
Equity	20.0%	\$ 132,504									
Debt	80.0%	\$ 52,748									
Annual principal repaid		\$ 55,984									
Annual interest paid		\$ 10,268									
* Cash flow calculation: is Operating Gain less Debt service plus principal repaid											

City Soil & Greenhouse LLC

Pro forma operating projections for Zoo New England Bioenergy Farm - no subsidy

Printed	9/30/2014	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantities											
Feedstocks											
	Units/day	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015	4,015
Food waste	11	730	730	730	730	730	730	730	730	730	730
Yard waste	2	730	730	730	730	730	730	730	730	730	730
Manure/bedding	2	730	730	730	730	730	730	730	730	730	730
Total	15	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475
End product											
Compost product as % of feedstock (ton)	30.0%	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643
Compost product (yards) (2.13 yds/ton)		3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499	3,499
Thermal energy (THERMS)		12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896	12,896
Crops	SF	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268	9,268
Waste product											
Screened residuals as percent of feedstc	2.0%	110	110	110	110	110	110	110	110	110	110
Tons to be landfilled annually											
Tip Fees, Prices and Costs											
Tip fees per ton	Annual Increase										
Avoided disposal costs per ton	3.0%	45.00	46.35	47.74	49.17	50.65	52.17	53.73	55.34	57.00	58.71
Prices											
Food waste	3.0%	20.00	20.60	21.22	21.85	22.51	23.19	23.88	24.60	25.34	26.10
Yard waste	3.0%	30.00	30.90	31.83	32.78	33.77	34.78	35.82	36.90	38.00	39.14
Manure											
Compost (per yard)	3.0%	35.00	36.05	37.13	38.25	39.39	40.57	41.79	43.05	44.34	45.67
Thermal energy (\$/therm)	3.0%	1.39	1.43	1.47	1.52	1.56	1.61	1.65	1.71	1.76	1.81
Crop yield value per SF per year	5.0%	8.50	8.93	9.37	9.84	10.33	10.85	11.39	11.96	12.56	13.19
RECs											
Costs											
Residuals haul/disposal	3.0%	90.00	92.70	95.48	98.35	101.30	104.33	107.46	110.69	114.01	117.43
Revenues and values											
Tip fees and avoided disposal costs	3.0%										
Food waste: tip fee revenue	3.0%	180,675	186,095	191,678	197,428	203,351	209,452	215,735	222,207	228,874	235,740
Yard waste: avoided disposal cost	3.0%	14,600	15,038	15,489	15,954	16,432	16,925	17,433	17,956	18,495	19,050
Manure: avoided disposal cost	3.0%	21,900	22,557	23,234	23,931	24,649	25,388	26,150	26,934	27,742	28,575
Product sales											
Compost sales @ \$35/Yrd	3.0%	122,448	126,122	129,905	133,803	137,817	141,951	146,210	150,596	155,114	159,767
Thermal energy sales (Value)	3.0%	17,925	18,463	19,017	19,598	20,175	20,780	21,404	22,046	22,707	23,389
Crops for Zoo use/sales	3.0%	78,778	82,717	86,853	91,195	95,755	100,543	105,570	110,849	116,391	122,211
Total		438,827	450,992	466,176	481,899	498,179	515,040	532,502	550,569	569,323	588,731
Expenses											
Operations	Annual Increase										
Technical assistance/management (City Soil)	3.0%	40,000	41,200	42,436	43,709	45,020	46,371	47,762	49,195	50,671	52,191
Operating Labor Cost (City Soil)	3.0%	130,000	133,900	137,917	142,055	146,316	150,706	155,227	159,884	164,660	169,521
Maintenance costs	3.0%	40,000	41,200	42,436	43,709	45,020	46,371	47,762	49,195	50,671	52,191
Contractors (plumbing, mechanical, electrical)	3.0%	20,000	20,600	21,218	21,855	22,510	23,185	23,881	24,597	25,335	26,095
Utilities and equipment fuel costs	3.0%	24,000	24,720	25,462	26,225	27,012	27,823	28,657	29,517	30,402	31,315
Custom Screening	3.0%	5,000	5,150	5,305	5,464	5,628	5,796	5,970	6,149	6,334	6,524
Residue disposal	3.0%	9,855	10,151	10,455	10,769	11,092	11,425	11,767	12,120	12,484	12,859
Overhead											
Insurance	3.0%	20,000	20,600	21,218	21,855	22,510	23,185	23,881	24,597	25,335	26,095
Property taxes	3.0%	2,000	2,060	2,122	2,185	2,251	2,319	2,388	2,460	2,534	2,610
Admin and General	3.0%	5,000	5,150	5,305	5,464	5,628	5,796	5,970	6,149	6,334	6,524
Total		295,855	304,731	313,873	323,298	332,987	342,977	353,266	363,864	374,780	386,024
Operating Gain		140,472	146,262	152,304	158,610	165,192	172,063	179,236	186,724	194,543	202,707
Capital cost											
Grants, offsets, intangibles											
*Cash flow		\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)	\$ (1,300,000)
Cumulative cash flow											
IRR	2.6%										
Operating Gain		140,472	146,262	152,304	158,610	165,192	172,063	179,236	186,724	194,543	202,707
Debt service \$1,040,000 @ 3.5% for 10 yrs is \$10,254/mo.		123,048	123,048	123,048	123,048	123,048	123,048	123,048	123,048	123,048	123,048
Debt service coverage ratio		1.14	1.19	1.24	1.29	1.34	1.44	1.50	1.56	1.63	1.70
Capital cost											
Grants, offset											
Financed cost											
Equity											
Debt											
* Cash flow calculation is Operating Gain less Debt service plus principal repaid											

10. Business Models

The Bioenergy Farm business model proposed in this study must meet the Zoo's criteria for project development: The project must be administratively and logistically simple, and afford ZNE a risk-free model for funding and operations that results in no net costs to ZNE. City Soil & Greenhouse proposes that the facility, equipment, and management of the operations be implemented under a 20-year land-lease agreement developed with the Commonwealth Zoological Corporation/Zoo New England. City Soil would be responsible for raising the funds for the design, permitting, construction, and operation of the facility. Products generated by the Bioenergy Farm would be marketed to support the costs of the operation and debt service. Avoided costs to ZNE for disposal of organics off-site would be quantified on a quarterly basis. Approximately 5% to 10% of the food crops grown in the facility would be dedicated to feeding ZNE animals.

There are financial variables that will need to be defined in greater detail and monetized as a next phase in project development. This information will be used to structure a business plan and a negotiated agreement to develop a project that is attractive to Zoo New England, City Soil and Greenhouse LLC, and equity and/or debt funding sources. These variables include proposed land lease payments, electrical power and equipment fuel pricing index, accrual and accounting for renewable and/or alternative energy credits (RECs and AECs), net energy savings to the Zoo, net organic waste disposal savings, net compost/mulch savings, net animal feed savings, value of share of profits from co-branded products, reductions or increases in water use, and benefits accrued to the zoo for reduced storm water volume, pollutant loading and irrigation.

Compost, mulches, soil amendments and growing media would be provided to ZNE at cost, and are estimated to be less than 10% of the total volume of product generated from a 15 ton per day facility. RECs and/or AECs and other environmental incentives with financial value would be accrued to the facility operations and their value factored into the negotiated business structure between ZNE and City Soil. Co-branded products would be sold with a portion of the net profits dedicated to Zoo general funds or to a dedicated pool such as the ZNE Conservation Fund.

ZNE would enter into an indexed PPA (Power Purchase Agreement) with City Soil for the energy derived from the operation that offsets fossil fuel-derived energy used for ZNE buildings and domestic hot water.

Additional infrastructure investments, such as connecting the bioenergy heating system to other buildings or facility expansion, would only be sought with prior ZNE approval.

11. Conclusions and Next Steps

This feasibility study demonstrates the economic and environmental benefits of an integrated system of composting with energy recovery and greenhouse crop production. Franklin Park Zoo offers an exceptional location to host a Bioenergy Farm designed around an enclosed 15 ton to 30 ton per day composting facility. This report proposes an operational model for composting that will most benefit key public and private stakeholders of the Commonwealth, City of Boston and the local community. The composting system described herein affords 100% containment and control of odors, vermin, and water quality impacts that can accompany poorly managed organic materials. Further more, energy efficient composting, biothermal energy recovery, and greenhouse crop production will help to mitigate the causes and effects of climate change.

City Soil & Greenhouses has designed, built, and successfully demonstrated the value of a closed greenhouse system. This highly efficient model utilizes the waste heat, CO₂ and water vapor produced during the composting of food waste, manure and yard debris. Having hosted a successful urban composting operation for pre-consumer and postconsumer food waste 20 years ago at the Franklin Park Zoo, Zoo New England is eager to re-activate this commitment to large scale composting.

Development and operation of the facility will be facilitated through a long-term partnership agreement between Zoo New England and City Soil & Greenhouse LLC. Capital costs for the facility, estimated at \$1.3 to \$1.8 million, will be financed through sources secured by City Soil. Operational costs, estimated at \$290,000 annually will be supported from sales of products, tip fees and saving for waste disposal and energy costs currently incurred by Zoo New England. Preliminary analyses show a substantial economy of scale can be realized by increasing the throughput of the composting system from one truckload of inbound materials to two per day.

Direct sales of large quantities of compost from the Franklin Park Zoo site are presently limited due to restricted public and commercial access. Zoo New England's overflow parking lot located one half mile from the zoo provides an excellent, accessible location for retail and commercial customers to purchase finished compost and soils in bulk or bagged form. Developing the market for the end products will improve the return on investment and reduce capital risk of a more costly state-of-the-art facility and distribution site located within the Franklin Park Zoo.

The Massachusetts Department of Agricultural Resources (MDAR) recently awarded a \$70,000 grant to City Soil & Greenhouse and the Suffolk County Conservation District for the design and construction of a demonstration model of the Bioenergy Farm; proposed to be implemented on City Soil's leased site at the Zoo Overflow Parking Lot. This site, which offers year-round public access, secure perimeters, ample parking, power, water, lighting, and engineered drainage. City Soil certified the site in October 2013 for Composting General Permit with the Massachusetts Department of Environmental Protection and the City of Boston's Inspectional Services Department and Public Health Commission.

A demonstration project at this location will benefit from the collective resources and expertise of many stakeholders, and address the priorities of a diverse constituent base.

This site provides the opportunity to accelerate and refine the proposed business model based on mutual economic and energy benefits. The infrastructure needed to establish this pilot facility can be

delivered by tractor-trailer and installed on a temporary basis requiring no poured concrete or fixed facilities. Other host community benefits including educational, employment, and environmental value have been considered but not monetized in this report.

A demonstration project based at the Zoo Overflow Parking Lot would provide heat to the MDAR funded greenhouse that will be developed with the Suffolk County Conservation District. A leased Containerized Isobar Unit from Agrilab could be effectively demonstrated on the site and used to supply heat to office and workspace on City Soil's site and the adjacent portable office trailers that are being installed by Boston Public Works Department to house the Lighting Division's operations staff.

With Boston hosting the BioCycle East Coast conference in October 2015 a fully functional Bioenergy Farm can showcase a remarkable partnership with tangible benefits to Zoo New England, the Commonwealth of Massachusetts, the City of Boston. Similarly, the MDAR project will deliver essential services and supplies to small businesses, urban growers and homeowners and will provide numerous environmental benefits to an underserved host community. This project will quickly yield tangible results from the investment in the feasibility study by the Massachusetts Clean Energy Center's Organics-to-Energy program, Zoo New England and City Soil & Greenhouse. It will implement a highly productive partnership between Zoo New England and multiple state agencies under the Executive Office of Environmental and Energy Affairs. This innovative pilot offers a meaningful opportunity to collaborate with local, regional and national environmental organizations and institutions with a strong interest in partnering in the development and programming of this facility.

The MDAR funding is an affirmation of City Soil's commitment to local enterprise and enhances its current 5-year contract as operator of the City of Boston's 4.5 acre yard waste composting site. Poised to divert the Zoo's manure and yard waste from the fall 2014 collection this project will increase local composting capacity using proven, innovative technologies to meet the new statewide Food Waste Ban. The facility could be generating crops without fossil fuels or synthetic fertilizers in early 2015. Pending authorization to proceed at both sites this 'center of excellence' will be a potent example of the commitment by Massachusetts, the City of Boston, and Zoo New England to urban agriculture, renewable energy, composting, and climate resilience.

Appendix A

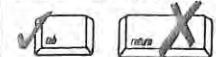
Zoo Overflow Parking Lot – Mass. Department of Environmental Protection General Permit Certification Form for New or Newly Acquired Recycling, Composting, Aerobic or Anaerobic Digestion Operations Pursuant to 310 CMR 16.04 (see attached)



Massachusetts Department of Environmental Protection Bureau of Waste Prevention - Solid Waste Program

General Permit Certification Form for New or Newly Acquired Recycling, Composting,
Aerobic or Anaerobic Digestion Operations Pursuant to 310 CMR 16.04

Important: When completing this form on a computer, use only the Tab key to move your cursor – not the Return key.



I. Property Owner, Operator, Responsible Official & Site Information

Note: Each box must be completed for this certification to be valid. Do not leave any box blank. Enter "N/A" if an item is not applicable.

Property Owner

Type of Ownership:

- Private - Select One: Corporation Limited Liability Corp. Partnership Sole Proprietorship Trust
- Public - Select One: Municipal State Federal Tribal Other – Specify: **Non-profit Organization**

Commonwealth Zoological Corporation

Name of Individual or Entity

(617) 989-2009

Telephone Number

rgeorge@ZOONEWENGLAND.COM

Email Address

1 Franklin Park Rd

Mailing Address

Dorchester

City/Town

MA

State

02121

ZIP Code

Operator

City Soil & Greenhouse LLC

Name

(617) 469-8164

Telephone Number

bfulford@citysoil.org

Email Address

285 Cornell St.

Mailing Address

Roslindale

City/Town

MA

State

02131

ZIP Code

Responsible Official

Bruce Fulford

Name

(617) 834-1934

Telephone Number

bfulford@citysoil.org

Email Address

285 Cornell St

Mailing Address

Roslindale

City/Town

MA

State

02131

ZIP Code

Site Information

City Soil & Greenhouse LLC

Operating Doing Business As (Company Name)

450 Canterbury Rd

Street Address (If Different from Above)

Roslindale

City/Town

MA

State

02131

ZIP Code

N42.290946, W71.0998928

Geographic Positioning System (GPS) Coordinates of Activity Location (Example: N42.355800, W71.060114)



**Massachusetts Department of Environmental Protection
Bureau of Waste Prevention - Solid Waste Program**

General Permit Certification Form for New or Newly Acquired Recycling, Composting, Aerobic or Anaerobic Digestion Operations Pursuant to 310 CMR 16.04

II. Type of General Permit Operation Requiring Certification

Please check the appropriate box below for the type of operation covered by this certification. A separate certification form is necessary for each activity and/or each location requiring a general permit pursuant to 310 CMR 16.04. **If the operation exceeds the applicable listed tonnage, it is not eligible for a General Permit pursuant to 310 CMR 16.04. Recycling, Composting, Aerobic digestion or Anaerobic Digestion operations that exceed the applicable listed tonnage (see below) may be eligible for a Recycling, Composting, or Conversion (RCC) Permit pursuant to 310 CMR 16.05.**

- | | |
|--|--|
| <input type="checkbox"/> Recycling Operation that receives no more than 250 tons per day of recyclable materials, not including paper. | Complete Sections III, IV, V & IX of this form. |
| <input checked="" type="checkbox"/> Composting Operation that receives no more than 105 tons per week and no more than 30 tons per day of Group 2 organic materials. | Complete Sections III, VI, VII & IX of this form. |
| <input type="checkbox"/> Aerobic or Anaerobic Digestion Operation that receives no more than 100 tons per day of organic material from on-site or off-site, based on a 30-day rolling average. | Complete Sections III, VI, VIII & IX of this form. |

III. Operation Start Date

- | | |
|--|---|
| 1. What is the start date of the operation? (The start date must be no sooner than 30 days after you submit this certification to MassDEP and notify the Board of Health in the appropriate municipality.) | <u>11/14/2013</u>
Date (MM/DD/YYYY) |
| 2. When and how did you provide a copy of this certification to the appropriate local Board of Health to notify the municipality of the start date? | <u>10/15/2013</u>
Date of Notification
Method Used:
<input checked="" type="checkbox"/> Email
<input type="checkbox"/> Fax
<input type="checkbox"/> Regular Mail |

IV. Preliminary Site Information

- | | |
|--|---|
| 1. Is the operation located at a solid waste management facility? (If Yes, continue to question 2 of this section. If No, proceed to the next applicable section.) | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No |
| 2. Does the site assignment allow recycling, composting, aerobic, or anaerobic operations to be conducted on the site assigned parcel? (If Yes, continue to question 3 of this section. If No, then the site assignment must be modified to allow this activity before the certification can be submitted.) | <input type="checkbox"/> Yes <input type="checkbox"/> No |
| 3. Does the recycling, composting, aerobic, or anaerobic digestion operation adversely impact the solid waste management facility, e.g., vehicular traffic, solid waste transport, handling or disposal, etc.? (If No, continue to question 4 of this section. If Yes, then the solid waste facility will comply with the requirements of 310 CMR 19.039 "Applicant's Request to Modify a Permit" before completing this certification.) | <input type="checkbox"/> Yes <input type="checkbox"/> No |

N/A
MassDEP Permit Approval Transmittal Number

N/A
Date of Approval (MM/DD/YYYY)

- | | |
|--|---|
| 4. Is the activity on the footprint of a landfill? (If No, proceed to the next applicable section. If Yes, then the landfill will comply with the requirements of 310 CMR 19.039 "Applicant's Request to Modify a Permit" before completing this certification.) | <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No |
|--|---|

N/A
MassDEP Permit Approval Transmittal Number

N/A
Date of Approval (MM/DD/YYYY)



**Massachusetts Department of Environmental Protection
Bureau of Waste Prevention - Solid Waste Program**

General Permit Certification Form for New or Newly Acquired Recycling, Composting,
Aerobic or Anaerobic Digestion Operations Pursuant to 310 CMR 16.04

IMPORTANT: The Operation will comply with the requirements listed in sections V through VIII below, as applicable, to be eligible for a general permit pursuant to 310 CMR 16.04. If you check "NO" for any of the requirements listed in Section V through Section VIII, then the operation is not eligible for a General Permit pursuant to 310 CMR 16.04. If the Operation is not eligible, the Owner and Operator may file an application for a "Permit for Recycling, Composting or Conversion (RCC Permit) Operation" pursuant to 310 CMR 16.05.

V. General Permit Requirements: Recycling Operation (310 CMR 16.04(2))

Provide the requested information by checking the appropriate boxes to indicate the operation is in compliance with each of the following requirements for a recycling operation:

1. The operation will prevent unpermitted discharges of pollutants to the air, water, land or other natural resources of the Commonwealth. Yes No
2. The operation will not create a public nuisance. Yes No
3. The operation will not become a threat to public health, safety, or the environment. Yes No
4. The operation is enclosed. N/A Yes No
Identify the Type or Manner of Enclosure for the Operation
5. The operation is covered. N/A Yes No
Identify the Type or Manner of Cover for the Operation
6. The incoming recyclable materials are not contaminated by toxic substances at levels that may pose a significant threat to public health, safety, or environment; and procedures are in place to prevent the acceptance of recyclable materials contaminated by toxic substances. Yes No
7. Identify the types of recyclable materials (i.e., bottles & cans, paper, etc.) that will be handled at this operation:

Types of Incoming Recyclable Material	
N/A	N/A
N/A	
N/A	N/A
N/A	
N/A	N/A

8. During processing, the recyclable materials are not contaminated by toxic substances at levels that may pose a significant threat to public health, safety, or environment; and procedures are in place to prevent the recyclable materials from being contaminated by toxic substances during processing. Yes No
9. The products are not contaminated by toxic substances at levels that may pose a significant threat to public health, safety, or environment; and procedures are in place to prevent the recyclable products from being contaminated by toxic substances. Yes No

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V. General Permit Requirements: Recycling Operation (Continued)

10. Identify the types of each of the operation's products and their uses:

Product Type	Use of Product
N/A	N/A

11. The operation will comply with one of the following residual rates for the specific type of recycling (check the applicable box):

- For single stream recycling, the residuals are no more than 15% by weight of the total amount of materials received in any quarter. For all other types of recycling operations, the residuals are no more than 10% by weight of the total amount of materials received in any quarter.

12. The percentage of residuals will be calculated using (check the applicable box):

- A Weigh Scale Standard Conversion Factors

13. If standard conversion factors are to be used, identify/describe the conversion method/formula:

N/A

14. The operation limits the storage of materials, in their as-received, in-process or processed condition, to one year from the date of their receipt at the operation. This time limit may be exceeded in the case of storage of a processed material pending accumulation of one full container load. Yes No
15. All waste materials generated during the recycling process are disposed in compliance with all applicable federal, state, and local laws and regulations. Yes No
16. The operation has obtained all other applicable MassDEP permits or approvals (e.g., Beneficial Use Determination, Stormwater Permit, Air Quality Permit, etc.). Yes No



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V. General Permit Requirements: Recycling Operation (Continued)

17. List all other MassDEP approvals below:

Other MassDEP Approvals or Permits with Transmittal Numbers	
N/A	N/A

18. The owner or operator will maintain accurate records for at least three years to demonstrate compliance with 310 CMR 16.04. Yes No
19. The owner or operator will submit a report and certification pursuant to 16.06(1)(a)3. to MassDEP by February 15 of each year that includes, but is not limited to, the amounts and types of recyclable materials received and the amount of residuals managed during the previous calendar year. Yes No



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VI. General Compliance Requirements: Composting & Aerobically or Anaerobically Digesting Organic Materials (310 CMR 16.04(3)(a))

Provide the requested information by checking the appropriate box to indicate the operation is in compliance with the following requirements for composting and aerobic or anaerobic digestion operations:

1. The operation is at least 250 feet from any existing water supply well in use at the time the operation begins operation. Yes No
2. The operation will not have unpermitted discharges of pollutants to the air, water, land or other natural resources of the Commonwealth. Yes No
3. The operation will not create a public nuisance. Yes No
4. The operation will not become a threat to public health, safety, or the environment. Yes No

The operation incorporates the following best management practices:

5. Produces stabilized organic materials. Yes No
6. Maintains proper thermal regulation and monitoring to prevent spontaneous combustion, destroy pathogens and prevent vectors. Yes No
7. Manages stormwater and leachate to prevent ponding and water pollution. Yes No
8. Has access to an adequate water supply with adequate pressure for fire control. Yes No
9. Employs the appropriate number of properly trained personnel for the size and type of the operation to properly maintain the operation. Yes No
10. Uses equipment that is appropriate for the size and type of the operation. Yes No

The operation has developed and will implement the following plans appropriate for the size and type of operation being operated:

11. A Toxics Control Plan that includes: Yes No
 - Procedures to minimize the entry of toxic materials and to prevent the organic materials and/or products from becoming contaminated by toxic substances (i.e., specifications for incoming organic materials, load inspection protocols, etc.) at levels that may pose a significant threat to public health, safety, or environment; and
 - Specific actions to be taken by personnel to prevent contamination.
12. An Odor Control Plan that includes: Yes No
 - Procedures to prevent the production and generation of odorous compounds; and
 - Specific actions to be taken by personnel that will be taken to address odors and odor complaints if unacceptable odors occur beyond the property line of the operation.
13. A Vector Control Plan that includes: Yes No
 - Procedures to prevent the organic materials and/or products from vector attraction before, during, and after composting, aerobic digestion, or anaerobic digestion; and
 - Specific actions that will be taken to address vectors and vector complaints if unacceptable vectors are present.
14. A Contingency Plan that includes all of the following: Yes No
 - Procedures for corrective actions for the management of the organic materials and/or products in the event of equipment breakdown, delivery of unacceptable loads of materials, spills, fires, extreme weather conditions or other events, including but not limited to the failure of the odor control plan or vector control plan.

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VI. General Compliance Requirements: Composting & Aerobically or Anaerobically Digesting Organic Materials (Continued)

15. Identify the types and sources (i.e., supermarket, restaurant, food processor, residential food collection, farm, etc.) of organic materials that will be handled at this operation:

Type of Incoming Organic Material	Sources of Incoming Organic Material	
Vegetative Material	Landscapers	Boston residents
	Vegetable and fruit Crop residue	food distributors & processors
	Spent grain & hops	Local breweries
	Coffee grounds	Local coffee shops
Food Material	Residential Source separated	Bootstrap compost
	Commercial Source separated	Save that Stuff, EOMS
	Institutional source separated	Dept of Corrections, Boston Public Schools, Shattuck
	Haymarket, farmers markets	restaurants, supermarkets
Agricultural Material	Manure & bedding	Zoo New England
	community gardens, urban farms	
	Ornamental crop residues	
Biodegradable Products	bioplastic service ware, bags	
Biodegradable Paper	Paper leaf bags	
	Paper plates, bowls and cups	

Table Continues on Next Page ►



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VI. General Compliance Requirements: Composting & Aerobically or Anaerobically Digesting Organic Materials (Continued)

Type of Incoming Organic Material	Sources of Incoming Organic Material	
Clean Wood	Wood chips	local arborists
	brush	Landscapers
	trucking/shipping wood pallets	
	source separated by construction co.	
Yard Waste	Commerical landscapers	Boston Parks Department
	Boston residents	Boston Housing Authority
	Private haulers	Local Universities/colleges
	Boston Public works	Local municipalities

10. Identify the types of each of the operation's products and their uses:

Product Type	Use of Product
Wood chip mulch	Stormwater control, weed suppression, moisture retention, aesthetics
Bark mulch	Stormwater control, weed suppression, moisture retention, aesthetics
Screened compost	food production, ornamentals, turf and perennials
Screened vermicompost	premium plant organic fertilizer, houseplant
Compost tea	turf management
Firewood	renewable energy- domestic heating

10. The residuals produced during any quarter will not exceed 5%, by weight, of the total amount of material received by the operation. Yes No

11. The percentage of residuals will be calculated using (check the applicable box):

A Weigh Scale

Standard Conversion Factors

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VI. General Compliance Requirements: Composting & Aerobically or Anaerobically Digesting Organic Materials (Continued)

12. If standard conversion factors are to be used, identify/describe the conversion method/formula:

Loose leaves : 5 cy/ton, food waste 1.33 cy /ton, grass clippings 3 cu yd/ton, herbivore manure and bedding 4 cu yd/ton

- 13. The operation limits the storage of materials, in their as-received, in-process or processed condition, to one year from the date of their receipt at the operation. This time limit may be exceeded in the case of storage of a processed material pending accumulation of one full container load. Yes No
- 14. The operation manages all solid and liquid materials produced as a result of the operation in accordance with all other applicable regulations and approvals, including but not limited to, a beneficial use determination, if necessary. Yes No
- 15. All waste materials generated during the composting, aerobic digestion, or anaerobic digestion processes are disposed of in compliance with all applicable federal, state, and local laws and regulations. Yes No
- 16. The operation has obtained all other applicable MassDEP permits or approvals (i.e., Beneficial Use Determination, Stormwater Permit, Air Quality Permit, etc.). Yes No
- 17. List all other MassDEP approvals below:

Other MassDEP Approvals or Permits with Transmittal Numbers	
N/A	

- 18. The owner or operator will maintain accurate records for at least three years to demonstrate compliance with 310 CMR 16.04. Yes No
- 19. The owner or operator will submit a report and certification pursuant to 16.06(1)(a)3. to MassDEP by February 15 of each year that includes, but is not limited to, the amounts and types of recyclable materials received and the amount of residuals managed during the previous calendar year. Yes No



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VII. Additional Compliance Requirements: Composting Operation (310 CMR 16.04(3)(b))

Provide the requested information by checking the appropriate box to indicate the composting operation is in compliance with the following requirements in addition to the requirements in Section VI:

1. The operation limits the total amount of organic material, whether as received, in process or final product, to no more than 5,000 cubic yards per acre. Yes No
2. The operation limits the total amount of organic material, whether as received, in process or final product, to no more than 50,000 cubic yards of organic material on site at any one time. Yes No
3. The operation does not allow more than 25% by volume of the total compost mixture to be a Group 2 Organic Material (see Instructions for more information). Yes No
4. The operation provides and uses adequate and appropriate bulking material consisting of Group 1 organic materials (see Instructions for more information) and ensures that such material is readily available on-site to mix with incoming Group 2 organic materials or other organic materials with a carbon to nitrogen ratio of 30:1 or less. Yes No
5. The operation mixes all Group 2 organic material or other organic materials with a carbon to nitrogen ratio of 30:1 or less into the compost windrows or piles to such an extent that the Group 2 material is unrecognizable as a separate material as soon as possible but no later than the close of business each day. Yes No
6. The operation aerates the compost on a timely and regular basis to ensure proper aerobic, temperature, moisture and porosity conditions. Yes No

VIII. Additional Compliance Requirements: Aerobic or Anaerobic Digestion Operation (310 CMR 16.04(3)(c))

Provide the requested information by checking the appropriate box to indicate the aerobic or anaerobic digestion operation is in compliance with the following requirements in addition to the requirements in Section VI:

1. Group 2 organic material generated off-site, are transported via sealed tank or vessel and delivered to the operation using a direct connection (e.g. hose) technology. This requirement does not apply to an operation that accepts less than 15 tons per day of Group 2 organic materials. Yes No
2. Organic materials are only handled in sealed tanks or vessels, with odor controls. Yes No
3. All organic materials are added to the active digestion system or stored in sealed tanks or vessels, with odor controls, by the close of business on the same day that it is received at the operation. Yes No



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General Permit Certification Form for New or Newly Acquired Recycling, Composting,
Aerobic or Anaerobic Digestion Operations Pursuant to 310 CMR 16.04

IX. Certification

"I attest under the pains and penalties of perjury:

1. That I am duly authorized to bind the entity (corporation, limited liability corporation, public entity, trust, partnership or sole proprietorship, etc.) which is subject to these regulations:
2. that I have personally examined and am familiar with the information contained in this submittal, including any and all documents accompanying this certification statement;
3. that, based on my inquiry of those individuals responsible for obtaining the information, the information contained in this submittal is to the best of my knowledge, true, accurate, and complete;
4. that procedures and plans to maintain compliance are in place at the operation and will be maintained even if processes or operating procedures are changed;
5. that I am fully authorized to make this attestation on behalf of this operation; and
6. that I am aware that there are significant penalties, including, but not limited to, possible administrative and civil penalties, fines and imprisonment, for submitting false, inaccurate, or incomplete information."

Signature of Responsible Official

Bruce R. Fulford

Print Full Name

President

Title

10/11/2013

Date of Certification (MM/DD/YYYY)

Appendix B

Food Safety Modernization Act, Public Law 111-353; Biological Soil Amendments: Subpart F

The proposed rule identifies possible routes of microbial contamination of produce and sets requirements to prevent or reduce the introduction of pathogens. Biological soil amendments of animal origin, such as composted manure, are one identified route of contamination because they may contain pathogens of public health concern.

Background

The FDA-issued proposed rule focuses on biological soil amendments of animal origin because of the potential for these types of soil amendments to contaminate produce with pathogens of public health concern. Currently, *within the U.S., composting of animal manure is not specifically regulated by any federal agency with respect to the safety of its use in the broad production of all produce.* Instead, state and local regulations in some cases provide oversight, but this varies in scope and complexity

Requirements:

- Establishes requirements for determining the status of a biological soil amendment of animal origin as treated or untreated, and for their handling, conveying, and storing (proposed §§ 112.51, 112.52);
- Prohibits the use of human waste for growing covered produce except in compliance with EPA regulations for such uses, or equivalent regulatory requirements (proposed § 112.53);
- Establishes requirements for treatment of biological soil amendments of animal origin with scientifically valid, controlled, physical and/or chemical processes or composting processes that meet or exceed specific microbial standards (proposed §§ 112.54 and 112.55);
- Establishes application requirements and minimum application intervals for untreated and treated biological soil amendments of animal origin (proposed § 112.56); and
- Requires certain records, including documentation of application and harvest dates relevant to application intervals; documentation from suppliers of treated biological soil amendments of animal origin, and scientific data or information relied on to support any permitted alternatives to requirements (proposed § 112.60).

Alternatives

You may establish and use alternatives to the composting treatment processes established in §112.54(c)(1) and (c)(2), and for the minimum application intervals established in § 112.56(a)(1)(a) and in § 112.56(a)(4)(a), provided you have adequate scientific data or information to support a conclusion that the alternative would provide the same level of public health protection as the composting treatment processes and the minimum application intervals established in the proposed rule and would not increase the likelihood that your covered produce will be adulterated under section 402 of the Federal Food, Drug, and Cosmetic Act.

Microbial Standards for Treatment Processes (Proposed §§ 112.54 and 112.55)

The following treatment processes would be acceptable for biological soil amendments of animal origin used in the growing of covered produce under the proposed rule. The choice of treatment process used affects the application options available under proposed §112.56 [see next section below].

1. (Proposed §§ 112.54(a) and 112.55(a)) Scientifically valid controlled physical processes (for example, thermal), chemical processes (for example, high alkaline pH), or combinations of scientifically valid controlled physical and chemical processes that have been demonstrated to satisfy each of the following microbial standards:

<i>L. monocytogenes</i>	Not detected using a method that can detect one CFU per five gram analytical portion
<i>Salmonella species</i>	Less than three (3) MPN per four (4) grams of total solids (dry weight basis)
<i>E. coli</i> O157:H7	Less than 0.3 MPN per one gram analytical portion

2. (Proposed §§ 112.54(b) and 112.55(b)) Scientifically valid controlled physical processes, chemical processes, or combinations of scientifically valid controlled physical and chemical processes that have been demonstrated to satisfy each of the following microbial standards:

- Less than three MPN *Salmonella species* per four grams of total solids (dry weight basis); and
- Less than 1,000 MPN fecal coliforms per gram of total solids (dry weight basis).

3. (Proposed §§ 112.54(c) and 112.55(b)) scientifically valid controlled composting processes that have been demonstrated to satisfy each of the following microbial standards:

- Less than three MPN *Salmonella species* per four grams of total solids (dry weight basis); and
- Less than 1,000 MPN fecal coliforms per gram of total solids (dry weight basis).

The proposed rule identifies two scientifically valid controlled composting processes that meet these microbial standards, and allows farms to establish alternative composting processes if they meet the same microbial standards and provide the same public health protection as the proposed rule and do not increase the risk of adulteration. The two identified composting processes are:

- Static composting that maintains aerobic (i.e., oxygenated) conditions at a minimum of 131°F (55 °C) for 3 days and is followed by adequate curing, which includes proper insulation; or
- Turned composting that maintains aerobic conditions at a minimum of 131°F (55 °C) for 15 days, with a minimum of five turnings, and is followed by adequate curing, which includes proper insulation.

Appendix C

Greenhouse Gas (GHG) Emission Implications for ZNE Facility

Literature Review Summary

Multiple papers on the carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and other gas emissions relevant to climate change have been prepared in recent years with specific considerations for the composting of food scraps, manure, leaves, and other biomass, and the use of compost. The most recent comprehensive study was prepared by the California Environmental Protection Agency through their California Air Resources Board (ARB) in 2011.⁵ Their methods built on the past work of the US Environmental Protection Agency (USEPA) and their Waste Reduction Model (WARM), studies of for the Intergovernmental Panel on Climate Change (IPCC) by Martinez-Blanco et al (2009), Blengini (2008), and other researchers.

A life-cycle analysis was performed to quantify and develop a compost emission reduction factor (CERF) for the net emissions from compost feedstock collection (transportation), composting process management (operations), and possible release of CH₄ or N₂O. Emission reductions were measured and totaled from increased soil carbon storage (CSb), decreased water use (Wb), decreased soil erosion (Eb), reduced fertilizer use (Fb), and reduced herbicide use (Hb).

Relevance to MCEC study at Zoo New England (ZNE)

The intent of this portion of the study is to assess the GHG implications of the proposed design and operating methods at ZNE, and any carbon offset potential. Markets for carbon offset payments have decreased in recent years, with uncertainty surrounding new GHG regulations, and a lack of cooperation and coordination among nations with the largest share of emissions. Nonetheless, state and regional goals for decreasing GHG emissions require planning, documentation, and analysis of new projects. Markets for carbon credits and similar schemes may improve in the future, although that timeframe is uncertain. Incentives from state or regional efforts may provide additional economic motivations to strive towards mitigation of emissions.

The California ARB, the USEPA, and the IPCC studies all document benefits from composting and compost utilization versus landfilling or other common solid waste management methods. The authors of this report intend to propose a design and operating plan that is equal or superior to the benefits described in the previous studies. In several cases, improvements on the typical CERF in California are also economically advantageous, such as reduced transportation costs from the local collection and composting of the zoo manure, neighborhood food scraps, leaves, and similar biomass.

The majority of the feedstocks proposed for composting inputs at ZNE are similar to the California Air Resources Board (ARB) study. One significant difference is the utilization of animal manure from the zoo and straw, hay, and wood shavings used as bedding. Other studies including Hao et al (2001) have examined emissions from feedlot manure composting and other manures. Importantly, feedlot manure is typically more dense, wet, and lower in carbon (C) to nitrogen (N) ratios than the zoo manure with abundant carbon-rich bedding.

5

Transportation emissions are one of several sources in the collection and processing phase of compost system management. The ARB used a typical distance from the point of generation (food scraps from grocery stores, leaves from municipalities, etc.) to existing commercial compost sites. The ZNE project makes an improvement on this, by reducing travelled miles (and corresponding emissions) for these Boston materials to landfills or to compost sites outside the urban area.

Process emissions in the ARB study are primarily from the diesel consumed by equipment in mechanically turned outdoor windrows. The ZNE project makes an improvement in this area by using the rotating drum and aerated static pile (ASP) methods of composting. There are significantly fewer hours spent on pay loaders and other diesel-powered equipment, as compared to the turned windrow composting method. Will Brinton, of Woods End Research Laboratory in Mount Vernon, ME, describes an ASP composting facility as using 25% of the total energy per ton of a turned windrow facility. This includes the electrical consumption of aeration fans versus diesel consumption of loaders and turning equipment.

The most significant sources of composting emissions in some scenarios come from CH_4 and N_2O . A wide set of variables influence these releases, including the carbon and nitrogen ratio of the feedstocks, the form and availability of carbon, (i.e. cellulose or lignin), the oxygen levels within the active composting mass, and moisture content. Those factors are further influenced by the porosity (bulk density of the mixture), the rate of aeration, pH, and feedstock particle sizes. Further, the existence or absence of biofiltration (odor control using carbon-rich material such as wetted shredded brush and wood chips), can affect the volume of fugitive CH_4 and N_2O .

As noted in the ARB report, methane (CH_4) from commercial composting operations was determined to be nearly zero due to the management and active turning of the windrows. Past studies found CH_4 to be present in compost windrows that were not turned or aerated. Such poorly managed windrows, with irregular density and portions of high moisture content, foster anaerobic conditions that favor biochemical processes and microbes that generated CH_4 and other biogas (2). Further, CH_4 would often oxidize if it formed in the core of the pile and then was exposed to oxygenated conditions as the gas migrated towards the surface of the windrow. The operating plan for ZNE is for active compost management, and the authors assume a similar GHG profile to the ARB CERF figures, with similarly low methane emissions.

Also noted in the ARB report, Hao study, and other papers, nitrogen (N) gas emissions from composting are influenced by C:N ratio, availability of C, rate of aeration and/or turning, pH, temperature and moisture content. While for compost producers this has often been most important for the conservation of N as an important source of plant fertility, the GHG implications are connected to fugitive nitrous oxide (N_2O) emissions. N_2O is an even more potent GHG than CO_2 or CH_4 (3).

The ARB study, the IPCC report, and others found that at composting facilities, N_2O emissions are highly variable, but were likely influenced by higher nitrogen feedstocks, such as manure, that were not mixed with available forms of carbon (lower C:N ratio). The ARB calculated a typical value of N_2O emissions to be 1/3 of CH_4 emissions. The ZNE operating plan is to avoid low C:N ratios in the mixed feedstocks, and therefore conserve N in the material to both have a higher fertility value end produce and minimize N_2O emissions. The ARB study also focused on outdoor turned windrow composting facilities and the ZNE plan is for aerated rotating drum and ASP composting with biofiltration. There is no biofiltration process in outdoor turned windrows for odor control or treatment/conversion of GHG emissions. However in the rotary drum and ASP composting method, negative aeration (vacuum) directs compost vapor into

ductwork. This is done to accomplish heat capture (thermal energy transfer) and to direct exhaust to a biofilter. The biofilter when operated in the desired range will effectively reduce potential odors and provide additional microbial and exchange sites to convert CH₄ and N₂O into non-GHG forms. As a result, the authors believe the ZNE project will result in lower levels of GHG emissions than modeled for typical CA composting operations.

The compost use emission reductions occur when the composted product from food scraps, leaves, manure and other biomass is applied to agricultural land and landscapes, and/or other urban soil with degraded conditions. Compost applications increase soil health and other physical soil properties, while providing plant fertility (N, P, K, and other nutrients) from local residuals (as opposed to fossil fuel sources, especially for N).

There are no major differences in the intended end use of the compost product from the assumed uses in the ARB study. Minor differences may include a greater portion of the ZNE compost being used in landscaping and stormwater infrastructure projects in the greater Boston area, and a smaller portion being used in agriculture such as urban gardens. The other difference worth noting is the compost benefit assigned to emission reductions due to decreased water use. The arid climate in CA results in a greater need for irrigation of crops and landscapes, and there are large costs associated with energy and water infrastructure use. That being noted, New England has experienced and is expected to experience an increase in severe precipitation events along with extended drought periods as an effect of climate change.

The authors invite and welcome interest from researchers to document the specific GHG emissions from the proposed project. The team will be reaching out to contacts at University of New Hampshire, Cornell University, and the University of Washington for additional guidance on best methods to assess GHG emissions for this project.

Citations

1. CA Air Resources Board (2011). Method for Estimating Greenhouse Gas Emission Reductions from Compost from Commercial Organic Waste. Planning and Technical Support Division, ARB, California Environmental Protection Agency.
2. Hao X, Chang C., Larney FJ., and Travis GR. (2001). Greenhouse gas emissions during cattle feedlot manure composting. *Journal of Environmental Quality* 2001 Mar-Apr, 30(2): 376-86, erratum in *Journal Environmental Quality* 2002 Mar-Apr;31(2):700. Agriculture and Agri-Food Canada, Lethbridge Research Centre, P.O. Box 3000, Lethbridge, AB, Canada T1J 4B1.
3. IPCC (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
4. USEPA (2009). Inventory of U.S. greenhouse gas emissions and sinks: 1990-2007. United States Environmental Protection Agency.

Appendix D

Utility rates

2013 NSTAR Electric rates (Jul - Dec 2013)

Residential: \$0.07506 per KWH

Sm Comm: \$0.07426 per KWH

Lg SEMA: \$0.07042 per KWH

Lg NEMA: \$0.07239 per KWH

National Grid Gas rates: Residential/Commercial
\$0.4644 per THM

Appendix E

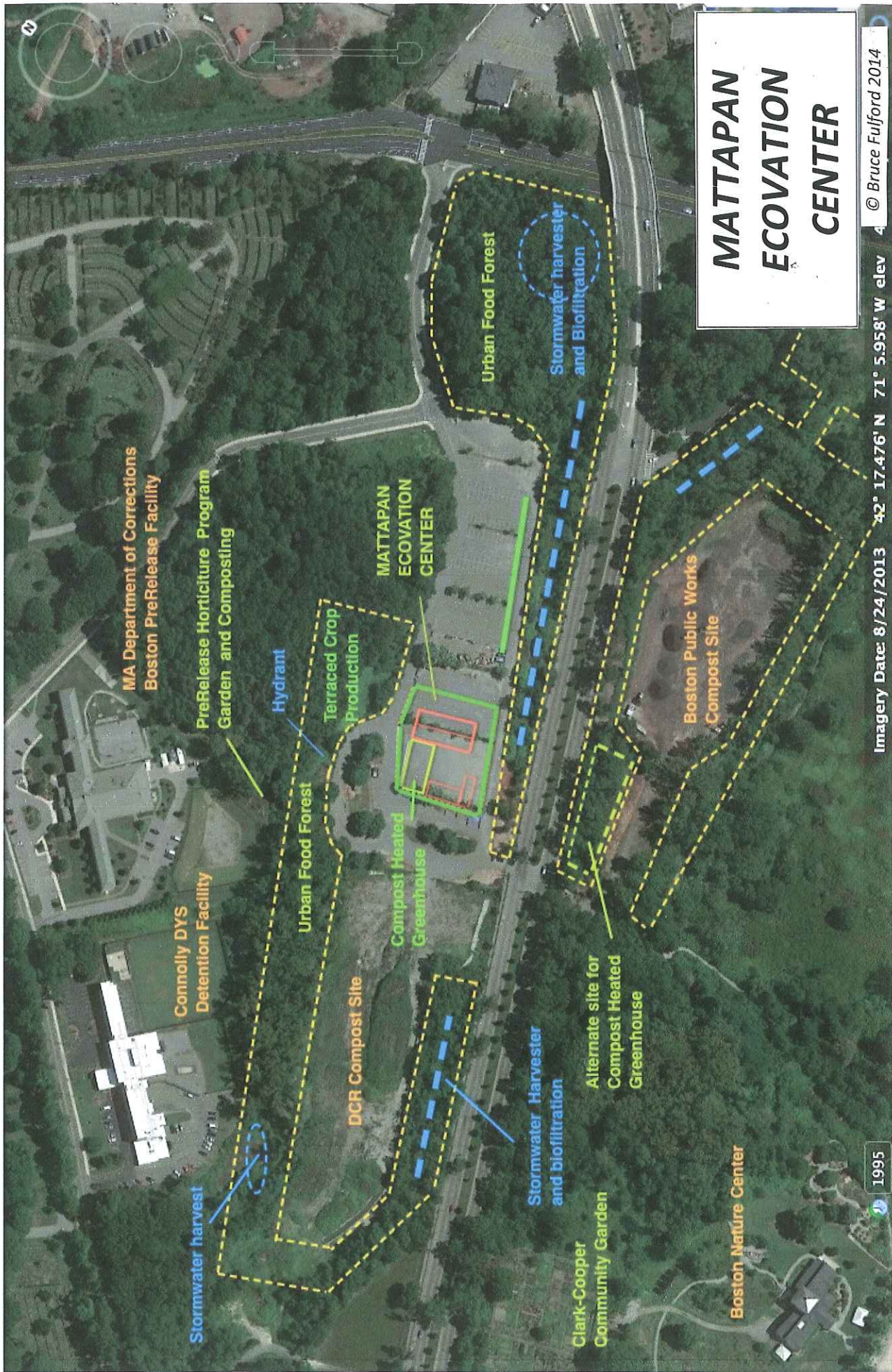
List of Stakeholders Contacted Community Engagement Plan for the Integrated Composting Bioenergy and Greenhouse Facility at Franklin Park Zoo

Governmental organizations	Name & Title	Date(s) of meeting
Boston City Councilors	Matt O'Malley Tito Jackson Ayana Pressley Charles Yancey Michelle Wu Michael Flaherty Tim McCarthy Frank Baker Charles Yancey	May 15, 2012 March 9, 2013 March 9, 2013 May 6, 2012 March 17, 2014 Feb. 6, 2014 Feb 4, 2014 & March 4, 2014 Feb 20, 2014 & March 24, 2014 September 21, 2014
Boston Dept. of Neighborhood Development	Aaron Schleifer Sr. Analyst, Office of Business Development	March 6, 2013
Boston Inspectional Services Dept.	Brian Glascock, Commissioner	April 5, 2013 May 4, 2013
Boston Parks & Recreation Department	Antonia (Toni) Pollak, Commissioner David Dederer, Senior Engineer Bernie Lynch, Superintendent Tom Williams, Senior Horticulturalist	April 27, 2013 April 5, 2011 April 15, 2013 May 3, 2013
Boston Public Health Commission	Vivian Morris Senior Project Manager - Policy & Planning	May 2, 2013
Boston Public Schools Department	Phoebe Bierle, Green Schools Initiative	Feb 12, 2013
Boston Water & Sewer Dept.	John Sullivan, Chief Engineer Amy Schofield, Project Manager Charlie Jewell – Senior Engineer, CEO	March 11, 2011, September 26, 2014
Boston Conservation Commission	Chris Busch Executive Secretary Stephanie Kruell, Executive Secretary	March 1012
Boston Energy & Environmental Services Environment Department Energy Department	Brian Swett, Chief Nancy Girard, Commissioner Brad Swing, Director -Energy Planning	Dec. 2013 Jan 6., 2014 Dec. 2013 Jan. 2014
Boston Redevelopment Authority	John Dalzell, Senior Architect for Sustainability, LEED AP, Board of Directors US Green Buildings Council	Feb. 2014 Sept. 20, 2014 March 11, 2013
Boston Water & Sewer Commission	John Sullivan, Chief Engineer Amy Schofield, Project Manager Charlie Jewell – Senior Engineer	March 5, 2014 Sept. 26, 2014
Mass. State Representatives	Russell Holmes	March 7, April 1, May 11, 2013

	Liz Malia Jeffrey Sanchez	March 28, 2012 June 2, 2012
Mass. State Senator	Sonia Chang-Diaz	April 5, 2010
Suffolk County Conservation District	Matthew Goode, Administrator Glynn Lloyd, Supervisor	April 4, 2013 Jan- May 2014
Community Organizations & Community Members	Name & Title	Date of meeting
Boston Natural Areas Network	Valerie Burns, Executive Director Vidya Tikku, Acting Executive Director	May 7, 2013
Clark-Cooper Community Gardeners	Jim Clark, President Dollie Taylor, Vice President Board of Directors	April 2, 2013 October 1, 2014
The Food Project	Danielle Andrews, Greenhouse Manager	April 17, 2013
ACE (Alternatives for Community & Environment)		April, 2014
Mass. Audubon Society/Boston Nature Center	Julie Brandlen, Executive Director Lou Wagner, Regional Scientist	March 17, 2013
MIT Urban Studies Institute	Mel King	March 28, 2013 April 22, 2014
Olmsted Green Complex	Olinka Briceno, Community Coordinator Leighton Belden, Resident	April 1, 2013 April 17, 2014 April 17, 2014
Mattapan Food & Fitness Coalition	Vivian Morris	May 14, 2013
Franklin Park Coalition	Christine Poff, Executive Director	February 12, 2014
Emerald Necklace Conservancy	Julie Crockford, President Mike Dukakis - Board of Directors Peter Barber - Board of Directors Ferris Donham - Board of Directors Ray Oladapo-Johnson Director of Planning	
Boston Conservation Commission	Chris Busch, Executive Secretary Stephanie Kruell, Executive Secretary	March, 2012 December, 2013

Appendix F

Ecovation Center



MATTAPAN ECOAVATION CENTER

Imagery Date: 8/24/2013 42° 17.476' N 71° 5.958' W elev 4 © Bruce Fulford 2014

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