FINAL REPORT

SMALL TO MEDIUM SCALE COMPOSTING OF FOOD WASTES IN NEW YORK CITY

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EXECUTIVE SUMMARY

SMALL TO MEDIUM SCALE COMPOSTING OF FOOD WASTES IN NEW YORK CITY

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II Purpose of the Study

Composting is one means of reducing the problems associated with landfills, incinerators, and other waste disposal methods. In urban areas, the dense concentration of business, industry, and housing results in large quantities of waste being generated in a relatively small geographic area, which creates unique opportunities for recovery. However, the density of urban areas also presents certain challenges. For one, composting requires space, which is scarce and expensive. In addition, given the likely proximity of neighbors to any site selected, the composting process must be strictly controlled in order to avoid odors and pests. Through this project, we sought to install and test different small- to medium-scale "in-vessel" composting technologies at a number of locations around New York City. In-vessel technologies are those systems that enclose the composting materials, thereby allowing for the efficient use of space and the capture and treatment of exhaust gases. The project was undertaken with two learning objectives:

To determine the technical and economic feasibility of on-site composting in urban areas by evaluating four small- to medium-scale, in-vessel composting systems at various commercial, industrial, and institutional locations in New York City.

To install permanent, on-site composting systems at two or more locations in the city, providing a combined annual processing capacity of 750 tons of food waste.

During the course of the project, the key market barrier identified was the cost (capital and operating) associated with the in-vessel systems currently on the market, relative to collection and disposal of wastes by a private waste hauler. Furthermore, the project highlighted other considerations vis-a-vis wide-scale implementation of on-site, in-vessel composting. Composting is a living, dynamic process, thus the maintenance of a composting system requires more attention and training than standard recycling and disposal alternatives. In addition, the proper mix of ingredients is required for optimal composting conditions (e.g., moisture level, C:N, porosity). Thus, an on-site food waste composting program may entail locating and acquiring other ingredients such as shredded paper, wood shavings, or wood chips, some of which may have to come from off site.

III Project Summary

During the course of the project we conducted evaluations of four different in-vessel technologies:

The "Earth Tub" from Green Mountain Technologies;
The Wright Environmental Composting Container;
Open Road of New York's "Hot Box"; and
The "Compost Man Pro", designed by Compost Man, LLC.

Each system was either leased and installed at a suitable NYC location, or was evaluated at an existing on-site installation in NYC. City Green, Inc. provided the on-site technical assistance -- installing equipment as needed, establishing waste collection programs, locating bulking agents, training staff, etc. Cornell provided the monitoring equipment and protocol, and performed the laboratory and economic analyses.

Waste throughput was measured by weight; temperature readings were taken manually and with a computer-based temperature recording device; gas sampling and analysis was done with Drager tubes; pH readings were taken on-site and in the lab; the composting process was monitored by regular sampling and lab analyses of fresh and composting wastes for volatile solids, bulk density, compost stability, and nutrient levels; and economic evaluations were performed based on equipment costs, operating expenses, and NYC waste disposal costs.

During the course of the project, the technical viability of each technology was demonstrated through effective processing of food wastes. In some cases there were problems and issues in equipment design or operation that needed to be addressed before the system would perform properly. Nevertheless, each technology did ultimately function, and together they represent a broad selection of equipment options with a range of throughput capacities (from less than 100 lb to several tons per day) and required capital expenditure (from $300 to $100,000+).

The per ton costs for managing food waste in these on-site systems was high relative to current NYC disposal costs. Note that the costs summarized here largely reflect the systems as configured and operated at the four sites studied. Thus, they are not necessarily "fully optimized" to minimize costs. Nor do they consider all current or planned investments in processes that precede or follow on-site composting. On the front end, such investments can significantly affect the characteristics and marketability of the compost that is produced.

On an annualized basis (and assuming that the installed system was used to capacity whether or not this was actually the case), the costs of composting machinery and accessory equipment alone ranged from an estimated $58 per ton for the Hot Box installation to an estimated $173 per ton for the Wright Environmental Compost Container. The comparable figures for the Compost Man Pro and Earth Tub installations were approximately an intermediate $68 and $95 per ton respectively. Consideration of additional fixed costs (primarily site improvements, but excluding lands costs) increases the annualized per ton cost at each installation by approximately $20 to $25, with the exception of the Hot Box installation, which incurred no significant additional fixed costs.

Per ton operating costs must be added to these figures to reflect full costs. Assigning a "going wage" rate to the labor hours involved results in high additional per ton operating cost estimates of $126 for the Compost Man Pro installation, $161 for the Hot Box installation, $173 for the Earth Tub installation, and $230 for the Wright Environmental Compost Container installation. Actual "out of pocket" operating costs are significantly less, as labor is typically reassigned from other food or waste handling tasks rather than hired for the composting operation. The observation that labor accounts for the bulk of the operating costs at each compost site (ranging from nearly three-quarters of calculated operating costs at the Compost Man Pro installation to essentially all such costs at the Hot Box installation), suggests that the ability to keep operating costs low rests primarily in the ability to keep incremental labor costs low.

The carting costs associated with food waste disposal were estimated to range from $60 to about $100 per ton. Estimated savings in carting fees were less than estimated composting costs at all of the observed sites. Moreover, none of the site operators earn significant revenues from compost sales. However, the operator of the Compost Man Pro operation is considering vermi-composting and marketing operations at a scale that, at least hypothetically, could lead to a revenue stream in excess of costs.

A more detailed description of each technology evaluation is provided below.

The "Earth Tub" from Green Mountain Technologies, Inc.

The Earth Tub installation at the New York Medical Hospital in Queens (NYMHQ) represents a technology that, after a series of modifications, has been successfully integrated into the grounds of an urban hospital.

Temperature profiles for the Earth Tub trials suggest that heating to proper temperatures for composting, pathogen kill, and weed seed destruction did occur, and that temperatures were maintained for a number of weeks. Odors were not a problem, even though the amount of nitrogen in the waste, generally 3% to 4%, was relatively high, probably reflecting a high percentage of meat scraps in the mix.

Not counting potential revenue from compost sales or offset in procurement of soil products for grounds maintenance, the hospital benefits economically from the composting system by reducing its waste carting bill. NYMHQ pays its carter a weight-based rate for waste disposal of approximately $0.03 per pound, or $60 per ton. With up to a half ton of food scraps composted per week at current loading rates, approximately $1,500 per year in disposal costs are avoided.

Assuming a modest value for the compost, the economic benefits to the hospital could conceivably approach $2,000 per year. However, if the full cost of labor is accounted for, operating costs alone are more than double this figure at nearly $5,000 per year, without including pre-composting food scrap preparatory labor. Assuming that all labor is simply redirected from less important tasks, the actual additional incremental operating costs are small. Still, with fixed investment costs exceeding $17,000, the project does not present an economically attractive proposition.

In sum, without subsidy or a more aggressive compost marketing strategy, it appears that economic incentives alone are unable to motivate investment in this kind of installation.

The Wright Environmental Container

The Canadian firm, Wright Environmental Management, Inc., has developed an in-vessel composting unit that is in use at a number of locations in Canada and the U.S. Wright has models ranging in capacity from a few hundred pounds up to several tons per day. During the course of the project we worked with two Wright units -- the WEMI #500 (total daily load: 500 pounds) and the WEMI #750 (total daily load: 750 pounds).

Our initial trials with the WEMI #500 at City College of New York were disappointing, and in retrospect, the complete odor control required for the indoor site selected was probably an unreasonable expectation for any composting technology. Operation of the second installation (a WEMI #750), at St. Barnabas Hospital in the Bronx, ran into problems due to a contaminated food waste stream. Thus neither of these trials provided for a thorough evaluation of the Wright system. However, the problems experienced were not with the technology itself, and a broader review of Wright installations around the country indicates that the technology does perform well, producing a reasonably stable compost product in 28 days, without odor problems.

Nevertheless, as with other units considered in this project, avoided collection and disposal costs (at current NYC rates) cannot justify the investment economically. With an $80,000 price tag ($82,000 including installation in 1996 dollars), the WEMI #750 has a per ton annualized, full-capacity processing cost of $173, based on capital costs alone (assuming a seven year equipment amortization). This does not take into account site preparation costs ($10,000 at St. Barnabas), leasing of land, or operating expenses.

The Compost Man Pro, from Compost Man, LLC

Outstanding Renewal Enterprises (ORE) operates the Compost Man Pro on a 10,000 square foot fenced area in the East River Park in Manhattan. This facility has an estimated capacity of 1.5 tons of food waste per day. It does not operate as an "on-site" system, since ORE collects food waste from the surrounding neighborhoods, including from consumers at the Union Square Farmer's Market. The Compost Man Pro has proven to be effective, producing a good compost product in an efficient time frame and providing sufficient odor control to make it suitable for urban installations.

Certain aspects of the operation are labor intensive. However, the operation is still under development and through experience and trials, processing is expected to become more efficient. The compost produced after 10 days is then moved to a vermi-composting system on the same site. The latter system was not included as part of this study.

Two issues – capital equipment that is being underutilized and the lack of product revenues – are the main factors affecting the current economics of the operation. The operation has these and several related hurdles to overcome if it is to transition from grant support to an independently viable business enterprise.

In total, based on the assumption that diversion of food scraps enables carters and/or generators to achieve a $60 per ton avoided cost savings, there is an estimated saving of nearly $9,000 per year associated with the 146 tons of food scraps currently being diverted into ORE's composting operation. The fact that ORE is operating at 50% or less of the rated processing capacity, implies that ORE could double collection quantities. Thus, a ball-park estimate of $15,000 to $20,000 in potential annual avoided costs could be associated with this facility. Some of this savings could presumably be shifted from the generators to the food scrap collector (ORE) through a collection fee.

In a full cost accounting framework, a site rental or acquisition charge ought to be assigned to the operation. However, in this case, the actual cost is $0. While a significant expenditure for site acquisition or rental could make sense for a strong business marketing a profitable compost product, generally speaking, urban composting will likely involve underutilized land or space with a relatively low value in any alternative use. It is likely to be either on the generator's own property or, as in ORE's case, at a site that is made available to the composter. The Parks Department seem relatively well positioned to provide such space for several reasons, not the least being their own routine need to manage their yard trimmings, which can be incorporated into this system as a carbon source.

ORE's total labor is approximately one hour daily (six days per week) plus somewhat less than two hours on the four to five days a week that a new box is started. Note that labor data do not include administrative activities. Total annual operating costs including labor, utilities, fuel, maintenance, and the like are estimated at $18,325. Note that these operating costs alone, even though they are based on a system operating at only roughly half capacity, are approximately the same as the maximum potential value of avoided disposal costs associated with operation at full capacity. Clearly then, the economic viability of the system depends upon a significant product sales revenue stream and/or significantly reduced costs.

Regarding product sales, ORE's current market price for worm castings produced after the vermi-composting step is $1 per pound in small quantity and $0.35 per pound delivered in quantity. At full-scale operation, the facility could theoretically produce 175 tons of marketable casting. Such a quantity of castings could be transformed into approximately 1,700 tons of potting soil mix, though the full associated costs have not been estimated. At a wholesale price of $0.10 per pound, there is at least the potential for nearly $350,000 in annual gross revenues from this operation.

In sum, the up front $140,000 investment in fixed costs for site improvements and equipment (nearly $170,000 including the collection truck) could conceivably generate a net revenue stream between $40,000 to $60,000 annually. While this estimate is based in large part on very tentative assumptions about implementation, it does suggest that an aggressive and successful production and marketing effort could ultimately result in a profitable enterprise with a reasonably short payback period if the vermi-culture process does not add significantly to the costs.

The "Hot Box" from Open Road of New York, Inc.

This technology is suitable as a small-scale, non-capital intensive approach to composting. The one cubic yard Hot Box with its passive aeration system requires relatively little space, no electricity, and little monitoring. The original prototype of the Hot Box was built in 1994. Subsequent trial and error, refinement and real world testing, led to the current design, for which a patent was awarded in 1998. Hot Boxes are currently in use at about 10 sites around NYC. These include public and private schools, community gardens, colleges, and restaurants. They are being used to compost a range of materials, including pre- and post-consumer food scraps, stable waste (horse manure and bedding), and grass clippings. For the monitoring program, we chose to work with two Hot Boxes installed in a greenhouse at the East Side Community High School in Manhattan.

Gas sampling for the Hot Box system showed lower oxygen levels than for some of the other systems, such as the Earth Tub, which operate with forced aeration. However, levels were still above 5 ppm and therefore considered satisfactory for aerobic composting. Nonetheless, this highlights the importance of porosity in the composting materials when using the Hot Box. The ammonia levels were low and were similar to those seen with the Earth Tubs.

The pH for the Hot Box as sampled on site was in the 6 to 7 range which is fine. When the pH goes above 9 or so, odors can be a problem, while too low a pH will kill the necessary microorganisms. By the time the samples were tested in Ithaca, the pH was a little higher, which may have been due to "anaerobic" conditions during transport and/or differences in the equipment/methods used to measure pH.

The temperature profile for the Hot Box showed good initial heating followed by a rapid temperature drop. This was sufficient for pathogen reduction, but suggests that much more curing will be required with materials obtained from this system as the total breakdown of organics is apt to be incomplete. In urban sites, the need for curing time and space may present a challenge.

Each Hot Box costs about $300 in materials and takes about seven hours to put together. This price assumes plastic lumber is used. Less expensive alternatives include plain pine (about $200) and plywood (potentially free, if used).

It is estimated that a system comprised of three Hot Boxes would be capable of processing seven to eight tons of dense or heavy food scraps per year. The capital costs for this system are estimated to total $2,225 (including an extra Hot Box for use as a curing bin), with an annualized value of $416 at a modest 8% interest. Annual on-site operating costs (essentially labor) are valued at $1,160.

On the benefits side, it appears the compost produced might have a value of as much as $7,200 per year (assuming 3.6 tons of compost at $1.00 per pound), and that, theoretically, there is a disposal cost avoidance of more than $400 per year. If it were indeed possible to market $7,200 of compost with minimal marketing costs, it is estimated that a small-scale entrepreneur might clear nearly $4,500 annually, in the context of a capital investment of $2,225.

IV Critical Factors/Issues Requiring Further Evaluation

On-site composting and composting in general could benefit from further study in the following areas:

1) Technology Improvements. Clearly, one of the largest obstacles to widespread composting is the cost of in-vessel technologies. Further research and development leading to more cost effective composting systems would make a large difference in the implementation of these systems.

2) Compostable Plastics. Compostable plastics have the potential to simplify food waste recovery and avoid compost contamination. With regard to such plastics, there are issues of cost,

availability, and compatibility with composting processes to be addressed.

3) Food Waste Compost Standards. Further research on food waste compost quality, and the development of standards and use guidelines would help in the marketing of food waste compost and the establishment of appropriate State regulations (as opposed to the bio-solids regulations, which currently apply).

4) Aesthetic Stability. At what point with each technology and composting process is the compost sufficiently processed so that it does not have an odor, attract vectors, or look like "food waste"? This is the point at which the compost might be moved to a less intensively managed (and less expensive) site while completing the thermophilic phase and subsequent curing. Park land may be appropriate for this purpose if no sale of finished compost is contemplated. Note that, under Part 360 regulations, this may also require permitting by the NYS Department of Environmental Conservation.

V Study Conclusions

The prospects for small- to medium-scale, in-vessel composting are mixed. On the one hand, there has been a tremendous amount of research and development in the private sector to the point were there are currently a number of functional and effective in-vessel composting systems available. On the other hand, the costs of purchasing and operating this equipment are difficult to justify given current waste disposal costs.

For institutions or businesses that have high waste disposal costs, and/or can capture significant value from the sale of compost, or are simply eager to implement an environmentally sound organic waste management program, there are now viable options that can effectively process food waste without odor or vector problems. Grant funding or other government subsidies could further encourage the implementation of composting programs. However, by and large, cost savings cannot be expected to lead to widespread adoption of these on-site composting systems, under current market conditions.

Cornell University intends to use the results of the project to continue to work with equipment designers to improve their equipment and lower the costs, and to look at alternative ways to accomplish intensive urban composting. The information gathered will also be used in education programs.

City Green, Inc. will continue to use the experience and information gained from the project in the promotion and implementation of on-site composting systems. There are a number of institutions, businesses, and municipalities that are eager to pursue on-site composting, and we are actively working to install systems at these locations. In addition, we will continue to closely track developments in the compost equipment industry, and work with vendors to make more cost-effective systems available.

VI Contact People

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List of Abbreviations

CCNY	City College of New York
CGI	City Green Incorporated
DOS	New York City Department of Sanitation
FHMC	Flushing Hospital Medical Center
GMT	Green Mountain Technologies
NYC	New York City
NYHQ	New York Hospital Queens
ORE	Outstanding Renewal Enterprises, Inc.
ORMD	Office of Recycling Market Development
WEMI	Wright Environmental Management, Inc.

PART 1. CITY GREEN ON-SITE REPORT

I. PROJECT BACKGROUND (Performance Targets)

Composting is the age-old process of converting organic waste materials into a key ingredient of soil -- humus. While composting has often been driven by the need to recover organic materials to maintain soil health, more recently, composting has been seen as a way of reducing the problems associated with landfills, incinerators, and other waste disposal methods. In urban areas, the dense concentration of business, industry, and housing typically results in large quantities of waste being generated in a relatively small geographic area. This concentration of waste creates unique opportunities for recovery.

However, the density of urban areas also presents certain challenges. For one, composting requires space, which is scarce and thus expensive. In addition, given the likely proximity of neighbors to any site selected, the composting process must be strictly controlled in order to avoid odors and pests.

Through this project, we sought to install and test different small- to medium-scale "in-vessel" composting technologies at a number of locations around New York City. In-vessel technologies are those systems that enclose the composting materials, thereby allowing for the efficient use of space and the capture and treatment of exhaust gases. We were interested in on-site as opposed to centralized composting systems for several reasons:

- Potential savings on waste transportation costs;
- The simplified regulations that govern on-site composting;
- The large number of waste generators in NYC and elsewhere that have expressed interest in on-site composting;
- The potential to improve the quality of the source separated waste and to establish better accountability;
- The small but growing number of companies developing and marketing in-vessel systems that can be sized to compost materials produced on site; and
- The potential for use of the finished product on urban soils.

This project was undertaken with two performance targets:

1) To determine the technical and economic feasibility of on-site composting in urban areas by evaluating four small- to medium-scale, in-vessel composting systems at various commercial, industrial, and institutional locations in New York City.

2) To install permanent, on-site composting systems at two or more locations in the city, providing a combined annual processing capacity of 750 tons of food waste.

We achieved our first objective, evaluating commercially available technologies through telephone and literature surveys, and subsequently installing, operating, and/or testing five different systems. Our second objective was also achieved, in as much as there are now several on-site composting systems installed in the city, which have been developed as a direct or indirect outcome of the project. However, we fell short of the quantitative aspect of the second objective, in that the combined annual capacity of these facilities is somewhat less than 750 tons. In fact, the total current capacity for on-site food waste composting that we are aware of in NYC (excluding backyard composting and the Rikers Island Compost Facility) is an estimated 450 to 600 tons per year.

Slow progress in developing on-site composting capacity can be attributed to a number of factors, which are discussed in this report. The most significant obstacle at this time appears to be the limitations and relative costs of the technologies currently available.

II. CHANGES TO THE WORK PLAN

There were several changes to the original project schedule. As described in this report, there were delays in installing equipment and implementing monitoring programs. The completion date for the project was also extended from October 31, 1997 to December 31, 1998. This extension, along with budget modifications, allowed us to work with more systems than originally anticipated and to help implement ongoing programs at more sites than planned.

III. SUMMARY OF FINDINGS

During the course of this project we had the opportunity to speak and work with many generators of organic waste, developers and vendors of compost technologies, consultants, government officials from other states and municipalities working with solid waste, and a variety of groups and individuals who have experience with on-site composting. Based on these contacts, as well as our own experiences, our principal findings can be summarized as follows:

- There is considerable demand for on-site composting, both in NYC and elsewhere in the state. The demand comes from institutions and commercial waste generators interested in the potential for cost savings and environmentally sound waste management.

- There has been a significant investment by the private sector in the design and manufacture of in-vessel composting technologies. While we still identify the relative cost and ease of operation of these systems as an obstacle to their widespread usage, the advances that have been made even during the course of this project have been tremendous.

- While we expect to see further improvements in in-vessel technologies in the years to come, there are systems that are currently available that have demonstrated their capacity to handle all types of food waste, successfully contain odors, ensure pathogen kill, and produce a quality compost product.

IV. COMPOSTING TECHNOLOGIES

For the project we considered a number of compost technologies developed by several companies. These included:
a) A small drum system by Augspurger Engineering;
b) A mid-sized drum from Bedminster/New Holland;
c) A silo-type system from Celto Canadian Envirosystems;
d) The Gaia Institute's in-vessel unit;
e) Two different systems designed by Green Mountain Technologies;

f) The Wright Environmental container;
g) Open Road of New York's Hot Box; and
h) A compost/vermi-compost hybrid designed by Compost Man.
Based on apparent suitability, size, projected costs, and availability of equipment, we chose to work with systems from the latter four providers.

A. Green Mountain Technologies, Inc.

Green Mountain Technologies (GMT) currently has available two different in-vessel compost systems -- the "Comptainer" and the "Earth Tub." The Comptainer is a 35 cubic yard enclosed roll-off type container, while the Earth Tub is a much smaller (approximately 750 gallons) unit. During this project, we considered testing both of these systems at different NYC locations. As described below, the Comptainer was ultimately not used. However, the Earth Tub, which was in the early stages of development at the time, was tested with several different prototypes.

Initially, we considered the Comptainer as an appropriate system to install at Blue Ridge Farms -- a large food processor in Brooklyn, generating 8 to 15 tons per day of cabbage leaves, onion skins, and potato peelings. Representatives at Blue Ridge expressed a willingness to participate in an on-site demonstration of composting equipment. Cabbage, potato and onion waste streams were sampled and analyzed, as were samples of various amendments.

Several locations at the Blue Ridge plant were reviewed for placement of the composting equipment. Six months after we began work at this site, Blue Ridge decided that they would not be able to provide the necessary space as expected. Consequently, demonstration of the Comptainer did not occur at Blue Ridge. Another appropriate site for the Comptainer was not identified for this project.

1. The Earth Tub - description of the technology and trials

In February 1996, we learned that GMT was developing a smaller in-vessel system, then called the "Mini-Comptainer" and later to become the Earth Tub.

The Mini-Comptainer was a 250 gallon insulated vat, 4' in diameter and 4' high. It was estimated that a two vat system could process 25 to 50 pounds/day of food waste. Each vat was constructed of high density polyethylene, and had a fiberglass lid with a hatch and removable cover for loading compostable materials. Cut into the side of each vat was an 18" square opening with a hinged door for removing composted material. Aeration was accomplished by drawing air down through the composting mass and through an aeration floor, which was covered with a 12" to 16" layer of wood chips. Air from the vat was drawn into a biofilter (a 60-gallon plastic can). Each biofilter was designed to accommodate two vats. Blowers, fixed to the biofilter, were controlled by adjustable timers. Leachate was collected at the bottom of the vat, and was meant to be pumped through a small tube attached to the floor of the vat. This tube was run through the aeration port at the base of the vat. The configuration required that the operator disconnect the aeration hose, attach a hand pump to the exposed end of the leachate tube, and pump the leachate into another container for disposal (i.e., into the sewer or an active composting vat).

Each vat was equipped with an auger to mix the material and augment aeration provided by the blower. The auger was fixed to a track assembly, which rode above a slot cut into the lid from the center to a point a few inches from the outer edge. The auger could be moved by rotating the lid and by sliding it back and forth along the track. The auger itself was made of steel and extended approximately 3' down into the vat. To power the auger, a portable power tool motor was attached to a gearbox in the track assembly. The motor was removable so that it could be used to mix a series of vats.

In June 1996, the first Mini-Comptainers were ready for demonstration, and a 4-vat system was purchased by DOS for the project. The initial plan was to use the system at The Parsonage, a 60 seat, high-end, restaurant located in the historic preservation area of Richmond Town on Staten Island. Due to delays in preparing a suitable site at the restaurant, the system was installed at the Flushing Hospital Medical Center (FHMC) in August 1996.

For the demonstration, FHMC provided space (30' x 40') in an unoccupied courtyard, which was surrounded on three sides by hospital buildings. Food waste was separated in the kitchens and cafeterias of New York Hospital Queens (NYHQ) -- a sister hospital located about a mile from FHMC -- and brought to the site by truck. Marriott Management Services, which provides food and maintenance services at both hospitals, provided assistance to the project with:
a) Waste separation and transportation;
b) Education within the hospital;
c) Preparing the site with fencing and utility hook-ups for the compost equipment; and
d) Loading, unloading, and monitoring the vats.

Loading of the vats commenced on August 21 and ceased on September 11. During this period, a total of 1,570 pounds of food waste and 390 gallons of amendment (approximately 1,200 pounds of wood chips and wood shavings) were loaded into two Mini-Comptainers. No material was removed during this period.

From the beginning, the equipment was put through very rigorous trials, both in terms of the quantities of waste loaded (up to 350 pounds in one day) and the composition of the waste (meat and dairy products, extremely wet and cooked food, etc.). From the beginning, we also began to identify problems with this first prototype and to work with GMT to find solutions. For example, the power tool motor used to turn the augers made excessive noise. GMT agreed to fabricate a housing for the motor to insulate the sound. However, even this proved insufficient and eventually the system was modified with a permanent electric motor replacing the portable motor.

On August 28, 1996, after five days of loading, the auger shaft broke while mixing vat #2. Loading of vat #1 continued, and on September 3, 1996, the auger in this vat broke. In order to continue to manage the material in these two vats, broken augers were replaced with augers from the unused vats. The broken augers were shipped to GMT for repair/replacement. GMT initially reinforced the augers with a steel sleeve, but these units also broke. On February 6, 1997, the gearbox in vat #1 cracked, rendering the auger useless. Through additional trial and error, these problems were addressed in the Earth Tub by using a heavy duty gear box/motor and stainless steel augers designed for heavy loads.

Removing leachate from the vats proved problematic. There was little space for collection inside the vat, causing leachate to fill the air hose. As a result, when the air hose was disconnected to access the leachate handling tube, leachate flowed onto the concrete pad on which the vats were sitting. At the same time, the tube was covered with leachate and difficult to handle. Leachate handling was later simplified and improved as described below.

Initially, rotating the auger and lid around the vat was relatively easy. However, as the vat became more filled, moving the auger back and forth along the track required two people and considerable effort. This problem was later addressed with a screw shaft that could be easily cranked to move the auger back and forth. In addition, the loading hatch in the lid was small (18" x 12"), which sometimes made loading a messy task. This hatch was significantly enlarged, as were the unloading doors on the sides of the vat. The latter, combined with other new Earth Tub design features, has greatly simplified unloading.

We experienced some odor problems in our initial trials with the Mini-Comptainers. As mentioned, leachate was difficult to contain, which resulted in a certain amount of odor. In addition, because aeration blowers were on timers and did not operate continually, odors were released from the vats when the blowers were not actively drawing air through the biofilter. These factors led to objectionable odors in the boiler room and engineering area, which were located directly below the site in the basement, and which were served by a large air intake vent 25 feet from the composting equipment.

On September 19, 1996, GMT delivered the next generation of the Mini-Comptainer to FHMC, where it was set up for testing. The new vat was 6' in diameter and 4' tall, with a capacity of approximately 600 gallons. This vat incorporated a number of improved features, including:
a) A larger loading hatch;
b) A screw shaft for moving the auger across the lid;
c) A reinforced auger;
d) A standard ball valve tapped through the wall of the vat near the floor for leachate drainage; and
e) A blower switch that allowed for continual or timed cycles of aeration.
The original power tool motor was still used to turn the auger, which continued to present a noise problem. In addition, on October 4, 1996, the auger shaft broke at a point just above the reinforcement sleeve.

Another new feature was an internal biofilter (a plastic cylinder approximately 18" x 36"), which was centered inside the vat. A blower was mounted at the center of the lid, where exhaust was vented. Because the biofilter was surrounded by composting materials that reached temperatures exceeding 140F, the biofilter media heated to the point where exhaust air could not condense inside the biofilter. As a consequence, the media became too dry, and due to its position within the vat, it was difficult to service. Subsequently, this biofilter was replaced with an external one, which remains the operating design of the Earth Tub.

During this phase of loading (September 19, 1996 to October 1, 1996), a total of 1,575 pounds of food waste was loaded into the 6' vat. As an odor control measure, aeration was operated in a continuous mode. This, along with better leachate management, resolved the odor problems experienced earlier. Temperatures between 104 and 144F were recorded. On December 12, 1996, compost was removed from both the 6' vat and the Mini-Comptainers and taken to the Queens Botanical Garden for curing at their windrow facility.

At this point in the project, none of the vats had been operated on a regular enough basis to conduct the planned monitoring program. However, the various parties involved with the project agreed to continue, along with a number of planned changes to the vats. GMT was to:
a) Equip each vat with a quiet, 2 horsepower electric motor to address the noise problem associated with mixing;
b) Provide an auger constructed of heavy gauge steel with a thicker shaft and a blower with a temperature feedback system for testing in the 6' vat;
c) Outfit the four original Mini-Comptainers with leachate drain valves and screw shafts for moving the auger along the track assembly; and
d) Equip the 6' vat with a 60-gallon barrel to replace the internal biofilter.

In September 1996, we delivered two Mini-Comptainers to The Parsonage on Staten Island, where a 15' x 15' fenced concrete pad was now prepared. In December 1996, the remaining two Mini-Comptainers and the 6' vat were moved to a new site at FHMC -- a 10' x 45' area sheltered under the overhang of an unoccupied hospital building. At both of these installations the vats were elevated on pallets to facilitate leachate handling, which was now based on gravity.

Upgrades to the equipment installed at the Parsonage were completed by the end of February 1997. Loading began on March 3, 1997. During the initial batch (March 3, 1997 to March 17, 1997), a total of 1,380 pounds of food waste and 625 pounds of bulking agent were loaded into the two vats. The food waste included significant quantities of meat and fish bones, fish heads, lobster shells, and other bulky food materials. By March 14, 1997 temperatures of up to 145F were observed in the vats and volume reduction was already significant.

Unfortunately, the only electrical outlet accessible to the system was in a storage shed/freezer room, and was used for a number of different functions. Consequently, soon after initial loading was completed, restaurant staff began leaving the system unplugged by mistake. The system's aeration functions were thus shut down for prolonged periods, resulting in anaerobic conditions in the vats. The system also suffered another setback when a gearbox broke in one of the vats; this problem was addressed by replacing the gearbox with one from an unused unit at FHMC.

Despite numerous attempts to correct the unplugging problem, the system was not operated as intended. While the management at The Parsonage continued to express their support for the project, it was decided to suspend further loading until a new electrical outlet was installed at the site specifically for the compost system. On June 24, 1997 the vats were unloaded. The material looked very good, only a few large bones were identifiable. The material was moved to a curing pile at the edge of the restaurant's garden, where it was to be used. By the end of 1997, the Parsonage had not installed the designated electrical outlet for the compost site. Ultimately, the two Mini-Comptainers were returned to GMT.

At the new hospital site, with the vats operating smoothly and on a regular loading schedule, we proceeded to implement a monitoring regime, including: sampling and laboratory analysis of feed stocks and composting materials, gas readings, pH monitoring, and continuous temperature readings. The on-site monitoring work was performed from March 25 to May 29, 1997.

At the completion of the demonstration project, GMT was developing its new unit -- the Earth Tub. While the project's budget did not allow for testing the Earth Tub, DOS, the Hospitals, and Marriott agreed to provide resources to continue the in-vessel composting work. CGI was hired to provide assistance with ongoing operation of the 6' vat and installation and field testing of a new Earth Tub. While the 6' vat was operating well, the Earth Tub incorporated many new improvements. Like the 6' vat, the Earth Tub is 4' tall, but the unit is tapered (the diameter at the top is 89" and at the base 64"). This shape, combined with an enlarged unloading hatch and an auger that is angled to draw material from the center to the edge of the unit, has facilitated unloading. The Earth Tub also has an increased capacity of 750 gallons, and blower controls are more sophisticated and flexible.

During the course of the project, many tours of the Hospital site were given. Staff from the following organizations made visits: DOS (Bureaus of Waste Prevention and Recycling, and Cleaning and Collection); NYC Office of Management and Budget (specifically staff assigned to DOS budget issues); ORMD; Queens Botanical Garden; and administrative staff from NYHQ, FHMC, and Marriott. Tours were given for the Lower East Side Ecology Center, Open Road of New York, the Gaia Institute, the Solid Waste Committee of the Sierra Club, Cornell Cooperative Extension, and WasteWorks (a waste management consulting firm).

Additional educational and promotional efforts that were undertaken included:
a) The 27th Annual National BioCycle Conference (presentation by City Green, Inc.);
b) The environmental awareness events at FHMC (educational materials and compost samples);
c) Several BioCycle Magazine articles (February, 1997; May, 1997; and April, 1998);
d) The ORMD newsletter (The Market, Winter, 1997); and
e) A Cornell Waste Management Institute video.

2. Conclusions

During the course of the project, GMT refined the Earth Tub from an early prototype fraught with operating problems to what is now an effective composting machine. While CGI and others continue to work with GMT on further improvements to the system, the technology has arrived to a point where it can be relied on to process a steady stream of food waste in a manner that should meet most functional and aesthetic requirements. There are now three Earth Tubs in operation at FHMC, two in operation at the Jamaica Food Court in Jamaica, Queens, and additional locations elsewhere in the city and state are under consideration.

B. Open Road of New York, Inc.

Open Road's "Hot Box" is a relatively low-tech in-vessel composting system that was monitored and evaluated for this project. The Hot Box was developed through a composting education program of Open Road of New York and the East Side Community High School, with support from DOS, private foundations, and volunteers. The original prototype of the Hot Box was built in 1994. Subsequent trial and error, refinement, and real world testing, led to the current design, for which a patent was awarded on June 16, 1998.

Hot Boxes are currently in use at about 10 sites around NYC. These include public and private schools, community gardens, colleges and restaurants. They are being used to compost a range of materials, including pre- and post-consumer food scraps, stable waste, and grass clippings.

1. Open Road's Hot Box - description of the technology and trials

The Hot Box consists of a one cubic yard box, typically made of untreated pine or plastic lumber, i.e., a material made from recycled plastic containers. The box is intersected by a series of horizontal perforated pipes, set at predetermined levels. Convection serves to draw air through these pipes and into the composting materials inside the box. Loading, mixing, and unloading are performed manually using standard garden tools. Materials can be either premixed and then loaded, or mixed directly in the box. The goal, in both cases, is to obtain a mixture with the proper moisture content (about 60%) and porosity, since after the initial mixing materials are not further agitated.

Bio-filtration is usually accomplished with a 3" to 6" layer of finished compost applied on top of the compostable material once the box is loaded. However, there is at least one site where Hot Boxes have been set up with an external biofilter as well. Lids for the boxes are constructed if an external biofilter is to be used, or if the system is operated out-of-doors. The front of the box is removable to facilitate loading and unloading.

For the monitoring program, we chose to work with two Hot Boxes installed in a greenhouse at the East Side Community High School in Manhattan. This site was chosen because:
a) There were two boxes side by side and identical in construction;
b) The greenhouse serves to moderate winter temperature fluctuations;
c) There were students and staff at the site to assist in the program; and
d) The two boxes could be dedicated for a controlled experiment without disrupting other activities.

Waste for the monitored trials was obtained from several sources. Food waste came from two local juice bars and a produce market. Bulking agent included wood chips screened from old compost and fresh wood chips from the Queens Botanical Garden.

One box was loaded gradually (from August 6, 1997 to August 21, 1997) in order to mimic a site where the generator might produce 50 pounds of food waste per day. A total of 450 pounds of food waste was loaded into this box. The second box was loaded in two days (August 21, 1997 to August 22, 1997), mimicking a much larger operation. This box received a total of 409 pounds of food waste. A third monitored batch consisting of 307 pounds of food waste was loaded on January 10, 1998. Bulking agent was not weighed for any of the batches.

2. Conclusions

The Hot Box has proven over five years of use in NYC to be a reliable and flexible system with relatively low capital costs. While it is generally used for smaller quantities of waste than other technologies considered under this project, the Hot Box has found its way into a broad array of applications. Despite the low tech nature of the system, it has proven suitable for different types of food waste in a variety of settings.

C. Wright Environmental Management, Inc.

The Canadian firm Wright Environmental Management has developed an in-vessel composting unit that is in use at a number of locations in Canada and the U.S. Wright has models ranging in capacity from a few hundred pounds up to several tons per day.

During the course of the project we worked with two Wright units: the WEMI #500 (total daily load: 500 pounds) and the WEMI #750 (total daily load: 750 pounds). Although we were involved to some degree with planning, installing, operating, and trouble-shooting these systems, we were unable to implement the full monitoring regime with either unit for a number of reasons, which are described below.

1. The WEMI #500 - description of the technology and trials

Our first trials with Wright involved the lease of a WEMI #500. The WEMI #500 is a stainless steel, rectangular chamber, divided into two zones. Probes monitor the temperature in each zone and signal an electric blower to circulate air within each zone. Material is loaded into a mechanical mixer on the top of the unit. Material is dropped onto perforated stainless steel trays from the bottom of the mixer, which transport the material through the two zones over a 28 day composting period. The zones are separated by a series of "spinners" that agitate the material as it moves from zone 1 into zone 2. There are spray nozzles located just above these spinners; as agitation occurs, moisture is added to the material. At the end of zone 2, horizontally mounted augers discharge material through a chute at the side of the unit. Aeration is computer controlled, and exhaust gases are processed through a biofilter, which can be mounted on top of the unit or set on the ground. Using a 28 day retention time, the capacity of the WEMI #500 is 500 pounds per day (350 pounds/day food waste plus 150 pounds/day amendment).

The institution selected for demonstrating the WEMI #500 was City College of New York (CCNY) in Manhattan. CCNY was chosen because there was a good recycling program in place with committed staff, support for the project from the administration, and a promising waste stream to use as feedstock. A waste composition survey confirmed the latter. This survey was performed at CCNY's main kitchen and cafeteria, located in the North Academic Campus (NAC) building, at 137th Street and Amsterdam Avenue. The survey revealed 300 to 600 pounds per day of pre-consumer food waste, including preparation waste, oranges from a large juice machine, left-over bread, coffee grounds, and unserved cooked foods. Using rough parameters provided by Wright, a space for the compost machine was found, also in the NAC building. The space consisted of one bay (15' x 32') of an enclosed loading dock area. Representatives from Wright inspected the site and determined that the site could accommodate the unit, and was suitable with regards to potential odor, noise, or vector problems. The bay was to be used for the composter, and the dock itself as a platform from which to access the mixer/controller, although additional steps still had to be built to provide easy access. CCNY agreed to run water and electrical lines out to the unit; Wright agreed to install their machine (a professional rigging company was contracted by Wright for the task).

In late August 1996 the WEMI #500 was delivered and installed at CCNY. During initial shakedown of the equipment, problems were experienced with the screw ram used to move the trays through the chamber. Subsequent repair of the ram resulted in a 6 week delay in the actual start-up of the system. During this delay, we continued to work with staff in the kitchen and cafeteria, establishing a separation program to produce acceptable food wastes, without being a burden for the kitchen and cafeteria staff. In preparation for start-up, a variety of bulking agents were also obtained, including sawdust and shavings from Bronx 2000 and wood chips from a local tree service company.

On October 28, 1996 loading of the unit commenced -- 373 pounds of food waste and 132 pounds of amendment were loaded into the WEMI unit. Loading an average of 312 pounds of food and 95 pounds bulking agent continued on a daily basis, Monday through Friday. On November 1, the fifth day of operation, odors were detectable in the loading dock area and adjacent hallway, leading into the NAC building. Wright was notified immediately, and their local service contractor -- Sinnott Company -- sent representatives to inspect the unit on November 6. The inspection revealed a faulty seal around the tray slot and ram area, which are located directly beneath the loading area for fresh food waste. They also found several leaks in the air handling system. Sinnott workers tightened a number of loose connections and realigned the ram. However, the odors persisted, and over the weekend of November 9, there were complaints of odors in the faculty dining room, also located in the NAC building. Sinnott made further inspections of the air handling system and determined there were gaskets and certain blower housings that should be replaced; this work was done during the week of November 12. While odors were lessened by these repairs, the Director of Physical Plant remained concerned about the recurrence of any further odor events inside the NAC building. On November 20, after a walk-through of the loading dock area, the Director of Physical Plant requested that further loading be stopped and the WEMI unit be removed from the NAC building.

During the operating phase (October 28, 1996 to November 11, 1996) of the WEMI #500, a total of 5,623 pounds of food waste were loaded into the unit. The grounds keeper for CCNY unloaded the material from the WEMI unit, and after curing the compost, used it in a flower bed that is part of a large CCNY landscaped sign on Amsterdam Avenue. During the time the unit was installed at CCNY, tours were given to groups from the City's botanical gardens, DOS, Columbia University, the United Nations, and the Council on the Environment of New York City.

At the conclusion of operations at CCNY, we sought to have the WEMI unit moved to a hospital site in Little Neck, Queens to continue the demonstration at an outdoor location. However, representatives from Wright wanted to return the unit to a facility near Albany, NY for overhaul and repair. Due to the short period of operations, formal sampling and data gathering were not conducted. In order to complete the formal sampling and data collection on a WEMI unit, it was proposed that the testing regime be carried out at St. Barnabas Hospital in the Bronx, where a new generation WEMI unit was scheduled to be installed. An agreement was reached between Wright, St. Barnabas Hospital, ORMD, Cornell, and City Green that provided for the completion of a formal evaluation on the newer WEMI unit.

2. WEMI #750 - description of the technology and trials

The WEMI #750 used in this project was installed at St. Barnabas Hospital in the Bronx in April 1997. The WEMI #750 is similar in design to the WEMI #500, with a few notable exceptions:
a) The screw ram is replaced by a hydraulic ram, which is less likely to experience mechanical problems, and also moves the trays faster;
b) The mixer unit has greater capacity and it has small knives welded to the mixer bars to help shred material;
c) Leachate is recycled into the composting material; and

d) The spinners between zones 1 and 2 are automatically run daily to prevent the material from settling and jamming the spinners.
In addition the WEMI #750 installed at St. Barnabas has some optional features, including a mechanical lift for tipping 64-gallon containers into the mixer, and a conveyor and shaker screen for segregating the end product into chips and compost.

The WEMI unit at St. Barnabas was installed away from the main hospital buildings in a parking lot, next to a maintenance garage. The unit was placed on a level concrete pad within a fenced area (approximately 20' X 45'). About 15 cubic yards of mulch and 75 cubic yards of wood chips (from ground construction waste and pallets) were stored at the edge of the parking lot. Pulped food waste from the hospital's kitchen was collected in 64-gallon wheeled carts and brought to the compost site by the hospital's building and maintenance staff, who also loaded and operated the system.

Initially, temperatures in the WEMI unit reached thermophilic levels. However, about a month after the initial loading, temperatures in the composting material began to fall. There were several reasons for this. First, the supply of mulch was exhausted and the staff began to use the courser wood chips. Second, there was a change in the food service operation, resulting in the near elimination of food preparation at the St. Barnabas kitchen (prepared foods were trucked in from a centralized facility). And lastly, the main on-site operator quit his job at the hospital. These changes affected the composting project in different ways. The change in bulking agent resulted in a much more porous mix. The lack of food preparation at St. Barnabas meant a sharp reduction in the amount of food waste in the material being collected for composting. It was now comprised primarily of pulped paper (plates, cups, and napkins), plastic (drink lids, cutlery, and shrink-wrap) and a small amount of post-consumer plate scrapings. The abrupt change in system operators further disrupted the loading of the unit with the proper recipe.

In addition to problems achieving thermophilic temperatures, feedstock materials lead to problems with the output material. The pulper created small plastic particles that passed through the mechanical screens and ended up in the compost. Larger plastic particles also contaminated the recovered wood chips, so that they had to be discarded after screening instead of being recycled through the WEMI unit. Given the nature and extent of the problems experienced at the St. Barnabas installation, the formal evaluation for this project could not be undertaken.
3. Conclusions

Our early trials with the Wright system at CCNY were disappointing -- in retrospect the complete odor control required for the indoor site selected was probably an unreasonable expectation for any composting technology. The St. Barnabas installation, on the other hand, is a relatively good site, and the equipment itself is also superior in several regards. As noted, we were unable to complete a formal evaluation on this equipment. Nevertheless, it appears that the remaining problem at St. Barnabas has to do with contaminated feedstock and not the compost technology. A review of other Wright installations around the country confirms that the technology does perform well, producing a reasonably stable compost product in 28 days without odor problems.

D. Compost Man, LLC.

Jim McNelly is the principal force behind Compost Man, LLC., but is more widely recognized as the

President of NaturTech, Inc., whose principal product is a roll-off container-based system using top-loading 40 cubic yard containers with aeration floors and external biofilters. While very large industrial generators might be able to use a system of this size, it is too big for most on-site composting applications. McNelly recently launched Compost Man, LLC, which offers a smaller system (1000 to 6000 pounds/day). This system, called the Compost Man Pro, is a static, aerated container, coupled with vermi-composting as a finishing stage. In late 1997, using grant funds from ORMD and other sources, Outstanding Renewal Enterprises, Inc. (ORE) bought and installed a Compost Man Pro at a site in the East River Park in lower Manhattan. It was decided that this system, which has been effectively operating since February 1998, should be included in our monitoring program.

1. Compost Man Pro - description of the technology and trials

The Compost Man Pro is a modular system comprised of a series of high density polyethylene 300 gallon tote boxes connected to a single (1.5 horsepower) blower, which draws air through the boxes and exhausts gases into a biofilter. Each box has a built-in pallet at the base and is fitted with a gasketed, air-tight lid. Air enters the box through a 2" port at the bottom and is drawn out through a 2" port in the lid. Flexible ducting and PVC pipe are used to connect the lid port to the blower; each connection has a ball valve near the lid port that allows the operator to adjust or block the amount of drawing action on any individual box. The bottom of each box is covered with a plastic mat, which forms the aeration floor. One edge of this mat is connected to a pipe that allows fresh air to enter from the bottom port. Leachate is drained through this same port and is piped to a 30 gallon tank buried just below ground level. Once collected, leachate is pumped into an above ground 30 gallon holding tank, and is used to add moisture to the boxes during active composting.

The box container portion of the system was studied for this project; the latter, vermi-composting stage was not. The system ORE purchased consists of 16 boxes for active composting, two boxes (filled with mulch and wood chips) for biofilters, an auger/mixer, a customized lift/tipper unit (fabricated by the McNelly Group), and a shaker screen. ORE also purchased a Bobcat with a standard bucket and a fork lift blade attachment. The ORE facility sits in a fenced 150' x 50' area in East River Park, and has an estimated capacity of 1.5 tons of food waste per day.

ORE collects source-separated food waste from several restaurants, food markets, and drop-off centers and brings it to their facility. Food waste is combined with an appropriate bulking agent in the bucket of the Bobcat. The Bobcat is used to load the mixer, which has a capacity of 5/8th of a cubic yard. The mixer unit has a drag-chain conveyor that deposits the material into the composting box. Boxes are moved by the Bobcat using the fork lift blade attachment. Due the limitations of the Bobcat, the boxes are only filled to 3/4 capacity at the ORE operation. After the material is processed (an estimated 21 day retention time), the box is moved to the lift/tipper, which dumps the material into the Bobcat bucket.

Monitoring was performed from August 31 to October 30, 1998. During the monitored run (30 days in-vessel) 2,381 pounds of food waste was loaded and composted in two boxes.

4. Conclusions

The Compost Man Pro is an effective system, producing a good compost product in an efficient time frame and providing sufficient odor control to make it suitable for urban installations. Certain aspects of the operation are labor intensive. For example, loading the food waste into the Bobcat bucket and then filling the mixer is time consuming; approximately 6 to 8 buckets are needed to fill each box. Also, the Bobcat bucket is less than a cubic yard, which makes unloading difficult because the tipper cannot dump the contents of a single box into the bucket at one time, so the box is tilted almost on its side and the contents are shoveled into the bucket. According to ORE and McNelly, the operation is still under development and through experience and trials, they expect processing to become easier.

PART 2. CORNELL ECONOMIC ANALYSIS

I. Flushing Hospital Medical Center– Green Mountain "Earth Tub" Technology

A. Introduction & Overview

The Earth Tub composting installation at Flushing Hospital Medical Center (FHMC) represents a technology that, after a series of modifications, has been successfully integrated into the grounds of an urban hospital. The composting effort appears to have been part of an aggressive waste reduction strategy. The overall waste reduction initiative was in partnership with a sister institution, The New York Hospital Medical Center (NYHMC). Since 1994, NYHMC "has reduced medical waste by 65%, and regular waste by 33%, while hundreds of tons of organic waste from cafeteria and patient service areas have been composted." *(see http://www.nyhq.org/compost.html)*

The NYHMC is a community teaching hospital counting 487 certified beds that logged 137,430 inpatient days for 1995. The FHMC listed 332 certified beds and 115,880 inpatient days for 1995. *(Health Care Annual: Data on Hospitals in New York, Long Island, and the Northern Metropolitan Area, 1997 Update New York: United Hospital Fund, 1997).* The two hospitals are within a mile of each other. The Queens Botanical Garden, which accepts the compost product, is also in the immediate vicinity.

On a weekly basis, NYHMC serves 9,000 patient meals, 10,000 cafeteria meals for staff and visitors, and 8,000 catered meals for hospital events. This generates approximately 10,000 pounds per week of food residuals.[1] Despite the location of the compost operation at the FHMC site, no food scraps from that hospital are composted in the Earth Tub system. In fact, relatively little food waste is generated at FHMC. Anticipating a complete phase-out of onsite food preparation, FHMC's current foodservice consists almost exclusively of trucked-in meals and snack food. In addition, only pre-consumer wastes (i.e., no plate scrapings) from NYHMC are composted at FHMC.

NYHMC started vermicomposting food residuals in 1995. That system currently handles a small amount of clean vegetable-only waste (about 50 - 100 pounds/day). Two years later a program was started to compost scraps from NYHMC's food preparation operations. Due to inadequate space at NYHMC, the compost installation was located at the nearby FHMC. In fact, FHMC's only real involvement in the composting operation is its provision of a site for the Earth Tubs. Both hospitals, like St. Barnabas Hospital, obtain foodservice through Marriott Foodservices.

The FHMC site has recently expanded to a three Earth Tub operation. The third tub is not yet optimally utilized, but currently provides a convenient option for curing compost. Though there was no appropriate space at NYHMC, the FHMC installation demonstrates the ability to tuck a compact composting facility creatively into a limited, underutilized area.

B. Collection and Precomposting Preparation

As reported by Paul Turci of City Green, NYHMC kitchen and cafeteria scraps, including food and

[1] Block, Dave and Molly Farrell, "Variety is the Spice of Composting", *Biocyle*, April 1998, p. 84.

paper residuals, are taken to the FHMC installation twice weekly. Food scraps are collected in plastic bags, which are placed into 44 gallon cans with casters. Up to 7 bags will fit into a 44 gallon container. The average weight of a bag is 35 pounds. Hence one container may weigh well over 200 pounds.

The containers are stored at NYHMC until they are brought by van to the FHMC site. This delivery takes place on Tuesday and Thursday mornings after most food preparation has concluded (i.e., after about 8:30 AM). On Tuesday mornings, residuals from both Monday and Tuesday are loaded into the Earth Tub. Similarly, on Thursday morning, residuals from Wednesday and Thursday are loaded. Waste generated from Friday through Sunday is discarded, though a small portion may be fed to the worms in their separate vermicomposting system. The containers are driven to FHMC in vans that are primarily used for other purposes (e.g., laundry handling). The 44 gallon containers are weighed as they are put onto the van. After the contents of the bags are dumped into the Earth Tub, the used plastic bags are thrown out as garbage, and the 44 gallon containers are returned to NYHMC.

Because it seems unusual for one hospital to use another nearby hospital's grounds to compost only its own food scraps (especially in a small facility), no analysis of the costs of trucking food scraps the short distance from one hospital to the other are considered. However, it appears that the actual cost is small because of the short distance and lack of need for dedicated resources. Though food scrap bins tend to be transported on a routine basis, even the half-hour or so in weekly transportation costs involves staff and vans that for other reasons frequently travel back and forth between the two hospitals.

In contrast to the hospital installation at St. Barnabas Hospital (see below), the shift in food scrap disposal procedures at FHMC was not associated with a parallel and significant investment in new processing technology inside the hospital kitchen. Instead, comparatively minor changes were required. One kitchen laborer spends up to an extra half-hour per day (four days per week) in food scrap preparation and in moving the containers to temporary storage until they are driven to and loaded into the Earth Tub (two days per week). The preparation time involves cutting up larger food scraps (like large watermelon rinds, hunks of dry bread) in order to facilitate composting in the Earth Tubs and removing contaminants. Only about 15 minutes of this time, primarily involved in collecting the containers and moving them to storage, is absolutely necessary. The food scraps are delivered to the compost unit in 44 gallon wheeled containers. The available onsite storage space permits the hospital to accumulate waste for a day or two before loading the Earth Tub.

The hospital labor is paid approximately $13 per hour. This figure lies between the Department of Labor's New York City survey estimates for the wages of foodservice workers and for managers (each measured at the 75th percentile). Assuming 25% fringe benefits and applying this labor rate to 20 minutes four times weekly yields an estimate of $1,127 in labor for the precomposting operation. In all likelihood, the actual opportunity cost of this labor is less. In other words, it is more likely that rather than increasing the hospital's labor costs, the labor is shifted away from other tasks. The economically efficient approach would be shift away from the least important or valuable of those other tasks.

Another cost is for the wood chips and shavings used as the bulking agent. Wood chips can routinely be acquired at no cost if there is room to accept a whole truckload of chips at the convenience of landscapers. However, for the FHMC installation, which requires only modest quantities of shavings and chips, delivery is not free even if the amendment itself does not cost anything. For the existing operation at FHMC, resupply is necessary about six times annually. At about three hours per resupply run, the estimated annual cost of at least one laborer (occasionally two; each at $13/hr plus fringe benefits), a driver ($15/hr), and a truck (estimated costs only for fuel and repair of $3 to $4 per trip) is about $650 annually. However, with this infrequent schedule, the hospital truck and labor are likely to be used only at convenient times. Once again, the out-of-pocket or real opportunity costs are likely to be less.

C. The Site

The Earth Tubs and ancillary composting equipment are located in a 10.5 by 42 foot area underneath the ground floor overhang of one of the hospital buildings. The site is amply sized for the composting equipment located there. The site already benefited from a concrete surface, accessible water, and drainage to an immediately adjacent storm drain. The hospital invested in fencing to secure the compact site as well as in high voltage electric outlets for the composting equipment. It is estimated that the fencing cost the hospital $2,230 while the electrical improvements cost $1,800.

There is of course no rental charge for the small space, which the hospital of its own volition dedicated to composting. The economic rental value of a 421 square foot urban space might be estimated in the abstract. However, it seems clear in this case that the value of this underutilized space, even considering its opportunity cost in other possible uses, cannot have been significant. This is likely to be a general rule for onsite urban institutional composters. Short of creative arrangements with sister hospitals, those who cannot fit a system into low valued areas of their grounds are unlikely to pursue this waste management strategy at all.

D. The Composting System

Each Earth Tub currently costs $5,875 per unit including biofilter. As manufacturing advances have been made, this price is somewhat reduced from the original price paid for the first units at FHMC. The initial package of two Earth Tubs cost $10,600 inclusive of shipping as the first payment of a lease-purchase plan. The purchase was completed for an additional $925 per tub.

Each tub, a tapered conical section, loads from the top, discharging compost from a large side door and leachate through an externally tapped valve. The tubs include an electrically operated rotating internal auger (mixer/shredder) and aeration blower that slowly but continuously draws the moisture laden air through an external biofilter. Other capital investments are $400-600 in storage bins and $200-400 in miscellaneous other equipment including a thermometer, tools, shovel, broom, hoses, extension cords, and the like. The site has approximately 3 cubic yards of bulking agent storage capacity.

Routine maintenance costs for the system over its life cycle are difficult to estimate accurately given the short-term experiences with a new technology. However, City Green estimates basic cleaning of each Earth Tub and greasing of the auger can be accomplished in about 1.5 hours. The work is necessary at least three times annually, for a total estimated cost of about $150 for two tubs.

E. Onsite Processing

Food scraps are loaded into the bins twice a week, as mentioned above. Each time one bin is loaded, a two person team requires approximately 40 minutes but can take up to one hour. The tasks involved include a variety of monitoring tasks including inspection of the site, checking the system and compost temperatures, and recording data. In addition, the stored food scrap containers must be obtained from storage (refrigerated in summer, loading dock in winter) and then loaded. Loading requires lifting of the bags to approximately four feet in height, and takes about 15 minutes in itself.

Liquids released during storage before loading collect within the plastic bags. Most of this liquid is dumped into the Earth Tub as the bags are emptied. A small quantity of the liquid, estimated at less than 2% of total weight, is retained in the plastic bags and discarded. Excessively wet or soupy wastes such as gravy or slop from the pot wash area are not collected in the bags to begin with.

Bulking agent is added by hand in an overall ratio of 40-50 pounds of amendment to each 300-400 pounds of food scraps. The ratio by volume is about 2 parts amendment to 3 parts food. Each Earth Tub batch is started by loading a layer of about 150-200 pounds of wood chips into the bottom of the tub. With each loading of food waste, a wood chip/wood shaving mix (80-90% shavings) is also added. The shavings are very dry with maximal surface area for efficient decomposition. Loading of the wood shavings/chip mixture adds approximately five minutes per load. The Earth Tub contents are mixed after each loading.

An electric motor powers the auger, which mixes the material. The amount of resistance to the auger depends on how fully each bin is loaded, but the auger is capable of mixing a ton of material in 10 to 15 minutes. The manufacturer estimates that the Earth Tubs consume approximately 640 kilowatt-hours annually for both continuous blower aeration and intermittent mixing. At the hospital's cost of $0.13 per kilowatt-hour, the cost is less than $100 per Earth Tub annually.

The quantity of food scraps the FHMC installation might theoretically handle is of course flexible, varying according to the number of Earth Tub units, waste characteristics, daily waste generation rates, retention times, and the like. According to Green Mountain Technologies, each Earth Tub is capable of processing as little as 50 pounds (25 kg) per day or as much as 1,500 pounds (700 kg) per day. They suggest more specifically that:

a single unit can handle approximately 150 pounds (70 kg) of biomass per day. When multiple units are used together, however, higher volumes can be added to a single tub. By using three Earth Tubs in rotation for example, up to 450 pounds (200 kg) could be added to a single tub. Each unit has a total of 3200 pounds (1500 kg) biomass capacity when full. *(http://www.gmt-organic.com/et_faq.html)*

In contrast to the manufacturer's apparently conservative capacity ratings, one Earth Tub at FMHQ was loaded with 5,438 pounds of food waste during a closely monitored six week cycle. According to Paul Turci, this occurred during optimal (warm and dry) weather conditions. The average full load at FMHQ is more like 4,500 to 4,800 pounds. City Green's experience with Earth Tubs at the Jamaica Market Food Court has been with similar loads. Current loading rates at FHMQ are 800-1000 pounds of food scraps per week. Thus it is evident that the Earth Tub system described here handles only a small portion of the total waste quantity of scraps generated. This is true even given that new food processing efficiencies have probably reduced generation rates below the cited estimate of 10,000 pounds per week of food scraps generated by NYHMC.

F. Compost Revenues, Marketing

The appropriate level of expenditure for testing and monitoring of cured compost depends on the intended end use of the compost and scale of production. Although the FMHC production process is not generating compost for market or general distribution, City Green has still recommended at least a minimal testing regime. For approximately $200 a year, it is possible to buy quarterly testing of compost stability, as well as an annual test for nutrient value and for pathogens.

Compost from the FMHQ site is delivered to the Queens Botanical Garden rather than sold. Thus, the hospital does not earn any revenues from composting. Nor does it avoid the purchase of soil amendment for use on its own grounds. Indeed, the transfer to the Botanical Garden incurs a minor transportation cost.

Nevertheless, it is possible to at least crudely estimate the revenues the compost might earn if it were sold. Based on actual measurement, the yield from the 5,438 pounds Earth Tub load was approximately two cubic yards of unscreened compost after six weeks. At this unusually high loading rate, approximately 18 cubic yards of quality compost might be produced per tub per year, or 36 yards in the unlikely case that each of two tubs was able to be loaded at this rate. Based on City Green's more routine working experience, the two Earth Tub installation can optimally handle 1000 pounds per week on a continual, batch-feed loading basis. This implies 3 to 4 weeks of residency time in an Earth Tub after the last fresh food scraps are loaded, with subsequent time in a curing pile before any horticultural use. At such an average loading rate, the quantity of compost produced by the two tubs would not greatly exceed that generated by the heavily loaded single tub.

According to CityGreen, area landscapers might be willing to make occasional purchases of compost for somewhere between $6-15 per cubic yard. This price for compost seems more appropriate to assume for a hospital producer than the higher value product, which might be marketed by more entrepreneurial organizations such as ORE or Open Road. At $15 per cubic yard, 36 cubic yards of compost earns $520. This estimate makes no attempt to account for the practicality of marketing compost at this scale of production, nor of the costs that would be associated with sales.

In addition to the potential for revenue from sales, the hospital benefits economically by reducing its carting bill. The NYMHQ pays its carter a weight-based rate for waste disposal of approximately $0.03 per pound, or $60 per ton. With up to a half ton of food scraps composted per week at current loading rates, approximately $1,500 in disposal costs is avoided.

Overall, then, the economic benefits to the hospital could conceivably approach $2,000 per year. If the full cost of labor is accounted for, operating costs alone are more than double this figure at more than $5,000 per year. However, assuming that all labor is simply redirected from less important tasks, actual additional incremental out-of-pocket operating costs of composting are small. Still, with fixed investment costs exceeding $17,000, even assuming that a net revenue stream of $2,000 per year is possible, the project does not present an economically attractive proposition. Given the assumed financing, annualized fixed costs are greater than $3,000, and thus, significantly greater than the assumed revenues. Even ignoring financing costs, the $17,000 is not recouped in a pay-back period that is short enough to be attractive to most businesses.

In sum, without subsidy or a more aggressive compost marketing strategy, it appears that economic incentives alone are unable to motivate investment in this kind of installation.

II. Open Road Hot Box Technology

A. Introduction & Overview

This technology is suitable as a small scale, low-technology, and generally low capital intensive approach to composting that has been successfully used for food scrap composting. The small one cubic yard capacity of the Hot Box and its passive aeration technology require relatively little land, no electricity, and little monitoring. While the system does tend to be labor intensive per cubic yard of incoming food scraps, the small scale means the total required hours per Hot Box is manageable for the basic labor of loading and unloading.

Open Road, which is an educational nonprofit organization, currently constructs, installs, and operates the school-based site primarily under consideration here. Like the ORE operation (see below), Open Road composts food scraps that are largely generated in the site's immediate neighborhood rather than onsite. There are currently Hot Boxes at 11 sites in New York City, with four being the greatest number per site. While there is no insurmountable reason why more Hot Boxes could not be installed at a single site, the time, interest, and capacity of people at the institutions hosting the current installations have so far been the limiting factor. Paula Hewitt, principal and founder of Open Road, notes that it is the institutions with a strong interest in using the compost product that are most likely to be motivated to produce more.

There are some cases where people have taken the patented Open Road design and, with a license freely available to nonprofit organizations, built Hot Boxes on their own. However, to date Hot Boxes have not been produced in any quantity runs. At this time, Open Road is considering the feasibility of moving into a small- scale production mode.

Open Road receives information from most of the eleven installations in the city. From the perspective of the low materials cost plus modest total labor requirements, this technology would seem quite suitable for trained onsite labor to manage after installation. However, the caveat is that avoiding problems with the open architecture and passive aeration system require relatively high levels of skill and attention to details, particularly during initial loading. As with essentially all composting technologies in urban settings, the system is likely to run into trouble without someone who has a sincere interest in and basic affinity for the process.

B. Collection

As is typical of the other Open Road sites, food scraps are brought from generators in the neighborhood to the Hot Box installation at the Lower East Side Park, which is adjacent to the East Side Community High School.

Concern about proper loading dictates a strong preference for a batch system that fills the box all at one time rather than an incremental daily loading system. In addition, because of the small size of the three Hot Boxes on site, and also because of the orientation of installations of this scale to the immediate neighborhood only, a regular food waste collection service is not feasible. Instead, Open Road collects food scraps from nearby generators only when more material is needed to start a new batch or "keep the Box hot." In general, this requires about three hours of collection labor per week. The food scraps are collected by hand in standard plastic garbage bags that are about half full. Assuming that the value of collection labor is $10 per hour, the labor devoted to collection is worth $1,560 per year.

Collection for the Lower East Side Park site is currently from two local markets and a juice bar (other local institutions have participated in the past with different labor implications). All are on the same block as the school. The small number of generators, their close proximity, and frequent contact help ensure that a high quality of source separation is maintained. On occasion, these generators or other neighbors will drop clean food scraps off themselves.

No fees are associated with collection. Open Road does not charge a tip or collection fee of generators, and of course, generators do not charge Open Road to collect its food scraps. Hence, from an economic perspective at least, the composter would benefit if more generators dropped clean material off at the neighborhood site. However, since the typical generator tends to pay for trash pickup on a fixed rate schedule, there are generally no avoided cost savings for them. As considered in more detail for the ORE collection route, the hauler then presumably benefits to some small degree by avoiding costs of disposal. Due to the small scale and irregular nature of the food waste diversion, the potential and incentive for a given installation to negotiate a change in the fee schedule with the hauler is small.

To put this in context, assuming that a three Hot Box installation diverts a total of 18 cubic yards of food scraps a year of average density of 30 pounds per square foot (i.e., on the heavy side), a hauler paying $60 per ton in disposal fees should face a reduced tipping costs of somewhat less than $450. For generators, the perspective could be slightly different in theory. According to research by CityGreen, a typical New York City commercial waste generator pays approximately $80 to as much as $98 on a per ton basis for hauling services. At these rates, a generator of 18 cubic yards of dense, heavy waste would seemingly avoid $583 to $712 by onsite composting. However, the CityGreen cots are high only because they are based on the typically observed relatively low commercial waste densities of 250 pounds per cubic yard (c.f., CityGreen's observed range of 175 to 375 pounds per cubic yard), with associated carting charges of $10 to $12.20 per cubic yard. Note specifically that 250 pounds per cubic yard is about 9.3 pounds per cubic foot, i.e., much lower than the 30 pounds per cubic yard assumed above. At the lower densities that are consistent with the high per ton price, generators who could capture the entire avoided $80 to $98 per ton cost associated with 18 cubic yards of waste might save about $180 to $220 annually.

In sum, it seems clear that economic incentives are not likely to be the prime motivation behind generator participation in this kind of neighborhood composting operation. On the one hand, total potential savings are modest for both generators and haulers. On the other, the ability of generators to negotiate savings with haulers is probably limited. Of course, as noted in the ORE analysis, some food scrap generators may prove to be exceptions to this rule and successfully negotiate with their haulers for at least some economic savings. Certainly, any facility that is already paying on the basis of weight would benefit automatically (assuming accurate scales!), even if the savings are small. Finally, if the collection system of even modest scale was designed such that a large proportion of a given generator's waste could be diverted, savings would be more likely realized.

C. The Site

The Lower East Side Park Hot Box installation is in the corner of a small greenhouse, which provides shelter and a controlled temperature for the Hot Boxes, which in turn contribute warmth and moisture to the green house environment. However, in general there are few site requirements for the Hot Box and operation outdoors is possible so that assigning some portion of the value of the greenhouse to the costs of producing compost would be misleading.

The boxes have a footprint of only one square yard each, and hence they can be tucked into many underutilized spaces in different institutional situations. Depending on the context, some form of security screening may be necessary to prevent vandalism, but many installations will not require even this investment. Moreover, the Hot Box design, recommended loading procedures (including a six inch layer of chips on the bottom) and mix recipes are intended to eliminate the possibility of leachate. This, together with the small quantities of material composted, and minimal access and storage needs, means that almost any level surface provides an acceptable location. Given the flexible requirements, most institutions considering using the technology on this scale would be able to site the Hot Boxes with no or minimal site costs.

D. The Composting System

Each Hot Box currently costs about $300 in materials and takes about seven hours to put together. This price assumes plastic lumber is used. Less expensive alternatives include plain pine (about $200) and plywood (potentially free, if pre-used.) Open Road staff provide assembly and installation labor.

In consonance with its mission and nonprofit status, Open Road's installation effort is considered first and foremost to be part of an educational process. Open Road's preferred market for the Hot Box is the nonprofit and educational sectors as exemplified by the school installation. Because Open Road is itself a nonprofit recognized by the city Park Department's gardening agency, "Green Thumb," federal funding fully subsidizes lumber costs.

Prior assembly experience already indicates that significant efficiencies can be achieved when the boxes are assembled in batches. In contemplating moves towards more of a small scale "assembly line" style production system, Paula Hewitt of Open Road estimates that the fully assembled unit cost of a Hot Box would be approximately $500, which would include a small markup above costs for the nonprofit. Presumably, even larger scale production, while not an Open Road goal, would be capable of achieving greater cost efficiencies.

E. Onsite Processing

After experimenting for about four years, Open Road has developed a number of "recipes" for mixing carbon and nitrogen sources in the Hot Box. In addition to the food wastes, Open Road has essentially unlimited free access to horse manure (relatively dry, with carbon rich bedding) and wood chips. Somewhat surprisingly, perhaps, there is an abundant urban supply of horse manure due to the presence of police stables and nearly twenty park-based riding stables. Coarsely chopped wood chips, which add a beneficial porous texture to the mix, are also available on an ad hoc basis from tree contractors who have limited access to disposal sites in urban areas.

The one cubic yard bins are filled with a 50-50 mixture by volume of food scraps and a bulking agent, be they chips, manure with bedding, or both. City Green estimates that the Hot Box loads typically include about 400 lb of food scraps. This dense material is largely juicer pulp and hand chopped product. Another 100 lb or more of bulking agent is loaded with the food scraps. A small quantity of screened, partially composted wood chips are also included in the mix. Loading the Hot Box requires about 45 minutes inclusive of clean up for the experienced Open Road operators. In order to optimize ingredient proportions, mixing quality, and promote uniformity throughout the composting process, filling the Hot Box all at once is recommended. However, this is not a necessity. Since most of the businesses that Open Road deals with generate a half cubic yard or more of scraps a day, it is regularly possible to fill the Hot Box a batch at a time.

Open Road has learned to take great care with loading, as batches that are not well mixed tend to go anaerobic. Particular care has to be given because meat and dairy products are included in the mix. Experienced Open Road staff are generally used for this task. However, they have had some success training others with less prior experience. Nevertheless, if Open Road was to scale up sales of the Hot Box beyond their capacity to monitor the sites themselves, there would presumably be a significant increase in costs associated with training, education, and technical assistance. This could well present an economic barrier if the organizational goal were ever to stretch beyond the current nonprofit education and outreach orientation to a bottom line business orientation.

Once the box is loaded it requires no further routine management, though Open Road encourages the host institutions to monitor and record temperatures on a routine basis. Daily monitoring is encouraged, with monitoring every few days more likely. For some materials, monitoring is necessary to ensure that the pathogen kill threshold of three days at 133 F or more has been achieved. However, the time required for monitoring is only a few minutes a day. Costs might be imputed at a value of several hundred dollars annually, including labor and temperature probe. Often, at an educational institution. this task is performed by a student interested in studying the process. For compost production at this scale at a nonprofit institution with limited distribution of compost, more intensive monitoring and testing has not seemed warranted.

At the Lower East Side Park greenhouse location, Open Road routinely keeps the material in the Hot Box for approximately a month. The goal is removal of the compost after it has passed through the initial "hot" phase of composting. Residence time in the Hot Box is flexible. This schedule is at times motivated by interest in helping warm the greenhouse. At this rate, and with an "all at once" loading routine, each box can handle a dozen cubic yards of material, or six cubic yards of food scraps, per year.

When the Hot Box is unloaded, the front panel of the Hot Box is lifted up and away. The material is shoveled into a wheelbarrow and moved to the screening area. It is then passed by hand through a homemade quarter inch mesh screen on a frame of two by fours. The six foot tall screen is leaned up against a wall with a Hot Box underneath for curing. While the use of the extra Hot Box at this stage is not necessary, the aerated and enclosed design provide for more efficient curing. The process of unloading and screening takes about an hour including cleanup.

The curing compost at the High School site is stored in a shed. Open Road has covered, secured areas at three of its main sites. Some kind of cover is important to control moisture content and nutrient leaching during curing. However, covering small piles with a simple tarp is probably adequate in most situations. For this reason, no attempt was made to account for the modest costs associated with the small curing shed that was built on the site. The compost is rarely if ever left to cure as long as the three months deemed most desirable by Hewitt.

The visible reduction of volume in the Hot Box after a month is "somewhat, but not as much as we had thought," and the surface does not "sink noticeably," according to Hewitt. After screening, however, there is a great volume reduction. Presumably, the bulking agent has retained enough structure that the loss of volume is simply not visible in the undisturbed Hot Box.

Screening of compost when it is removed from the Hot Box permits recycling of wood chips. Because of the size of some of the chips, they may be recycled as many as six times. The amount of cured compost volume produced by a full Hot Box has not been measured. However, composting always produces significant volume and weight loss. Hewitt estimates that less than half a cubic yard of compost is left after chips are recycled. Especially considering the recycled wood chips, it seems likely that significantly less than half a cubic yard of cured compost is produced for each load. If bedding manure is used for bulk instead of chips, they are of course not screened out of the finished product.

As with the ORE system, it is difficult to separate Open Road's core administrative functions from its educational and outreach functions. No attempt to assign a dollar cost to administration has been undertaken. However, this underestimates the real cost of composting, and potentially significantly. While the administrative and related costs associated with any given facility (e.g., locating supplies of food scraps and wood chips, dealing with neighbor relations, record keeping, employee training, etc.) are likely to be small in absolute terms; once a given installation is established, such costs would likely be significant for an organization like Open Road if it attempted to expand operations significantly or spin off a more bottom line operation.

F. Compost Marketing

Open Road does not have much experience selling the compost product. However, the recent experiences they have had selling a limited number (33) of two pound bags for $2 per bag have been encouraging. High school and junior high school students selling the bags at their busy Manhattan (First Avenue) street front location sold all 33 bags to passers-by within three hours.

Hewitt is optimistic that much, if not all, of the compost produced in Hot Box installations, and more, could be easily sold according to this model. Based on prior work establishing gardens in the city, Hewitt observes that, "The thing that is logical about selling within urban areas is that the difficulty of getting soil within urban areas is so great. Getting small amounts of good quality soil was a very difficult part of my program." As also suggested by ORE's sales of castings at the Green Market, where a suitable local match between small scale producers of quality compost and small scale user/consumers is convenient, a low overhead sales strategy can sell the available product.

The total amount of compost produced at the high school is not certain since no measurements are taken. However, considering the type of materials being mixed and the aeration pipes in the cubic yard box, an assumption of approximately 500 pounds per box seems justifiable. A further assumption of 60% reduction by weight (assuming that wood chips are recycled from each load) implies that each Hot Box load yields approximately 200 pounds of compost. With all three Hot Boxes in year round production, approximately 7,200 pounds (3.6 tons) of compost would be produced. If all were sold in the $2 bags, $7,200 would be earned (not accounting for any materials or labor costs associated with the sales).

Alternatively, the economic value for an institution using the material onsite might be the avoided cost of other purchased soil amendments. The $1 per pound price for a "premium" soil amendment (for both Open Road's experimental sales and ORE's Green Market sales of worm castings) would then serve as an upper bound estimate of value, and ORE's projected $0.30 per pound for retail sales of a potting soil mix might serve as a lower bound, suggesting a value somewhere between $2,160 and $7,200.

A more pessimistic view of potential revenues is also possible, especially in thinking beyond the capacities of Open Road to a more general model. It is likely that some small-scale urban composters who would otherwise be successful would not find a convenient way to market their output. They may also have little or no onsite demand for compost. In this case, no value can be assigned to the product. In the experience of Hewitt, even nonprofit compost giveaway programs can require significant preparation, organization, and time commitment. And while the current project being studied was predicated on the city Park's department interest in using the compost, Hewitt has in the past heard from the same department "some sobering statistics on how much it costs to spread" compost. Hewitt cautions that finding someone willing to transport and accept, or even simply accept, the product could require some effort. Insofar as this is true, it underscores the important role of entrepreneurially oriented businesses or organizations in servicing the needs of waste generators who would otherwise never compost food scraps.

G. Costs and Revenues

In an economic summary of the analysis, it is estimated that annual costs of collecting compost are $1,560. This assumes that labor is compensated at $10 per hour. The fixed or capital costs are estimated to total just $2,225 (including an extra Hot Box for use as a curing bin), with an annualized value of $416 at a modest 8% interest.[2] Onsite operating costs (essentially labor) are valued at $1,160.

On the benefits side, it appears that the compost might have a hypothetical value of as much as $7,200 per year. Carters might avoid costs in tipping fees of more than $400 per year. Generators at this small scale are unlike to realize much in the way of avoided costs, though some might be able to

[2] The "right" interest might be higher or lower depending on specific financing options, but the general assumption is that the money is either borrowed or that there is an "opportunity cost" to money that might be used otherwise.

negotiate savings from their carters. If it were indeed possible to market $7,200 of compost with minimal marketing costs, it is estimated that a small-scale entrepreneur might clear nearly $4,500 annually in the context of a capital investment of $2,225 (and less without the fourth Hot Box). Taking the capital charge on an annual basis reduces the annual net revenue to closer to $4,000.

This analysis makes the investment seem potentially attractive economically, though small scale. There are three most important caveats. First, it is certainly not a foregone conclusion that occasional compost sales totaling $7,200 annually from a small site like this are practically achievable on a routine basis, if at all. Second, this analysis is largely site-based and does not account for the full overhead of an operation like Open Road's. Finally, and at least indirectly related to the last point, costs are able to be kept low in part because of the small scale of the operation. The analysis would almost certainly change if greater scale was implemented from an individual site perspective or if there was a significant increase in the number of sites tended by an operation similar to Open Road's.

III. St. Barnabas Hospital –Wright Environmental Management, Inc. Technology

A. Introduction & Overview

The Wright model 750 in-vessel composting installation at St. Barnabas Hospital represents a technology designed to handle relatively large quantities of waste in a single unit. The operation involved onsite food waste generation, onsite compost production, and onsite use of the compost product. With its $80,000 price tag (approximately $82,000 including installation cost, 1996 dollars) and a 750 pound per day manufacturer's rating (500 pounds of food scraps, 250 pounds of amendment), the unit compared most closely in scale to the modular and so far one-of-a-kind Compost Man Pro system.

Its hospital setting and functional context, however, most nearly resembles that of the Earth Tub installation at Flushing Medical Center. Wright's in-vessel unit has a compact footprint and is fully enclosed. The compost site seems to have been easily integrated physically into the hospital grounds. As at the other hospital, the St. Barnabas Hospital's composting program was introduced as part of a complex overall waste reduction and recycling program. The hospital was particularly interested in removing the food waste fraction, which is heavy, wet, and odor producing, from its 30 cubic yard compactors.

The operational details of the following analysis are based primarily on 1997-1998 interviews with Mark Vacarro (Wasteworks, Inc., consultant), Steve Anderman (St. Barnabas Hospital, administrator), Ed Boyd (Wright Environmental Management, Inc.) and Paul Turci (City Green, Inc., consultant). However, two of these key sources ended their involvement with the project and were not available for clarification or follow-up interviews. Hence, compared to the other systems analyzed, there was less opportunity to double check or fill in the gaps in the information that was provided.

Of even greater importance is the fact that the hospital food waste stream never reached the projected quantities or composition that could have been compatible with economic functioning of the composting unit. Among several key reasons for this was the waste reduction effect and the pulped comingling of food, plastic, and paper wastes that was associated with the installation of a Hobart

Pulper in the kitchen. In part because of these changes in the character and quantity of the waste stream, use of the compost unit has been discontinued and WEMI is looking to relocate it.

Because of these limitations, this analysis should be considered comparatively tentative.

B. Collection and Precomposting Preparation

St. Barnabas was rated in 1995 as a 474 bed hospital with an 85% occupancy rate and, at 8.2 days average length of stay, 142,209 patient days. (*Health Care Annual: Data on Hospitals in New York, Long Island, and the Northern Metropolitan Area, 1997 Update* *New York: United Hospital Fund, 1997).* However, according to Mark Vacarro, the compost unit serviced 430 onsite hospital beds, with a hospital FTE staffing level of 2,600, plus a nursing facility with an additional 199 beds. In addition to the onsite food service, meals for these 199 beds were prepared at St. Barnabas' and trucked to the other facility. Vacarro estimated, based only on visual observation, that approximately three-fourths of the waste associated with the 199 beds was then trucked back to St. Barnabas. Finally, the cafeteria also served some unknown proportion of the approximately 700 walk-in patients per day. According to the hospital, these figures translate into the need to service approximately 600 trays three times daily. So the food waste stream was associated with daily scrapings from about 1,800 meals served plus the cafeteria's internal wastes.

As already described in some detail elsewhere in this report, food prep, room service, and cafeteria operations can have a major impact on the operations of a composting unit. In St. Barnabas' case, the in-vessel composter was installed and began operations during a period of significant flux in several of the operations that determine the quantity and characteristics of the waste stream. Some of these problems were indicative, as much as anything else, of the difficulties of getting all parts of a differentiated, bureaucratic system to communicate in a timely fashion and adapt smoothly to changes in one particular part.

Some of the specific changes affecting the composting unit (e.g., the departure of the employee primarily responsible for composting, or the replacement shortly after start-up of onsite food preparation by a new service using a "cook-chill" food operation whereby the meals were prepared offsite) were unplanned or poorly coordinated from the perspective of the composting operation. However, the hospital did make one very significant change that was integrated into initial planning for the composting operation, at least from the hospital's perspective. This planned change was an investment of approximately $35,000 in a Hobart pulper, and associated changes in the workers' routine for disposal of food scraps. Anderman indicated that the pulper was the driving innovation in the cafeteria's waste management system, with the compost unit to some extent a secondary consideration.

The introduction of the pulper was significant in many respects. Without any consideration of the needs of the composting unit, the investment in the pulper alone was intended to both reduce kitchen labor and food scrap volume, and to a somewhat lesser extent the weight, of food service wastes. According to Vacarro, this reduction alone can equal 40-50% of the weight of scraps. Other expected advantages of the pulper included its impacts on water use (the pulper recirculates water) given the heavy demand on water by the hospital's water-cooled pumps and concerns about maintaining water pressure during the summer.

Staff training inside the hospital's food service operation was a critical factor in determining what was happening outside in the composting unit. In fact, in order to ensure a relatively uniform, clean source of food scraps for any food composting unit, there will almost by definition (short of some kind of costly mechanical prescreening operation) be a need for an important kitchen staff training/retraining component. This training at St. Barnabas was very intensive in the first months. After that, given relatively little staff turnover, Anderman estimated that a "reeducation" program was needed about once every three months. Mark Vacarro recalled that, after the first few very intensive weeks, he still was averaging a half hour to an hour in the kitchen per week on issues related to food source quality during the first four or five months. Some of this time might best be termed "training," some "trouble-shooting."

In terms of the anticipated labor savings, both the composting consultant and the hospital administration considered the labor savings associated with introduction of the pulper to have been balanced by the increased labor required to remove non-biodegradables from the waste stream before it is introduced into the compost unit. Although no quantitative estimates of labor use were made available, it is clear that removing noncompostable materials from the literal stream of wastes flowing by the kitchen staff requires significant staff commitment. Net labor savings were not expected until certain problematic parts of the waste stream (utensils, cartons with plastic film, labels, etc.) could be replaced by biodegradable alternatives.

The economic benefit to the hospital of removing wastes from the hospital dumpsters is primarily in the avoided disposal fees. The original projected savings were based on a plan to reduce the food waste stream from an annual total of 754 tons to 227 tons by composting 527 tons. This volume of waste, about 1.5 tons per day, would have required a composter with more than double the capacity of the Wright 750 that was actually installed.

For several reasons, neither the initially projected volume of waste nor the per ton dollar savings were achieved. Introduction of the pulper in itself significantly reduced the volume and weight of the food stream while simultaneously changing its composition, density and related characteristics. The decision to adopt the off-site cook-chill food preparation system also significantly reduced the food scrap portion of the waste stream heading into the composter. Both of these changes significantly changing the avoided cost equation. Measurements of the waste that was actually composted average only 200 pounds per day (well below the manufacturer's rated capacity of 500 pounds per day) after the waste is dewatered in the pulper. This quantity would lead to the composter handling only 37 tons of food scraps on an annualized basis. The quantity also indicates that, aside from any other considerations, the WEMI 750 unit was significantly oversized for the actual hospital waste stream. The hospital's decision to discontinue use of the unit was, according to Boyd, based in part on its conclusion that its food waste quantities were not going to increase.

In addition, under the "old style" and very expensive New York City hauler contracts, it was initially estimated that the hospital would have saved an enormous amount of money due to very high carting fees. However, with the recent reform in New York City's waste management industry, hauling cost and hence the projected savings were significantly reduced. Regulations proposed by the New York City Trade Waste Commission in late 1996 were implemented in 1997 as a cap on the maximum rate carters can charge. The maximum rate private carters can charge for uncompacted rates was set at

$12.20 per cubic yard of waste. The maximum rate carters can charge for compacted waste was set at $30.19 per cubic yard. The maximum rate for 55 gallon bags was $2.66 per bag, and the maximum rate for each 30 gallon bag was set at $1.45.[3]

Prior to the diversion of the cafeteria waste stream, the 30 yard compacters frequently were reaching 14 tons and more per pull. Disposal costs are levied on a per pull basis, so the economic incentive for the hospital is to load them as densely as is practical. The hospital had been paying $1,100 per pull in prior years. However, under the extant, more competitive hauling system, the WMX three year contract set the fee at a reduced level of $700 per pull. For a 30 cubic yard container, this implies costs of about $23 per cubic yard.

Given the fee structure, the hospital saves money by reducing the frequency of pulls. (While not an economic incentive, the hospital also wished to improve control over dumpster odors, a benefit which was achieved.) With the full range of modifications to its waste management routines, the hospital (as of late 1997) was able to reduce the frequency of pulls from every 3 days to every 4.5 days (somewhat less than the targeted 5-5.5 days). With the new contracted cost per pull, this implies a reduction in annual hauling costs from approximately $85,000 to $57,000, a $28,000 annual saving.

This saving is attributable to much more than just the composting operation itself. It is not possible to say precisely how much of the reduced pull frequency can be attributed to composting alone. However, with an estimated 200 pounds of pulper wastes per day being composted, an estimated annual total of just 37 tons annually is removed from the compacter. Assuming the 200 pounds of pulper waste is denser than heavy, yet uncompacted food scraps but lighter than densely compacted food scraps, 200 pounds might equate to 50 pounds per square foot and therefore occupy 4 cubic feet (about 30 gallons) in volume. Over the four and a half days between pulls, then, this uncompacted waste would cumulatively represent only about 2/3 of a cubic yard of waste diverted from a 30 cubic yard compacter. It appears, in other words, not to be a major contributor to the reduced frequency of pulls.

Another way to think of the savings associated with the diverted wastes is to consider the hypothetical carting costs of disposing of just this waste. Assuming the same volume to weight ratio (50 pounds per square foot), 365 days of waste at 200 pounds per day would yield about 54 cubic yards of waste annually. At $23 per cubic yard (based on $700 per pull for the 30 yard compacter), slightly more than $1,200 are saved. Even assuming the maximum permitted charge of $30 per cubic yard of compacted waste, only about $1,600 in annual savings is achieved.

Yet another way to think of the avoided costs is in terms of the actual avoided tipping fee. It currently costs New York City about $40 per ton to operate the Fresh Kills landfill and about $55 per ton to export wastes.[4] In these case studies, a slightly more generous (from the perspective of maximizing

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[3] Source - http://www.ci.nyc.ny.us/html/misc/html/cartbill/html
and http://www.ci.nyc.ny.us/nyclink/html/om/html/96/sp663-96.html

[4] Source – " Roundtable Two, Reducing The NYC Waste Stream: The Potential Role for Composting, April 3, 1998," conducted by The Cornell Waste Management Institute, sponsored by The U.S. Environmental Protection Agency Region 2 on behalf of The New York City Department of Sanitation, Final Report , August 1998 - Internet Version,

avoided costs) $60 per ton has been assumed. However, applying this fee to the estimated 37 tons of composted scraps yields only $2,190 in savings.

Based on these figures, doubling or even tripling the quantity of waste composted would not translate into large avoided cost savings in the context of an investment of more than $80,000 in composting equipment alone. As with the other units considered in this report, avoided disposal costs alone cannot justify the investment economically.

D. The Site

The composting equipment, not including a nearby pile of wood chips, is located in an enclosed 20 by 45 foot area. The location is in a large, sloping controlled-access ground level parking area and is immediately adjacent to a garage structure.

The site required a number of improvements, which were undertaken by the hospital. The most significant included pouring a concrete pad, the installation of steps to more easily access the unit, fencing, and the extension of water and electrical service for a relatively short distance to the site. The site drains to a dry well. According to Anderman's order of magnitude estimate, the improvements cost approximately $10,000 in total.

An additional site improvement was for restoration of a small, pre-existing greenhouse. The cost of the upgrade was approximately $3,500 in materials, and perhaps an equal amount in labor. According to Mark Vacarro, only part of the original justification for the renovation was to house the worm bins that were proposed as part of the initial grant.[5] Other factors included its historical value as the original botanical greenhouse for the hospital, its potential for therapeutic uses with the nursing home residents, and its potential for a variety of uses by the hospital's groundskeepers. Largely due to the delays and technical problems in getting the composting system to function smoothly, the worm bins were never purchased and installed. The greenhouse was used at least incidentally as part of the actual composting operation (e.g., for enclosed storage of compost). However, Vacarro argues that it could have been restored for less money and was never an integral part of the composting plan. He has had successes with worm beds left in the open. On this site Vacarro recommended putting the bins in the immediately adjacent garage.

Because the composter is on hospital grounds, there was no land rent or acquisition cost for the area dedicated to composting. There also appears to have been no economically significant alternative use

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http://www.cfe.cornell.edu/wmi/WastRed/CompNYC.html

[5] The hospital used Steve River of One River Grants to put the initial grant together. Vacarro's contract with the hospital was as part of a solid waste management consulting firm called Wasteworks. The contract with Wasteworks involved more than the composting operation, with Vacarro representing the "organics" expertise in the company. The original grant involved a total of $122,500 in capital costs, including $7,500 for worm bins, $35,000 for a Hobart Pulper, and $80,000 for the WEMI composter. Vacarro, who had previously worked for the Queens Botanical Garden and has his own company call Organic Technology, also was responsible for onsite landscaping improvements which used the compost being produced.

for the space, so it is assigned a value of $0.

D. The Composting System

The unit installed at St. Barnabas was a Wright Environmental Management, Inc. model 750, with a design capacity of 500 pounds of food scraps and 250 pounds of bulking agent per day. The 1997 list price of this unit was $55,250 for the basic unit. The leachate recirculation system was listed for $2,625 and the winterization option for $3,000. Each option was included in the unit installed at St. Barnabas. Other extras included shaker screens, a bucket lifter, and conveyor belt, all contributing to the total $80,000 plus price tag. When the machine is working well with a compatible feedstock, it is designed to require relatively little, although fairly skilled, labor.

The additional major piece of equipment used onsite for materials handling (particularly bulking agent) is a Bobcat skid loader (est. new price $20-25,000). However, the primary reason for acquiring the skid loader at St. Barnabas was for snow removal, not composting. One can make an argument that anywhere from nothing up to the full value of the loader ought to be charged to the composting operation. In the present case (the entire pile can be turned over in about 10 minutes), it seems fair to assume that only a small portion of the value of the loader (hundreds rather than thousands of dollars on an annualized basis) should be charged to composting. Similarly, an old laundry van does double duty transporting the food scrap bins from the kitchen to the compost site, but spends little total time in compost use.

Other relatively minor costs include the 64 gallon wheeled containers used to deliver food scraps to the composter from the kitchen, as well as the usual variety of associated minor materials handling or measurement implements.

In part because of the inherent complexities and many initial problems, start up training costs were high. Mark Vacarro estimates that during the first three months he spent 3-4 hours a day, three days a week in training. He points out that more than one worker needs to be trained in the operation of the machine in order to provide back-up capacity for a daily operation. In addition, key points of coordination regarding operations had to be established and reestablished between the primary operators and other backup and trouble shooting support.

E. Onsite Processing

Food scraps were loaded into the composter three days per week. The containers were wheeled from the kitchen out to a loading dock, then taken in an old laundry van to the compost unit and loaded, along with amendment, into the machine. Loading the food and wood took about an hour. Together with other routine monitoring and operational functions, the process took a trained operator perhaps an hour and a half each time. Mark Vacarro estimates associated labor of 5-7 hours per week, with the lower figure representing an "efficient" figure. These loading figures include the simultaneous operation of the automated unloading and screening system. In addition to this, cleanup costs involved about two hours biweekly.

Insofar as possible, the labor needed for the compost unit was reprogrammed rather than new. In other words, groundskeepers and kitchen labor were not "new hires," but were instead reassigned to different tasks. A value of $20 per hour has been assigned as a labor cost. This appears to be consistent with the pay scale experienced hospital groundskeepers would earn.

Initially it took a significant effort to find the right compost "recipe" that took into account fluctuations in food waste composition. Problems were related to working with the technology itself and, most dramatically, to variations in the composition of the waste stream. Both the volume and composition of waste varied greatly from day to day. This depended on what was on the menu and who was running the scrapers. The quantity of paper and plastic that was included in the pulped output of kitchen, cafeteria, and food prep waste presented an ongoing challenge for the proper operation of the compost unit. Plans for reducing the amount of plastic contaminants included switching to biodegradable utensils, reducing shrink wrap by switching to foods without individual wrapping, changing the brand of milk carton, and so forth.

The compost system included a shaker screen that proved to be fairly efficient at separating plastic film, but not as good at removing some of the other plastics. Typically, about two filled 36 gallon containers of residuals were generated for each stainless steel tray rammed through the WEMI machine. For use of the compost on the grounds, some additional hand screening was done, though the cost and extent of this (presumably modest) effort is not available. Obviously, the effectiveness of contaminant removal in the kitchen directly affects the need for, effectiveness, and costs of screening the compost. No information was made available about the quantities of compost produced.

Initially, the system was loaded on Mondays, Wednesdays, and Fridays with 600-1,100 pounds of pulped cafeteria scrapings with each loading (i.e., approximately 2,000 to 3,000 pounds per week). Amendment was added at the recommended target ratio of 50% of the weight of the pulped waste. After some time, the loading rate was stabilized at a lower rate that was closer to the aforementioned 200 pounds per day, or 1,400 pounds per week on average. The food waste included food scraps and all other paper and plastic materials that came out of the pulper. The reduction achieved involved a number of factors, including improved kitchen practices. It was also realized that with the pulped waste running at nearly half paper content, much less amendment ought to be added.

Two loads of bulking agent were initially received for free. This constituted about 80 cubic yards of material, approximately a year's supply for a 200 pound per day food waste loading operation. Because some wood chip sizes caused operational problems with the system (bent blades on the conveyor), additional custom ground chips were purchased from the hospital's solid waste carter (WMX) for somewhere between $100 to $200 per 40 yard load. Costs are related more to trucking costs than to the nature of the chip material. Finding occasional loads of wood chips for free in New York is not necessarily a problem, though custom sizing of the chips costs money. There is not a routine "market price," at this small and intermittent scale of use, the chips are normally most available on a "spot market" basis. Mark Vacarro estimated that 40 cubic yard containers of chips would be available essentially for the asking at a price of at least $200 per load. There is a potential to pay significantly more if trucking from well outside the neighborhood is necessary.

For St. Barnabas, the source for the free wood chips was someone who worked on a construction and demolition job at the hospital and only had to truck the chips from a few minutes away. Regarding the purchased chips, WMX initially wanted to charge much more for immediate delivery, but the price was negotiated down by pointing out that WMX already was under contract to the hospital as its trash hauler, and by agreeing to the acceptable cost of a week's delay in delivery.

Utility costs were estimated based on the manufacturer's estimated system requirements for electricity and water. The estimated use of electricity 160 kilowatt-hours per week would cost just over $900 annually at 11 cents per kilowatt-hour. It should be noted, however, that Mark Vacarro's impression was that actual electricity use significantly exceeded the manufacturer's rating. The 6-8 gallons of water needed per day costs almost nothing even on an annual basis at the city's standard rate of $1.25 per cubic foot.

Repair and maintenance costs for the machinery were not estimated. However, Vacarro estimated that an electrician's services and help from the hospital's engineering staff would be required for the equivalent of perhaps one or two days annually.

F. Compost Use and Marketing

None of the compost produced at St. Barnabas was sold, and there were no plans for any sales. As a compost unit intended to be operated onsite by hospital staff, there was also no onsite staff capacity to market compost. As seen with the other compost installations analyzed, it is only through the possibility of revenues associated with a quality product that the economics begins to look very attractive from an enterprise perspective. Though it is certainly possible to imagine evolution towards an urban marketing infrastructure under which the hospital could sell some of its compost, this seems very unlikely in the near term, so it seems fair to assign the compost no sales value.

Some of the compost was used on the hospital grounds for subsoil. The compost contained too many plastic contaminants for visible surface use even after post-production hand screening. Once onsite hospital uses were saturated, Anderman expected that a cleaner compost would be accepted by the nearby Botanical Gardens. Other possible sites included area community gardens. The hospital itself owns some vacant lots, which Anderman suggested might be turned into gardens. Thus, while there was probably some small value to the hospital of the soil amendment that might otherwise have been purchased for the grounds, this economic value was restricted by both the quality of the final compost and the limited long term onsite demand. No attempt to estimate a specific positive value has been made here.

IV. East River Park – Compost Man Pro technology

A. Introduction & Overview

Like the Hot Box installations, the East River Park composting program offers a useful contrast to the two hospital based systems considered in this report. In each of the hospital cases, it is the actual food scrap generator who composts using an onsite composting system. Even with substantial support and technical assistance available, in each case it is the generator rather than a specialized processor who is fundamentally responsible for integrating a new waste management process into existing grounds and operations.

In the model exemplified by the system at East River Park, a "compost entrepreneur" collects urban food scraps, composts them, and eventually produces and markets compost products. It must be noted that the East River Park system has not yet achieved this degree of vertical integration in practice, nor indeed reached full capacity even in terms of compost production. The operation is apparently in the middle of an evolving, developmental phase in many inter-related aspects including collection, the composting technology itself, onsite operational matters, and product development and marketing. However, the arrangement does offer at least conceptually the opportunity to consider the financial aspects of an integrated system that spans the economic equation from waste material generation to product marketing.

At the East River Park site, Christine Datz-Romero of Outstanding Renewal Enterprises, Inc. (ORE) provided the local start-up initiative and continues to operate the composting operation. Datz-Romero, expanding on prior urban composting experiences with the Lower East Side Ecology Center (ORE is the parent company of the Ecology Center), works full time on urban composting tasks. The compost bin system and vermicomposting technology and technical support are provided by Jim McNelly of the McNelly Group. Datz-Romero also devotes some of her time to managing a windrowed leaf pile on the site, though this operation is largely, but not completely, incidental to the basic food scrap composting facility analyzed here.

Datz-Romero's related experiences date at least to 1990, when New York City provided to the Lower East Side Ecology Center an empty lot for the purpose of creating a neighborhood garden. Composting offered a strategy for producing a soil amendment that would enable successful gardening on the lot. By the mid-1990's, after some experiments with neighborhood recycling, Datz-Romero was composting drop-off green wastes collected at the Union Square farmers' market (Green Market). This market was also providing an outlet for sales of her compost related products which currently include worms, worm castings, and "worm condos." Due to stockpiled production, these products continue to be sold at the market even though no products from the current facility have yet been marketed.

When the 15,000 square foot lot on which windrow composting had been successfully established was partially reclaimed by the city for a housing development, Datz-Romero turned to the city's Department of Parks and Recreation. The compost operation was moved to a 10,000 square foot site along the East River in the East River Park. With this fenced in area of the park already in use primarily as a leaf dump by the Department, an agreement was negotiated whereby ORE could use the site at no cash cost in return for better management of the site. This contract was scheduled to start at the beginning of 1997, but actual operations did not commence until March of 1998.

As mentioned, the Compost Man Pro system is not yet being operated at full production capacity. For a number of technical, operational, and management reasons, ORE is currently utilizing only eight bins of a sixteen bin system for the initial compost phase. The associated vermicomposter finishing system is also not yet generating castings that are routinely harvested and marketed, so there is so far no direct product sales revenues to offset system costs. These two issues – the ownership of capital equipment that is not being used anywhere close to capacity and the lack of product revenues – are the main factors affecting the current economics of the operation. Overall, the operation still has these and several related hurdles to overcome if it is to transition from grant support to an independently viable business enterprise.

B. Collection

ORE collects organic wastes on a local route that varies some by day of the week but is driven six days per week. All the generators are located in a compact neighborhood of New York City. The route is driven by Datz-Romero in a $28,000 commercial GMC model W4 medium-duty gasoline fueled truck (109 inch wheel base). The truck was outfitted with a lift gate in order to facilitate loading and unloading the enclosed rear body of the truck. Commercial generators place their non-meat food scraps in plastic bags that are then set into alleys in 32, 44, or 55 gallon containers.

The collection route requires about an hour to complete on average. On average, somewhat less than a half ton of material is collected daily, a quantity which sums to about 5,600 pounds of material collected weekly. Of course, there is some variance in the quantities collected from week to week and day to day.

Residential organic wastes are collected four days per week at the Lower East Side Ecology Center's stand at the Union Square Green Market. Approximately 400 households drop off a total of 1,300 pounds per week. In addition, food scraps are currently collected from five commercial generators six days per week. The commercial generators account for approximately three-fourths of the total collection quantities. All of them are in the neighborhood surrounding Union Square. Several if not all of the generators – a health food store, two restaurants, a restaurant/brewery, and a restaurant/sandwich shop – have an interest that goes beyond pure economics in working with ORE to dispose of food scraps in an ecologically beneficial manner. ORE maintains regular communications with a contact person at each establishment to maintain high quality source separation. Regular monitoring and feedback/reminders are important in this regard.

No information about implications of the food scrap collection system for the generators (commercial or residential) was obtained directly from them. However, the required operational changes are presumably minor from an economic perspective. Each generator must evidently put some extra effort into maintaining new habits of source separation (i.e., producing contaminant free wastes), storing in their limited space the food scraps briefly prior to pick-up, and generally dedicating one or more containers to storage of food residuals. Presumably, most residents engage in activities other than dropping off their food residuals during visits to the Union Square Green Market.

At the present time, ORE absorbs all costs of collection as it does not charge anyone, including the commercial generators, a collection or carting fee. Presumably, the carters hauling other wastes and/or the generators themselves reap any financial benefit of the diversion of food scraps from the rest of the waste stream. Fee structures can vary greatly, but in general carters charge a fixed (e.g., periodic) and/or volume/container based fee to generators (e.g., per dumpster "pull"), while they in turn must pay a weight based tipping fee ($60 per ton assumed here). Note that a volume based fee structure provides no special incentive to the generator to remove heavier materials from the waste stream.

If the carter's pick-up routine is essentially unaffected despite the reduced weight, it is likely that the generator will continue to pay the same amount and the carter will benefit. However, if the reduction in waste volume is significant, the generators may see a reduction in their carting bills. Indeed, one of the generators on ORE's collection route was able to negotiate a $1,200 per year reduction in carting fees, the equivalent of approximately $12 per cubic yard in terms of actual collection volumes. While carter fees are negotiated with a wide variety of actual prices paid, carters are allowed by law to charge the generator up to a maximum of just over $12 per cubic yard of uncompacted waste. Hence, this carter appears to be passing on all the savings to the generator.

An assumed $12 per cubic yard fee translates into hypothetical carter revenues of $15 (compacted) to $111 (loose, uncompacted) per ton applying a reference range of food scrap densities. According to recent empirical estimates by CityGreen, commercial waste generators typically dispose of commercial waste with densities of 175 to 375 pounds per cubic yard. Assuming an intermediate 250 pounds per cubic yard and a $12.20 per cubic yard carting fee (the maximum allowed for uncompacted waste in New York City), this yields estimated costs to generators of nearly $100 per ton for carting commercial waste.

Given the estimates of food scrap volumes collected from this specific generator by ORE and the reference range of typical volume to weight conversions, the generator's annual $1,200 savings is bracketed by estimates of the carter's $660-$2400 in avoided disposal costs for this amount of material (see spreadsheet). Since the food scraps are picked up daily in bags, the carter's actual avoided disposal cost is presumably closer to the $660 figure associated with uncompacted wastes than to the $2400 for compacted wastes.

In total, based again on the assumption that the diversion of food scraps from the waste stream enables carters and/or generators to achieve a $60 per ton avoided cost savings, carters avoid costs of nearly $9,000 per year associated overall with the 146 tons of food scraps currently being diverted into ORE's composting operation annually. Generators, on the other hand, could conceivably save almost $15,000 per year. This assumes they are in fact paying $12.20 per cubic yard for disposal of 146 tons of wastes that are in the 250 pound per cubic yard range, and that the entire avoided costs accrues to them.

The fact that ORE is only operating at approximately 50% or less of the rated processing capacity implies that ORE could roughly double collection quantities eventually. Thus, a ball-park estimate of $15-20,000 in potentially avoided annual costs from the perspective of generators, might be associated with this facility operating close to full capacity. Some, though not all, of this savings could presumably be shifted from the generators to ORE through a nonzero collection fee.

C. The Site

As mentioned above, the ORE compost facility is located in a fenced-in area of an existing city park. The site was previously used by the city primarily for leaf disposal. ORE is able to use the site rent free in return for upgraded management of the site, including some management of the leaf pile. The site, which is in a heavily used urban park, has been well screened visually to keep the composting operation out of sight. Despite the open air urban setting, there appears to date to have been no significant problems with odor from any part of the composting operation.

In a full cost accounting framework, a site rental or acquisition charge ought to be charged to the costs of the operation. In this case, the actual cost is $0 in cash, and this is reflected in the accompanying East River Park spreadsheet. No attempt was made to place a value on the negotiated rental rate of "improved management" of the site.

Of course, almost by definition urban land values are very high. In highly developed Manhattan, the value of air rights is probably a more relevant concept than that of land rights, and the notion of the market value of undeveloped land does not even fit well. Although it may provide an inappropriate high-end context we undertook a cursory review of existing asking prices for undeveloped parcels zoned for traditional development (residential/institutional/commercial) currently on the market in Brooklyn, Queens, and the Bronx (not in Manhattan itself). This review showed asking prices ranging from approximately $5 to $50 per square foot for sites ranging from about 2,000 to 50,000 square feet.

Translating even a fraction of these per square foot values into outright acquisition costs of a 10,000 square foot lot would add a significant if not insurmountable additional dollar outlay to any urban composting operation. To put say a $10,000 outlay ($1 per square foot) in context, it might be noted that the equipment cost for the Compost Man Pro system under consideration is approximately $100,000 in round numbers. In addition, it should be noted that while the ORE 10,000 square foot site does not waste space, it does also accommodate a significant quantity of leaves. Only about 6,000 square feet of the enclosed area are devoted to the Compost Man Pro system and working area. It is true, as described below, that ORE does manage and use the leaf windrows for some important functions related to the Compost Man Pro system. However, the extensive windrows are associated more with the Parks Department needs than with the food scrap composting operation.

While a significant expenditure for site acquisition or rental could make sense for a strong business marketing a profitable compost product, these observations generally underscore the notion that a site utilized for urban composting will likely involve underutilized land or space with a relatively low value in any alternative use (its "opportunity cost"), i.e., an area that is not zoned or otherwise practically available for other more valuable forms of development. It is likely to be either on the generator's own property or, as in ORE's case, at a site that is made available to the composter through some kind of special arrangement. Parks departments seem relatively well positioned to provide such space for urban food composting for several reasons, not least being their own routine need to manage their vegetative trimmings.

Although ORE has had no cash acquisition or rental costs associated with the site, it did have to make a quite substantial investment in upgrading the site, and even this cost was partly subsidized by in-kind contributions by the city. According to Datz-Romero, ORE's expenditures on the upgrade totaled approximately $30,000. Included in this cost are $7,200 in fencing and screening, with the balance of the expenditures going to the provision of water and electricity on the site. Though these costs are significantly higher than might be necessary at sites with other configurations or in less costly urban environments, they actually did not cover the full costs of the installation of these utilities. In fact the skilled professional labor (e.g., plumbing) and equipment use for trench digging was provided at no cost by the city Parks Department. In addition, the Department of Transportation made significant in-kind labor, equipment use, and materials contributions to upgrade the site's working surface to asphalt.

Although not yet installed, one other major site improvement is planned to enable the worm composting operation to succeed. A $10,000 greenhouse has already been acquired and will eventually provide a controlled environment for the worm apparatus. In addition to the cost of the greenhouse itself, additional administrative, construction, and assembly costs will be involved. Further expenses are also likely to involve some kind of climate control (e.g., heating) and improved misting capacity.

ORE expects to obtain the assistance and support of the Parks Department in installing the greenhouse. Because the greenhouse will be considered a permanent structure, it requires investment in a substantial foundation (involving test borings, structural engineering design for the pilings, etc.) not to mention the approval of at least two city permitting authorities (the building department and arts commission). In consideration of additional equipment needs as well as the time needed to shepherd the project through completion, and excluding the contributions of the Parks Department in materials and labor, ORE estimates its own investment in the greenhouse will total $18-20,000.

In sum, ORE is itself committed to an approximately $50,000 investment in site improvements alone.

D. The Composting System

The Compost Man Pro composting system acquired by ORE included the basic system, an industrial mixer, a small skid loader, a tipper, screener, conveyor, bagging equipment, and other sundries. The basic two stage composting system consists of the vermicomposter on the one hand and a module of sixteen bins with two biofilters and system controls. The bin system utilizes a blower to create a negative air pressure in the compost bins.

As detailed in the accompanying spreadsheet, the basic system was sold for just under $50,000 in capital costs. Additional necessary equipment was purchased for just under $30,000. Both the mixer and skid loader were bought used, saving nearly $30,000 in initial outlay compared to new equipment prices. In sum, the actual cost of equipment was $75,000. All new equipment would have cost $91,000. In addition to the equipment costs, the vendor assessed a $15,000 installation and delivery charge, bringing the primary capital costs to $90,000 (as paid) or $106,000 at new equipment prices. These costs can be annualized or depreciated legitimately using a number of assumptions. Assuming a 7 year average life and financing cost of 13% (a recent Small Business Administration lending rate for small loans) yields an annual payment of approximately $20-23,000. A 5-10 year economic life seems reasonable for most system components, though obviously some suffer from greater wear and deterioration than others. Spreading payments over a longer than seven year life or applying a lower interest rate (prime rate has been near 8%) would reduce annual payments and could well be justifiable depending on a given purchaser’s specific financing options or equipment-specific estimates of usable life (e.g., in this case the used equipment purchased would presumably have a shorter life than new equipment, resulting in higher annual payments than actually calculated).

Finally, it should be noted that the actual sales prices are for a first-of-a-kind system acquired almost entirely through the benefit of a grant from the state. While one might theoretically expect lower prices through improved system design and economies of scale if the system was commercialized, produced, and sold in quantity, this seems unlikely in practice at least for the near term. Aside from the problematic potential for substantial quantities of future sales, the system is assembled from individual components, many of which are unlikely to be acquired at reduced cost with increased sales. Moreover, because of the developmental nature of the installation and the grant support for the project, the system vendor indicates that he did not assign a full business markup to the system price.

Indeed, he is only tentative about the practical business viability of this downscaled version of his larger system. This concern rests in large part with the difficulties in recovering certain relatively fixed costs (especially for installation and initial and ongoing technical support) that eat away at profits that are much thinner for small systems.

E. Onsite Processing

Once the collected food scrap material arrives at the compost site, it is processed in two separate phases. Phase One takes place in the 16 bin system, where each bin has a 37 cubic foot capacity and the designer gives the system as a whole a rating of 1 ton of compost mix per day. Phase Two involves vermicomposting in a separate worm holding apparatus. One of several key factors defining the operational relationship between the two phases of the system is the inter-related residency times. Within the constraints of limiting biological and physical parameters, themselves affected by the characteristics of the compost mixture, the length of time the mixture composts within the bins can vary. This directly affects the work involved transferring the wastes to the worm apparatus, as well as vermicomposting residence time, and several other factors affecting costs of the vermicomposting phase.[6] At this point, ORE's roughly half scale (8 bin) operation is based on 10-14 day bin residence times during Phase One.

At current collection and retention rates, four to five bins are emptied and refilled with new compostables each week. On some days (generally days when the Union Square Green Market wastes are collected) the volumes may fill an entire bin and then some. On other days only a fraction of a bin may be filled. Even "full" bins are not filled to the 37 cubic foot capacity due to considerations of weight affecting the skid loader's handling characteristics.

Though the windrowed leaf pile is not an integral design component of the bin and vermicomposting system, it does serve an important buffer function for ORE in terms of excess material. It also functions well in absorbing the leachate that collects in a sump from the Phase One bins and is manually emptied into the leaf pile periodically, given that the site has no drain or sewer connection. At times when the system is down (an estimated 8 hours per month on average) or when bins are full or unable to accommodate wastes of a particular character, ORE simply works excess collected material into the leaf pile. This happens perhaps once a week, involving an unmeasured quantity of incoming material. For example, brewery wastes are regularly emptied into the leaf pile, which composts more effectively with the added nitrogen in any event. Excess brewery wastes are relatively difficult to manage in the bins because of density and moisture content, and must be mixed in with relatively large quantities of bulking agent. Because they are collected in uneven quantities over time (e.g., quantities peak around the holidays) and in barrels that must be returned to the brewer on schedule, disposal of excess quantities in the leaf pile is convenient. In this way, ORE is able to provide consistent and uninterrupted collection service to its client.

While other "buffer" or excess capacity options exist, this one seems well-suited to the East River

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[6] As a polar if disputed example, McNelly points out that at least one prominent expert advocates feeding the food scraps directly to the worms. McNelly argues against this practice himself. He does argue, however, that brewery wastes can be most economically fed directly to the worms. Datz-Romero does not agree about even the brewery wastes.

Park circumstances in the absence of onsite sewer connections, though there is presumably increased need for careful odor management procedures. However, neither capital nor operating cost implications of either this existing back-up capacity or alternatives have been included quantitatively in this analysis. It should be noted that insofar as food scraps are actually diverted out of the bin/vermicomposting system, the current estimates of that system's per ton operating costs and product yield will seem more favorable than is accurate.

The onsite operation consists of three basic composting steps. On the four or five days a week when a new bin is started, the full bin which has been composting the longest must first be emptied and the contents transferred to the worm apparatus. This process takes approximately 45 minutes on average. Second, the food scraps must be debagged and mixed with bulking agent (sawdust and shavings plus some finished compost) in the mixer and then loaded into the compost bins. This process takes approximately an hour. Third, management and harvest of the worm apparatus is necessary, including bagging of the worm castings or production of a potting mix for market. However, the amount of labor for this part of the operation is only speculative because it has not yet been implemented. To date, the worm apparatus is operating significantly below capacity and in any event no castings are being harvested. In addition to these basic tasks, ORE spends roughly a half an hour a day on leachate management, cleaning the blower, and other routine maintenance, plus an additional half-hour on cleanup. Thus total labor currently associated with onsite composting is approximately one hour daily (six days per week) plus somewhat less than two hours on the four to five days a week that a new bin is started.

In somewhat more detail, the first two basic food scrap/compost handling stages described above include the following steps and equipment. First, the day starts by emptying a full bin. This involves using the skid loader with a forklift attachment to place the full bin on the freestanding tipper. The tipper is then used to tilt the bin on its side. Next, the operator manually scoops the material out of the bin into the bucket of the loader. From there, the partially composted material is driven to the worm apparatus and dumped. This transfer requires several repetitions.

Second, after the arrival of new food scraps on the site, the containers of material are manually unloaded from the rear of the GMC truck. The material is then dumped by hand, and thereby debagged, from the rear of the raised truck bed. Sometimes, the operator dumps the wastes onto the moveable conveyor belt, which then conveys the material directly into the mixer. At other times, the material is emptied into the bucket of the skid loader and then deposited in the mixer. Because of the operator's concerns about stresses on the mixer's auger, each load is mixed when the contents have reached approximately half the full volume capacity of the mixer. This entails about four loader buckets full of food scraps, plus the added sawdust and compost innoculant. The compost and sawdust are added to achieve target consistencies of approximately 60 percent moisture content. The mixture is then loaded into an empty bin via the conveyor belt. There is some flexibility in the range of moisture content, of course. A greater quantity of food scraps can physically fit in a full bin if the ratio of sawdust amendment is lower, but at the cost of increased bin weight plus increased density of the material, with associated poorer aeration and composting performance.

Note that the hourly labor data do not include any estimates of the time spent on administrative activities (overhead). In fact, Datz-Romero spends a significant part of each afternoon on a combination of administrative, trouble-shooting, and educational tasks. During a developmental phase of innovative technology application this kind of time requirement is frequently high, and some portion of this time would be necessary for any compost entrepreneur. In addition, the ORE's involvement with grantsmanship and its fundamental educational orientation expand's the staff time devoted to these tasks. There is no clear information on a "minimal" amount of time that would be required for administration of a full scale production facility of this type. In order to avoid arbitrariness, no explicit cost of this task is quantified.

For the purposes of this analysis, onsite labor has been valued at $15 per hour as a reasonable approximation of the actual return to the current ORE labor. However, it is likely that at least some of the various tasks might, in other situations, be assigned to staff earning either significantly more or less. While certain tasks (e.g., clean-up) might be accomplished by workers at the lower end of the wage scale in New York City (say $8-10 per hour), the complexity involved in managing a biological system suggests that the classes of worker normally earning $20 or more an hour might be more suitably engaged to operate the system.

Total annual operating costs including labor, utilities, fuel, maintenance, and the like are estimated at $18,325. Again this figure excludes any charge for administration or leaf pile management. Note that these operating costs alone, even though they are based on a system operating at only roughly half capacity, are approximately the same as the maximum potential value of avoided costs associated with operation at full capacity. While doubling throughput need not necessarily fully double labor costs, it would certainly increase them significantly. Clearly then, the economic viability of the system depends upon a significant product sales revenue stream and/or significantly reduced costs.

It should be noted that discussions with both ORE and the Compost Man Pro designer indicate that there are both system design and operational modifications that have the potential to reduce labor or operational costs. However, Datz-Romero is generally much more skeptical than McNelly about the potential magnitude of these reductions. From her operational "on the ground" perspective, Datz-Romero has already tried to optimize the current configuration of equipment and operations given existing capacities and resources. McNelly, with a system designer's sense of flexibility and fine-tuning of possibilities, has made a number of additional suggestions that would be intended to either improve efficiencies or address existing difficulties in operating the system. While some of these suggestions have already been implemented in the system as described, Datz-Romero is concerned that a number of suggested modifications will either not work as planned or introduce unacceptable costs in terms of new labor requirements or additional dollar investment. Ultimately, the other suggestions do remain to be tested in practice, and the question of their feasibility therefore remains an empirically open question. Certainly, it is not yet proven that they can be practically integrated into the East River Park composting system, are affordable for ORE at least in the near term, or would necessarily achieve the desired savings in practice.

In a number of the suggested options the trade-off for improvements or other reduced costs is greater capital intensity. Thus, as an example, at least one of the labor saving options is contingent on the use of biodegradable bags, which is not feasible with the current mixer. In pursuit of this possibility, McNelly has designed and had a commercial manufacturer build an improved, more flexible mixer that is both water tight and has a shredding capacity capable of adequately handling degradable bags.

McNelly asserts that the new mixer has two primary advantages. First he argues it has the potential to significantly reduce food scrap unloading and mixing time. With some additional small investment (e.g., in a grappling hook), McNelly envisions the possibility of loading biodegradably bagged food scraps more directly from the truck into the mixer. In addition, the new mixer might make more attractive the option of filling the mixer completely before mixing.

The mixer was also designed to address a second concern. Currently, the compost is at approximately 50% moisture content when it leaves the bins, whereas the worms thrive at approximately 80% moisture content. At this point an overhead hose with adjustable spray nozzle is used to add water to the surface of the compost in the worm apparatus. The hose is occasionally moved to ensure complete coverage. McNelly suggests that new mixer can more effectively achieve desired moisture content. The mixer, with 54 cubic foot capacity (easily handling the contents of a 37 cubic foot bin) is watertight. McNelly's "new mixer scenario" would involve working with the tipper and mixer as a unit. A full bin would be taken to the tipper, which could then be used to empty the bin directly into the mixer. At this point, water could be added to the partially composted material to achieve a worm friendly moisture content. From the mixer, the conveyor could be used to deliver the "mud" directly to the worm apparatus.

Again, these new mixer improvements promise reduced labor or a more productive worm composting phase as a trade-off for increased capital intensity: the $12,000 capital cost of this mixer is double the $6,000 actually paid for the used mixture currently in service.

As one final example McNelly cites of the divergence between theoretical efficiencies and actual circumstances that involve capital/labor trade-offs, the original manifold was designed to drain to one end thereby facilitating condensate collection and management. However, the grading on the site does not make this possible, so manual intervention is required at the low points where water collects. Again there is a technical fix in the works in terms of redesigning the system to be more forgiving of the grade, but additional investment is required for the upgrade.

Lastly, it should be emphasized that these examples are given mostly to illustrate that this technology, like others that have been studied, is a system that is still evolving in a site- specific context. Each round of evolution changes the mix of costs and benefits associated with the technology. The direction this evolution will actually take, at least on this site, depends on the ability of the system designer to convince a skeptical operator that each proposed change is likely to benefit the operation in practice as well as theory.

F. Compost Marketing

Production and marketing of a compost product is an enterprise option that is very unlikely to be pursued directly by a food scrap generator. Even if they manage to compost successfully onsite, few compost operators are likely to have the skills, available labor, scale delivery mechanisms, organizational incentives, marketing savvy, or scale economies necessary to succeed in such an endeavor. A third party intermediary, whether it is itself a compost producer like ORE or merely a collector and marketer, is much more likely to play this role.

As mentioned, no worm castings from the ORE production facility are currently being harvested and marketed. Thus, it is not possible to make an empirical report on either the costs or revenues associated with the final stages of processing and product marketing. However, because of ORE's history of specialty sales of castings through the Union Square Green Market, it is possible to derive some estimates of potential revenues. Key factors to consider include ORE's current market price of $1 per pound in small quantity and $0.35 per pound delivered in quantity. Approximately 4.5 tons of castings are currently sold annually, with sales peaking in Spring.

Sales currently take place through the Union Square Green Market, and involve marketing labor compensated at $8 per hour. However, larger scale production and marketing of castings would involve a new marketing strategy. ORE plans to move in this direction when the castings production capacity becomes available. According to Datz-Romero, "I've been biting my tongue in terms of really trying to push the product so far. What we've really been trying to do is push the message…. And I'm lucky I haven't because I couldn't deliver." Datz-Romero needs to do more market research, as a detailed marketing plan is not yet in place. Both McNelly and Datz-Romero do agree, however, that the market for potting mixes is significantly larger and potentially more profitable than the more limited market for worm castings. McNelly estimates that the potting soil market would support sales of potting soil at $0.10 wholesale and $0.30 retail.

Several scenarios for revenue projections are possible. For example, it is possible to assume that the current production facility scales up to "full capacity" (still less than the system designer's full capacity rating) by doubling the material collected and using all 16 bins in the first composting phase. In this hypothetical case, somewhat under 300 tons (291 estimated) of food scraps per year would be processed. If the wood sawdust/shaving amendment comprises 15% of the mix by weight, a total of just under 350 tons (an estimated 343 tons) of organic material would be composted each year. If, quite generously, 50% of this material by weight is harvested as castings, the annual yield of marketable castings would be approximately 175 tons.

According to several assumed parameters provided by McNelly, such a quantity of castings would be transformed into approximately 1,700 tons of potting soil mix. At a wholesale price of ten cents a pound, there is a potential for nearly $350,000 in annual revenues from this operation. This figure obviously dwarfs the other annualized cost and revenue figures considered in the rest of the analysis.

Using McNelly's per pound estimates of the costs of purchasing the amendment, then bagging and delivering the potting soil, adds costs of approximately $160,000 for this quantity of potting soil. This leaves a margin of approximately $180,000 of revenues over just these costs. The estimated net cost of material collection is currently not offset by any revenues, and could exceed $20,000 annually if collection doubled to provide a doubling of throughput. Of course, if a collection fee were charged this deficit could be significantly reduced and perhaps even fully offset. In this case, the remaining margin of $160-180,000 would still have to absorb the slightly more than $40,000 in current annualized costs in the composting phase, so it would still leave an estimated maximum of $120,000 in annual revenues.

This margin would also have to absorb the costs of scaling up to full production capacity in the sixteen compost bins. Based upon the cost of current half-scale operations, this would require approximately $20,000 in added operating costs if no new efficiencies were achieved. In addition, the remaining $100,000 margin would have to cover the operational costs of moving the vermicomposting operation into full scale production mode, which would entail a variety of new activities including loading additional wastes into the worm apparatus, monitoring and managing the worms, and routinely harvesting castings. Since most of these unaccounted for annual costs are associated with labor rather than any unaccounted for capital investments, it seems quite plausible that this could be achieved with perhaps $60,000 or more dollars annually in profit left over. McNelly, for example, estimates that significantly greater production quantities could be generated and marketed annually with one FTE in labor.

In sum, the up front $140,000 investment in fixed costs for site improvements and equipment (nearly $170,000 including the collection truck) might generate a net revenue stream that ranged between $40,000-60,000 annually. This margin could increase significantly if ORE was able to charge generators a carting fee that captured a major portion of the generators' avoided cost. While this estimate is based in large part on very tentative assumptions about implementation, it does suggest that an aggressive and successful production and marketing effort could ultimately result in a profitable enterprise with a reasonably short payback period.

APPENDICES FOR PART 2

Appendix 1. Spreadsheet for the Flushing Hospital Medical Center -- Green Mountain "Earth Tub" Technology

Appendix 2. Spreadsheet for the Open Road Hot Box Technology

Appendix 3. Spreadsheet for St. Barnabas Hospital -- Wright Environmental Management, Inc. Technology

Appendix 4. Spreadsheet for the East River Park -- Compost Man Pro Technology

PART 3. CORNELL TECHNICAL ANALYSIS

I. METHODS AND MATERIALS, INCLUDING METHODOLOGICAL CONSIDERATIONS

The purpose of the compost monitoring program was to evaluate the effectiveness of the composting system. Ideally the monitoring program provides useful feedback to the operator, both in adjusting the current process and in improving the process in the future. Some of these parameters can be measured in real time, such as temperature, while others require an analysis that takes time and can only be used for future improvements.

Other than temperature, which is a well accepted composting parameter, the value of other analytical tests remains ambivalent. In many cases the value of the test may also depend on the particular system being used. Furthermore, the value of some tests will be higher in the early stages of developing a composting process when large changes are being made. Other tests are sensitive to smaller changes such as the daily variability of the raw materials, and the changing weather conditions, and can be used to monitor a fairly stable process. In some cases the test is valuable, but a well trained operator can observe the pile and obtain the same information, e.g., the range of the moisture content and the presence of ammonia may be determined "observationally" rather than require routine scientific measurements.

In this project a number of parameters were measured to begin to get some scientific information about composting with different equipment and processes. Many measurements were made on each system. Both the frequency and types of measurements made have value at the moment, but often these are of limited value beyond the actual specific experiment because of the major changes that had to be made to the systems as the research progressed. In this section we will describe the various methods and give some insights into their potential value. Within the discussions of the actual systems, some limited amount of data will be presented, when it adds to our understanding of the process.

We have chosen to discuss some of the issues we considered in deciding how to make these measurements and what the results may mean. Hopefully, this information, rather than a dry, detailed methods and material section that focus' on technical details and site specific details will be of more value to composters, particularly those who may, themselves, be involved in small and medium scale composting.

A fair amount of judgement is called for in setting up individual composting programs. Even with a "standard" piece of equipment, the process, raw materials, and site conditions will have a significant impact on the composting program. At the current stage of composting equipment development, many variables are changing and even the methodology is changing rapidly so that a single "right" measurement program does not exist.

A. Sampling

One of the most critical issues in any research protocol is sampling. Compost, by its very nature, is a particularly difficult product from which to obtain "representative" samples. Food waste tends to be non-uniform. Even after some mixing with bulking agents, the mixture is not uniform. Furthermore, given the relatively small size of the samples that can be easily handled by researchers – particularly if many samples are needed, the problem is compounded. Furthermore, in this project we had the additional limitation of the need to ship samples from NYC to Ithaca. During the time of shipment, these inherently unstable materials may change. Thus, more than usual, composting data should be viewed with a healthy skepticism.

To provide for continuity within a particular type of equipment, a carefully drawn up sampling plan is needed. It, at least, establishes consistency from sample to sample. Because each piece of equipment being used is so different, the sampling plans for each piece of equipment is very different. Sometimes physical limitations, i.e., access to the samples, will further limit the ability to sample at all points that might be ideally examined. In those cases where the food is chopped ("pulped") before composting, the homogeneity of the compost material, and, thus, the quality of the samples would obviously be improved. (However, the practical results to date with composting systems suggests this is not necessary for the composting process.)

Other important consideration with respect to sample monitoring is whether the process is continuous or batch, and whether the compost is mixed during processing. One often needs to account for both time and location dependent variables for each process.

In previous work at Ithaca College (Ithaca, NY), we have established that the raw materials (input) can be qualitatively characterized in terms of its major constituents, i.e., fruits and vegetables, starches, meats, etc. Composters can often even estimate the percentage of each of these types of materials as a way to semi-quantitate the character of the materials. This helps the operator identify the potential amount of moisture in the food waste, and the potential nitrogen content. In all cases the volume and/or weight of the total food waste needs to be estimated so that the amount of material diverted is known.

It was possible to design a rigid sampling plan for the Hot Box because the interior of the unit was fully accessible for sampling and is unmixed after the material is put into the unit. A copy off this plan and the basic instructions that went with it are shown in Appendix I.

B. Temperature

The simplest and most common measure of a compost's behavior is to monitor its temperature. Temperature monitoring can be automated, and even collected using a data logger. In many cases, an air blower or other equipment that might modify the compost pile can be turned on or off based on real time temperature measurements. But the biggest concern remains the question of where to place the probes. It certainly has to be deep enough to get at the real internal temperature, but at other times the gradient to the ambient surface temperature may also provide a more comprehensive understanding of what is happening across the compost material. With really big compost volumes, temperatures deep in the material are difficult to measure.

In general an extended temperature above 130F is considered to be ideal during the initial thermophilic phase since it means the pile is operating well and also is sufficiently hot to kill pathogens. Above 160F one starts to kill beneficial bacteria and there is some concern about the continued composting of such a pile. Once the pile gets below 100F, it generally suggests that the process is slowing down.

However, it is important to determine whether this temperature decrease is due to imbalances in nutrients or other problems with the pile, most commonly moisture loss, in which case an adjustment would start it heating again; or whether the thermophilic phase is complete. Once the thermophilic phase is complete (i.e., during curing), significant heat buildup is generally a sign that something is amiss. At this point the exothermic chemical reactions that were not completed in the thermophilic phase may be involved which if not modified can lead to a pile smoldering, i.e., it can become a fire hazard. (The material tends to be dryer at this point then in the thermophilic phase and is often formed into larger unmonitored piles.)

C. Moisture and Gas Monitoring

The composting process is a biological oxidation ("burning") process. Thus, oxygen is used up, while carbon dioxide and water are produced under the most ideal conditions. If oxygen becomes rate limiting, the reaction will turn anerobic and will produce more of other organic compounds and less carbon dioxide and water. In a real pile, other compounds are produced even under the most aerobic of conditions. Both sulfur and nitrogen containing organic molecules must be converted to some inorganic form – the issue is always which forms. Is it a volatile compound, and if it is a volatile compound, what is its odor threshold? The odor threshold is the concentration of the gas at which a person can detect the presence of the compound. Obviously some compost breakdown compounds may be produced at levels above the odor threshold and can then be detected. There will be a range of detection levels for different people. In general, one needs to pay attention to the most sensitive people. The second component of odor concerns relates to how "obnoxious" or "foreign" is the odor. Even if one can smell it, it may not be a problem unless it becomes overwhelming, e.g., perfume at too high a level can be terrible but at low levels are desirable. Or if one cannot place it contextually at the location, this can also be a problem, e.g., a barnyard odor in an urban setting.

A "Drager" tube is used to measure specific gases, often outside of a controlled laboratory environment. These are one shot devices that give a color reaction that can then be used to estimate levels of gases. Devices also exist for the continuous monitoring of gases. Such a system was tested as part of this program, mainly for carbon dioxide and oxygen, although carbon monoxide was also considered. (Making a field rugged sensor is not trivial, particularly in the harsh environment found within a compost pile.)

A bilge pump was used to extract gases from the pile. After initially flushing the equipment, a Drager tube was opened and additional pumping through the Drager tube was accomplished. Determination of the final concentration was done by comparison to a set of standards provided.

The production of carbon dioxide is a sign that the system is actively composting. The amount of carbon dioxide production should go down as the process peaks and goes into curing. At the end of curing carbon dioxide production should be quite low. The amount of oxygen should remain sufficiently high throughout composting to provide aerobic conditions. If oxygen drops too low, incomplete oxidation of acidic compounds can occur and the system can go anerobic. The presence of carbon monoxide is another indicator that the system is not functioning correctly and is not getting enough oxygen. Hydrogen sulfide and other odiferous gases occur when the system is not properly functioning. Ammonia can occur in either an aerobic or anaerobic setting, and primarily indicates that the compost is too high in nitrogen. Both nitrogen and sulfur should ideally be going to non-volatile compounds within a compost pile. (Mercaptans, etc. are big odor concerns with anerobic degradation.)

The human nose is also a “gas sensor” – at least for the odiferous compounds -- and the use of such a test should not be discounted. People are often as good or better than a “machine,” at least when they are working correctly, i.e., with a sensitive nose, no colds, and paying attention. The biggest problem with humans is that they are easily saturated – in general, the longer they are exposed to a smell, the less they notice it. Some work suggests, however, that “foreign” odors will be detected much longer, whether they are dangerous or not.

The measurement of moisture is a useful adjunct to temperature measurements. Research is showing that 50-59% moisture is probably the best range for composting. Above 59% one interferes with air movement and thus the compost pile can potentially go anerobic and/or have problems with leachate. Below 50% moisture the bacteria involved in composting do not seem to do as well: not enough moisture. However, if the density is too high, air diffusion will be prevented and even 50% moisture may lead to problems.

Moisture is measured by drying the sample under mild conditions, just over 100C (212F) to drive the moisture off. The weight loss is equal to the moisture.

It should be noted that the moisture changes in a compost can be attributed to:
1) The loss of moisture due to evaporation because of heating;
2) The increase in moisture produced chemically by the composting process; and
3) The movement of moisture, usually as water vapor, as different conditions occur in the materials.
Because of the heat generated in the compost, the moisture content may not, and may not need to, be uniform. In fact, recent work at Cornell suggests major moisture gradients occur in static compost piles. Besides the impact of moisture levels on bacterial growth, these gradients in moisture may also lead to channeling of airflow with its concomitant problems.

D. pH

The pH of a sample is an indication of the acid/base balance in the material being examined. This can be valuable to know for at least two reasons. Many of the “obnoxious” organic compounds of concern are basic, and tend to be more volatile when the compost is basic. So the more acidic the media, the less likely are obnoxious odor problems. A slightly acidic pH is probably the best pH for the composting organisms. Too low of a pH will inhibit bacterial growth. A very low pH indicates that incomplete oxidation of materials is occurring, and the compost is essentially pickling itself. For the level of accuracy needed in this work, and the need to take pH readings at the time of sampling, before shipment to Ithaca. pH paper was used and compared to the color standard provided with the pH paper.

E. Nitrogen Measurements

Generally the nitrogen content of food materials and, by extension, of compost can be measured by the Kjeldahl method. This method has long been used to measure nitrogen. By calculation from the presumed composition, one can usually estimate the carbon content. The ratio of carbon to nitrogen is often taken as a major compost "processing" parameter. However, because these calculations do not take into account the "availability" of carbon (and possibly of the nitrogen), it is really only a rough guide.

A good composting pile should retain some of the nitrogen, since it is one of the most valuable nutrients compost can supply to the soil (and growing plants). On the other hand, most composts are not fertilizers and should not be thought of in those terms although their contribution to nitrogen (and phosphorus) should be accounted for when managing soil nutrients.

F. Compost Stability

The absence of respiration, i.e., oxygen usage and carbon dioxide production under ideal conditions is a measure of stability. A simple test, the Solvita test has been developed by the Woods End Lab of Maine to examine this property. It is a relatively inexpensive, field test that has been separately collaboratively tested in our laboratory and a report submitted to the NYS Department of Economic Development. It was considered to be a satisfactory test when sufficient attention to details by the test operator occurred. A few samples from the end of thermophilic processing and during curing were analyzed using this test.

G. Bulk Density

This measurement gives an indication of the porosity of the material and of the impact of changing raw materials on the weight to volume relationship. It is nearly impossible to accurately obtain, given the density is so completely disturbed in most sampling procedures. Basically a bucket of known volume is filled with material – trying to pack it similar to the actual sample. The heavier the sample, the higher the bulk density. In general, too high a bulk density means that the product has poor aeration characteristics.

H. Steaming

A semi-quantitative scoring system has been devised to evaluate steam coming out of the piles. Strong steaming occurs when steam is observed as one approaches the compost pile or equipment, before any turning or mixing. Medium steaming occurs when you only see the steam when right at the composter. Little steaming occurs when one can occasionally see steam when standing at the composter or one has to really look hard to find the steam. No steaming is for all those cases where the previous three observations were not observed.

I. Volatile Solids

Ashing of materials at high temperature (e.g., 550F) leads to the production of an ash, that represents only a small part of the weight of the original sample. This ash represents the inorganic salts and minerals. The remainder of the material that is volatilized under these circumstances (minus moisture) is considered to be the volatile solids and is a rough measure of the organic matter. This number, when multiplied by an arbitrary factor of 0.56, is sometimes used to calculate the amount of carbon present in the material. As a rough rule of thumb, one needs 30 parts of carbon for each part of nitrogen in order to successfully compost materials. However, in actuality the amount of available carbon is probably more important. For example, a log and very fine sawdust have the same amount of actual carbon (or volatile solids) but the sawdust has orders of magnitude more available carbon.

J. Timing

Given that compost systems, especially the small ones, may be subject to daily ambient conditions and the circadian cycle, the time when the observations are made needs to be noted. The best possible case is when all of the measurements are made at the same time. This was not always possible in this set of experiments, particularly when the observations were being made by someone other than the regular operator.

K. General Analysis

Cornell University's Nutrient Analysis Laboratory provides general compositional data on soils and, again by extension, of compost materials submitted to it for micro-nutrient analysis. A few such samples were submitted and the analyses will be presented.

II. COMMENT ON THE ROLE OF THE NYC PARK'S DEPARTMENT

One of the original goals of this project was to prepare a "semi-stable" compost. This would be a compost that was not smelly, was visually not seen as "food waste," would not attract various vectors, and would, therefore, be acceptable for placement on park land. This would not necessarily require completion of the thermophilic phase on-site. Final thermophilic composting might occur on park land in addition to the curing phase. The logic of this approach was that any one generator/composting site would have space limitations, the sooner the generator could move the "compost" off the site, the less capacity that would be needed at the site. The parks of the City of New York could use these materials to improve the parks. They actually have the labor force to do the further work necessary – they are usually limited in resources for purchasing materials. Given the many city parks in the city, the local compost producers would not require extended transportation to get the product to a local park. We believe that it should be possible to work out a pick-up system with the parks department.

By keeping production and eventual use local, we also felt that a number of additional benefits would accrue. First, the product would be traceable to the producer, so that the incentive for doing a good job of source separation, i.e., keeping the plastic and glass out, would be high. On the other hand, by providing useful materials to the local community parks, the generator would get the benefit of appropriate publicity and community support. This creates a powerful incentive for participating. If in addition the project was a cost-saver, or even permitted the company to break even, the acceptability of participating would be optimized.

The entire City of New York would benefit by having less organic waste to dispose of, particularly once Fresh Kill closed. Also seeing the commercial sector compost might encourage more household organics diversion with further benefits to the City. At the same time the parks of the city would be improved by increased soil quality.

Unfortunately, the smaller amounts of compost generated during the life of the project, because of the problems encounters with the larger generators/systems, did not permit the proper exploration of the full range of issues that would be involved in such an effort to develop a partnership between commercial companies and the NYC Department of Parks. We do hope, however, that this concept is not lost as food waste composting moves forward in New York City.

III. OVERALL CONCLUSION

In setting out to do this project, the feeling of those involved and consulted was that some very interesting pieces of equipment had been developed that should be appropriate for the scale of composting appropriate to a variety of urban settings. The assumption was that the equipment was sufficiently developed to be evaluated and that the real problems would be whether they were applicable to the urban environment. The next stage of development and adaptation could occur as we learned what new issues might surface when the equipment was used in the urban environment. However, it seems that many of the problems this project actually had to deal with were equipment limitations that were not unique to the urban environment we were operating in. The only system that seemed ready for use was the "Hot-Box" – which was the simplest of the systems (i.e., essentially no mechanical parts) and which does pretty much what it claims to do. Its major limitation is size. It is probably the most appropriate for the smallest scale of operation. Given its non-mechanical nature, it is probably the most reliable, but also probably the most labor intensive. The other systems clearly need to be fined tuned to the needs of food waste composting, but all look to have potential with certain scales of operation. Certainly working with these companies during these project has already led to equipment and procedural changes that have made the equipment closer to field ready. We remain optimistic that future composters in NYC will find that these various pieces of equipment, and similar products by other companies, will permit urban composting in NYC to everyone's benefit.

IV. TECHNICAL RESULTS AND DISCUSSION

The samples sent to Cornell University are described in some detail in Appendix II for the Green Mountain and Wright Systems. These reports include the operator or field personnel's comments. The analytical results generated in Ithaca for these two systems are found in Appendix III.

A. Green Mountain System

The gas sampling results using the Drager tubes (Appendix IV) are described along with the details of the experimental method, i.e., the gas sampling, along with showing some typical results. (This report was prepared by Dan Cogan of the Cornell Waste Management Institute in conjunction with Erin McDonnell, a graduate student in Food Science, working in Dr. Regenstein's laboratory.)

The oxygen levels were quite high so that the system was easily operating aerobically. The carbon monoxide, dimethylsulfide, and ammonia levels were not particularly high initially and decreased with time, which is also ideal. Thus, these results suggest that the overall operation was working fine.

The temperature profiles (Appendix V) for the Flushing system suggest that heating to the proper temperatures for composting, pathogen kill, and weed seed destruction did occur and was maintained for a number of weeks. (Some of the spikes observed in the data represent equipment problems.)

From the data in Appendix III, we see that the moisture content of the samples is generally within the required range. The samples with the lowest moisture content (i.e., below ideal) are actually from the bulking agent and would be expected to have relatively low values. The amount of nitrogen, generally 3 to 4%, is relatively high and probably reflects a high amount of flesh food scraps in the mix.

The data for this system suggest that the system is working well, and this was also reflected in the fact that the operation has continued and even expanded slightly by obtaining a third Earth Tub.

B. Wright System

From the data presented in Appendix III, it appears as if the samples (with bulking agent) for the Wright system were a bit higher in moisture and lower in nitrogen than the samples at the hospital. Some of the samples may in fact be a bit too wet and this might account for some of the odor problems observed with this system.

C. Hot Box System

The sampling procedure for the Hot Box as previously mentioned could be highly standardized and is shown in Appendix I.

In contrast to the Green Mountain Equipment, the gas sampling for the Hot Box system shows a much lower oxygen level (Appendix VI). This, however, is still above 5 ppm and is therefore still considered satisfactory for aerobic composting. But it does highlight the importance of having the ventilation system (i.e., the internal pipes) operating correctly. The ammonia levels were low and were similar to those seen with the Green Mountain equipment.

The pH for the Hot Box as sampled on site was in the 6 to 7 range which is fine (Appendix VII). When the pH goes above 9 or so, odors can be a problem, while too low a pH will kill the necessary microorganisms. By the time the samples were tested in Ithaca, the pH was a little higher (Appendix VIII). This may have been due to "anerobic" conditions during transport and/or differences in the equipment/methods used to measure pH.

The moisture content was at times a little above ideal, i.e., over 60% while the volatile solids levels are reasonable (Appendix VIII).

The one temperature profile available for the Hot Box shows good initial heating followed by a rapid temperature drop (Appendix IX). This is sufficient for pathogen reduction, but suggests that much more curing will be required with materials obtained from this system as the total breakdown of organics is apt to be incomplete. In urban sites, the need for curing time and space may present a challenge.

D. McNelly System

The gas results for the McNelly system (Appendix X) show that the initial dimethylsulfide is high, the ammonia in box 2 is high and the oxygen levels are somewhat low. With time the dimethylsulfide was reduced but the ammonia level continued to stay high. The temperature profiles for box 1 also suggest that the system was operating properly and heating up well. The slow heatup of Box 2 suggests potential problems that seem to be consistent with the gas monitoring results. Thus, Box 2 does not seem to be operating ideally.

The Ithaca analysis of samples from this system (Appendix XI) suggest that the moisture content may be a bit on the high sides at times, while the nitrogen content is similar to that for the Wright system, which means that should not be causing any special problems.

Again this is a system that is still undergoing development, but attention to operating parameters in the boxes may be critical for proper composting.

APPENDICES FOR PART 3

Appendix I. Hot Bot Sampling Grid and Instructions

Appendix II. Materials Log and General Comments for the Green Mountain and Wright Systems

Appendix III. Chemical Analyses for the Green Mountain and Wright Systems

Appendix IV. Gas and Temperature Monitoring of Urban Compost Systems -- Flushing Medical Center

Appendix V. Weekly Temperature Records for the Green Mountain System

Appendix VI. Gas Monitoring Records for the Hot Box System

Appendix VII. pH Monitoring Records for the Hot Box System

Appendix VIII. Chemical Analyses for the Hot Box System

Appendix IX. Temperature Record for the Hot Box System

Appendix X. Gas Monitoring Records for the McNally System

Appendix XI. Chemical Analyses for the McNally System