The Green Triangle of Boston, Massachusetts: An Eco-Industrial Cluster
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ABSTRACT
This paper details a proposal for an eco-industrial park (EIP) in a section of Boston, Massachusetts, known as the Green Triangle. The paper reviews local efforts to revitalize the region by identifying common goals and leveraging the area’s available resources. In particular, the paper focuses on four organizations that have formed a Green Triangle Coalition: the Arnold Arboretum, the Franklin Park Zoo, the Massachusetts Audubon Society, and Lena Park Community Development Corporation.

In the short term, the proposed EIP will include the four organizations listed above. Over time, we recommend that the EIP add a compost facility, to become the anchor, and other facilities, such as a centralized equipment facility and an organic farmers market. We have applied the principles of industrial ecology in the development of our proposal. As we will show, the application of industrial ecology principles to the study area creates a number of great opportunities for environmentally progressive economic development.

INTRODUCTION
The Green Triangle of Boston is an area with untapped potential that struggles with a poor image brought on by high unemployment and high crime rates. The eco-industrial park (EIP) could become a backbone for overall Green Triangle revitalization efforts. It would create opportunities for environmental and economic improvement by closing material flow loops, sharing commonly used resources, and developing synergistic exchanges. Our short-term plan focuses on integrating, planning, and formalizing relationships that have already begun to develop, as well as suggesting new, untapped opportunities for materials exchange. We also suggest firm-level approaches to conserving resources.

We next broaden material exchanges to include new, logical participants through the anchor-tenant model of an EIP. This anchor would create opportunities for new “tenant” facilities to become a part of the material exchange process. These are medium-term goals, requiring additional planning, possibly new infrastructure, and some alteration of current operational paradigms.

The aim of our long-term proposals is to increase connectedness among the EIP facilities. By adaptively reusing the existing infrastructure, and in some
cases creating entirely new infrastructure, we hope to improve the efficiency of materials exchange.

The park will enhance profitability of existing enterprises by reducing input needs and adding value to residual streams. The enterprises envisioned will dovetail with existing plans for community revitalization by creating jobs and by fostering a sense of connectedness within the Green Triangle area.

BACKGROUND
South of the city of Boston, Massachusetts lies a string of parks and open spaces called the Emerald Necklace. The “Necklace,” named for its elongated and gem-like shape, was designed by the noted American architect and planner Frederick Law Olmsted in the late 1800s. Running along a northeast to southwest axis, the string of six parks extends from the Boston Common downtown to Franklin Park in Roslindale and Roxbury. Jamaica Pond, which lies just north of the Arnold Arboretum, is one of the jewels of the Necklace. It was one of Boston’s first drinking water reservoirs, and is now a beautiful recreational area where visitors can walk or rent a sailboat. Franklin Park lies in the south end of the Necklace, and at more than 500 acres, is the largest single piece of land in the Necklace. In Boston’s heyday as an industrial center, wealthy neighborhoods with sprawling Victorian homes encircled the Necklace. But as Boston’s economy changed during the post-war years, much of the city’s wealth moved to the suburbs, shrinking the region’s tax base. Today, many communities that border the Necklace struggle with issues of crime and unemployment.

The area surrounding the south end of the Necklace has been particularly hard hit by high unemployment and crime rates. The mean household income is 50% lower than the Boston Metropolitan Statistical Area. This area, now commonly referred to as the Green Triangle, includes four sections of Boston: Roxbury, Jamaica Plain, Dorchester, and Mattapan. The Green Triangle is the southernmost part of the Emerald Necklace, extending from the Arboretum to Franklin Park (see Figure 1).

In an effort to address the challenges faced by the Green Triangle, the nonprofit organization Boston Advisors, working with the Initiative for Competitive Inner Cities (ICIC), is leading a campaign to revitalize the region and develop the resources of the area. ICIC works with four organizations that have formed a Green Triangle Coalition to advance their common goals: the Arnold Arboretum, the Franklin Park Zoo, the Massachusetts Audubon Society, and Lena Park Community Development Corporation. These nonprofit organizations have identified recreation, conservation, education, and entertainment as their common missions, and recognize the region’s potential as a resource for the greater Boston area. The group’s economic development plans seek to attract more local residents and visitors to the area by making it a safe and fun place for families to spend an afternoon.
Figure 1 Map of the Emerald Necklace

KEY
1 Franklin Park
2 Arnold Arboretum
3 Jamaica Park
4 Olmsted Park
5 The Riverway
6 Back Bay Fens
The campaign to revitalize the Green Triangle area is supported by several consulting organizations, including the Boston Consulting Group and Anderson Consulting. These groups, along with Boston Advisers and ICIC, have devised a regional plan of action for the Green Triangle. The plan includes clean-up, signage, and a broader effort to help link the activities and goals of the Arboretum and the Zoo, as well as other entities in the area. In the words of its members:

The Green Triangle is a coalition of not-for-profit organizations who share the common goal of strengthening and inter-linking Boston’s natural and cultural assets located at the [south-] western end of the Emerald Necklace. The coalition is committed to increased coordination among its members (Boston Consulting Group 1998).

The Coalition has many challenges to overcome, including issues of accessibility and attractiveness. It also must overcome the public’s perception that the Green Triangle is located in an unsafe neighborhood. Our proposals for an EIP will help the Coalition meet its goals of conservation, education, recreation, and entertainment, and its desire for economic development.

OVERVIEW OF MAJOR CO-LOCATED FACILITIES
The following section provides a brief overview of the facilities located in the Green Triangle. As seen in the map below, the Green Triangle possesses a plethora of natural and capital resources that can be attractive for economic revitalization, including the formulation of an eco-industrial park.

The Franklin Park Zoo
The Franklin Park Zoo occupies 78 acres of land, 55 of which are currently developed. Development consists of pathways for walking and driving, pens, barns, cages and other facilities to shelter animals, and buildings that house administrative and operational facilities. The Zoo is home to more than 800 animals that represent about 250 species (A.T. Kearney 1996). During 1998, the Zoo attracted approximately 170,000 visitors: 30% from Boston, 20% from the nearby towns of Braintree, Arlington, Brookline, and Needham. Ninety percent of these visitors traveled to the Zoo by car. Visitation provided slightly more than 1% of the Zoo’s approximately $11 million revenue in 1998. Major funding came from the state (63%) and corporate donors (22%) (Boston Consulting Group 1998).

The Zoo is currently leaving behind a period of instability. According to a 1996 A.T. Kearney report, “Decades of budget contractions, mismanagement, benign neglect and... undeserved negative publicity have brought the [Zoo] to the brink of failure” (A.T. Kearney 1996).

The past two years, however, have demonstrated the Zoo’s potential to become a significant Boston area attraction and a financially viable entity. Revenues for 1998 were twice as large as 1996 revenues, while long-term plans project another doubling before 2006.
project another doubling before 2006. To achieve this growth, the Zoo plans to significantly increase the size of its collections and further develop most of its property. Tentative plans call for including 150 additional species, developing 18 more acres of land, and increasing visitation by 250%.

The Arnold Arboretum
The Arnold Arboretum is a 265-acre botanical research and education institution owned and operated by Harvard University. It was founded in 1872 by the Arboretum’s first director, Charles Sprague Sargent, who designed the grounds in collaboration with the landscape architect Frederick Law Olmsted, as part of Boston’s Emerald Necklace park system. Today the Arboretum’s collections include nearly 16,000 plants belonging to more than 4,000 taxa. Temperate zone species are the focus of the Arboretum. Trees and shrubs common to the northeast United States, including pine, spruce, oak, maple, rhododendron, and forsythia, are grown throughout the facility. Other species, including a small collection of tropical plants, are propagated in four greenhouses. Over 250,000 people visit the Arboretum each year.

The Arboretum is funded from three main sources: endowments maintained by Harvard University, grants, and memberships. In fiscal year 1997 the Arboretum received $4.1 million in endowment income, $1.4 million in grants, and $660,000 in membership dues, while expenses included $3 million for salaries, $1.4 million for services, and $1 million on supplies, equipment, and other operational outlays (The Arnold Arboretum 1997). Since the Arboretum is part of the city park system, roadway maintenance and repair is provided by the City of Boston.

The Massachusetts Audubon Society
The Massachusetts Audubon Society, an independent nonprofit organization founded in Boston in 1896, is the largest environmental organization in New England and one of the oldest conservation groups in the world (Massachusetts Audubon Society 1995). Through educational programs, land and wildlife conservation, research, and advocacy, the Massachusetts Audubon Society works to enable Massachusetts residents from all walks of life to experience the beauty of the natural world and to learn about and care for the ecological systems that sustain life on this planet.

The Massachusetts Audubon Society plans to develop a nature sanctuary on 65 acres of the 175-acre Boston State Hospital site, which includes Shattack Hospital. Its master plan includes: building and operating a 7,500 square foot environmental education center; preservation, restoration, and interpretation of the ecological systems on the property; and management and enhancement of existing community gardens.
The Massachusetts Audubon Society has been working closely with other Green Triangle Coalition members to ensure that its site development plans complement the Coalition’s overall goals. The Massachusetts Audubon Society intends to develop the property as a community resource that 1) provides exciting programming for children and adults; 2) preserves, restores, and interprets the site’s valuable ecological systems; and 3) brings the revitalizing effects of an enhanced relationship with the natural world to residents in the surrounding neighborhoods and Boston as a whole. The organization hopes the sanctuary will be a fully utilized resource and a source of pride for the community, attracting positive interest in the neighborhood and offering residents opportunities to enrich their lives by learning from, interacting with, and helping to care for this abundant tract of natural beauty (Massachusetts Audubon Society 1995).

**Lena Park Community Development Corporation**

Lena Park Community Development Corporation is a social outreach organization, self-described as a multi-service center for minorities. Lena Park operates several programs, including housing, care for mentally retarded adults, day care, social service, care for senior citizens, youth sports, summer camp, general recreation, and youth development. Lena Park operates on a $2.7 million annual budget which covers housing rehabilitation for 236 subsidized housing units in 19 buildings in addition to staffing for the above listed programs.

**Area Cemeteries**

The Forest Hills Cemetery sits on a large piece of land between the Boston State Hospital site and Franklin Park. The Cemetery attracts numerous visitors every year, many of whom come to view the old statues and other artwork spread throughout its grounds. Because of its location and its ability to attract visitors, it would make an interesting member of our eco-industrial park.

   St. Michael’s Cemetery, Mount Hope Cemetery, and Calvary Cemetery lie just south of Forest Hills. They all sit on much smaller pieces of land. At approximately 500 acres, the total size of these four cemeteries, however, rivals that of Franklin Park.

**Franklin Park**

At over 500 acres, Franklin Park is the largest park in the Emerald Necklace. It includes the 18-hole William Devin Golf Course, the oldest public golf course in the United States, and is host to major cross-country running events. The Park also is home to the Franklin Park Zoo, White Stadium, Scarborough Pond, and several baseball diamonds and tennis courts. All facilities except the golf course are maintained by the City of Boston’s Department of Parks and Recreation.
Area Hospitals
Faulkner Hospital is located on Center Street on the western side of the Arnold Arboretum. Faulkner Hospital is a 130-bed community teaching hospital principally serving Jamaica Plain, Hyde Park, Roslindale, West Roxbury, and Dedham. Faulkner is one of Boston’s major health care providers, offering complete medical, surgical, and psychiatric adult and inpatient care, as well as a full complement of emergency, ambulatory, and diagnostic services. Faulkner also boasts two nationally renowned Centers of Excellence that provide special services to specific populations: the Faulkner Sagoff Breast Imaging and Diagnostic Center, and the Faulkner Breast Center.

Other Facilities
Two other facilities that could play important roles in the development of an eco-industrial park lie within the Green Triangle. The Massachusetts State Laboratory sits in the northeastern corner of the Arnold Arboretum along Washington Street. In the past, the Arboretum has assisted the Laboratory with landscaping. The Arborway Yard is located on Arborway Drive between the Arboretum and Franklin Park. It is currently being used by the city as a bus depot, but the mayor has proposed building an ice rink and other recreational facilities there.

EXISTING MATERIAL FLOWS
In the above section we briefly outlined the facilities located within the Green Triangle that are of interest to our project. In the following pages, the materials flows for each facility will be described in detail. We have placed primary focus on the Franklin Park Zoo, the Arnold Arboretum, and the Audubon Society.

Franklin Park Zoo
The following section addresses each of the major inputs required for Zoo operation. The intent is to present a current picture of materials consumption and energy use. Proposals for adapting these flows using the principles of industrial ecology follow in later discussion.

Water
Abundant water is essential for Zoo operations. Water is consumed by and provides habitat for the Zoo animals, serves as a solvent for cleaning, and is the basis for the Zoo septic system, which includes toilets, fountains, and faucets. All Zoo water is provided by the Boston Water and Sewage Commission (BWSC). Currently, very little water is re-circulated after its primary function has been served. All wastewater is returned to the BWSC for treatment. At this

<table>
<thead>
<tr>
<th>Estimated Monthly Consumption</th>
<th>3,601.5 gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated/Adjusted Total Annual Consumption</td>
<td>48,980.4 gallons</td>
</tr>
<tr>
<td>Estimated Total Annual Cost</td>
<td>$132,247.10</td>
</tr>
</tbody>
</table>

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time, the Zoo is charged on a per gallon basis for consumption, and also pays to treat as much water as it draws from the city system.

The Zoo is currently working to establish a dual metering system that would save money by recording the precise amount of water returned through the city system for treatment. Without that metering system, there is currently less incentive to find creative uses for water after its primary use.

One of the Zoo’s primary attractions is the $26 million Tropical Rainforest. This freestanding, enclosed structure, completed in 1989, is home to more than 360 animals. The feat of mimicking a year-round tropical climate in the state of Massachusetts is accomplished through creative engineering and massive water use. The facility uses some 2.3 million gallons of water every month, or 64% of the Zoo’s total water consumption. Although a large portion of this water is re-circulated and filtered, the Zoo pays to dispose of all of the water that it withdraws. The cost of water consumption and disposal for this facility alone is approximately $30,000 per month.

Planned facilities reflect greater concern for on-site water use. Barns that will house future collections of zebra and giraffe will be equipped with “living machines” that will treat water to be used for cleaning onsite and reduce the need for disposal.

Food
Collectively, the Zoo’s animals currently require more than 20 varieties of grain and a specialized horsemeat. Grain is purchased from Blue Seal, while the horsemeat product is shipped from a Nebraska supplier. Food for human visitors is provided through a fast food stand. Proposals include developing a push cart program that would allow local vendors to sell food in and around the Zoo area.

Energy
The exotic species housed at the Zoo depend on carefully regulated climates throughout the year. Heating needs are met predominantly through natural gas and oil. The main heating element is a natural gas boiler located next to the rainforest exhibit. Hot air from this boiler is fanned through the Zoo via a system of pipes. Electricity is used to power lights, in addition to fans and pumps that are critical for air and water circulation in many of the Zoo facilities. The Zoo also has a back-up diesel-fired generator on-site, which is used only during black-outs. In 1996, this generator on occasion failed to operate properly.

Trash
Trash currently is separated for recycling into high BTU waste that is suitable for incineration (vinyl, hard waste) and compostable organic material. An average of 60 cubic yards of trash is generated from the Zoo each week.
Manure
Zoo operators have recognized that manure is a valuable by-product of Zoo operations. For years, the Zoo has developed agreements with landscaping companies in the area to exchange manure for fees and/or services. An initial program that allowed on-site storage of excess manure was abandoned when the Zoo decided that it needed the space. The most recent arrangement has provided the Zoo with free landscaping services and compensation on a sliding scale in exchange for the Zoo’s manure. The Zoo generates about 20 cubic yards of manure each week.

Plants
Maintaining flora both in and around animal homes is critical for the Zoo. Plants, shrubs, and trees are purchased from outside vendors while some mulch and wood chip needs are met through the Zoo’s manure-for-services trade. The trading program does not, however, meet all of the Zoo’s landscaping material needs. Soil, loam, sand, stone dust, and gravel are all purchased on an annual basis. Use of the chips and mulch provided through the manure swap is often limited because of aging requirements. The Zoo uses an Integrated Pest Management (IPM) system for pest management.

Equipment
The Zoo currently owns a tractor-style lawn mower, a front-end loader, a Bobcat, backhoe, tractor, pothole digger, and a sweeping truck. During the current phase of expansion, these vehicles are being used regularly.

Arnold Arboretum
For the purpose of identifying the major material flows at the 265-acre Arnold Arboretum, the facility will be divided into two areas. The first, grounds maintenance, includes the preservation and improvement of natural assets—trees, shrubs, lawns, soil, and streams—as well as the repair and upkeep of constructed stock such as trails, signs, and fences. The second is greenhouse operations. This encompasses not only plant propagation but also the operation of the four greenhouse facilities.

Grounds Maintenance
It is not surprising that grounds maintenance represents the major activity of the Arboretum. In terms of land area covered, materials used, and residues generated, maintenance of open-air assets is the facility’s largest operation. This broad responsibility can be broken down into five areas:

- production of organic debris from pruning, tree removal and mowing;
- planting and flower bed care;
- pesticide and fertilizer application;
- watering; and
- upkeep of man-made capital stock including pathways, bridges, constructed water bodies, and signs.
A major source of organic debris is wood material collected during pruning, tree removal, and storm damage operations. Tree limbs may be removed because they represent a hazard or obstruction to visitors and workers. Pruning is also used as a horticultural management tool, since removing branches can promote the growth of trees with poor limb structures and allow additional sunlight to reach nearby species. Old or diseased trees, taken down because they are dangerous to people or other trees susceptible to disease, are another source of wood debris. Recently, the Arboretum supplemented its debris supply with “imports” from a neighbor, the Massachusetts State Laboratory, located on South Street. The debris generated there is brought back to the Arboretum.

Considerable wood debris is generated by storms, although the amount varies from year to year. A blizzard in April 1997, rated the most destructive storm to hit the Arboretum since the hurricane of 1938, affected over 1,700 trees, of which 400 were entirely removed and 1,300 pruned.

Table 2 shows the breakdown of the wood debris generated by the Arboretum in 1998. The input sources were almost entirely internal, though a small amount, approximately 20 cubic yards (cy), originated from the Massachusetts State Laboratory. The wood input is processed into four outputs: small junk wood, large junk wood, wood chips, and firewood. Junk wood is defined generally as wood that cannot be directly used by the Arboretum and is thus disposed of off-site. Small junk wood, including thorny brush, is undesirable as firewood or mulch, while large junk wood, including tree trunks, is too large for the Arboretum’s chipper and undesirable as firewood. Collected in twelve 30 cy dumpsters last year, the small junk wood is taken to “stump dumps” in the suburban towns of Tauton and Rayham, located twelve miles southwest of the Arboretum (it is unknown whether these dumps are landfills or recycling facilities). Logging trucks with estimated capacities of 30 cubic yards (cy) remove the large junk wood. According to the Arboretum’s Superintendent of Grounds, the trucks take the wood to facilities with “whole tree chippers” or to mills where they become wood product inputs. For both sizes of junk wood, the Arboretum pays the cost of removal.

Much of the wood debris, however, is reused by the Arboretum or its employees. 480 cy of firewood-grade material was cut last year and distributed to Arboretum employees. The firewood is grouped in cords which are 4.8 cy each. A two-step chipping process turns the 250 cy of debris gathered on-site and the 20 cy from the State Lab into high-quality mulch. A chipper brought into the field grinds the wood once, before a second machine known as a “tub chipper” turns the coarse chips into finer grade mulch. The mulch is applied to the bases of trees and to planting beds to prevent desiccation and insulate against cold weather.

Two other sources of organic debris are grass clippings and leaves. Grass clippings generated from the limited number of mowed acres are left on the ground unless the grass grows excessively high. Leaves are gathered in the fall in some areas, but most leaves are left uncollected and allowed to recycle back
### The Arnold Arboretum Organic Inputs and Outputs From Grounds Operations

<table>
<thead>
<tr>
<th>Material</th>
<th>Internal or External</th>
<th>External Source Name</th>
<th>Quantity</th>
<th>Type</th>
<th>Processing</th>
<th>Use/Fate</th>
<th>Quantity (waste)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf litter</td>
<td>External</td>
<td>Harvard Yard</td>
<td>500</td>
<td>Compost</td>
<td>Deposited in composting yard</td>
<td>Applied as mulch</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Internal</td>
<td>n.a.</td>
<td>100</td>
<td>Compost</td>
<td>Deposited in composting yard</td>
<td>Applied as mulch</td>
<td>100</td>
</tr>
<tr>
<td>Wood debris</td>
<td>Internal</td>
<td>n.a.</td>
<td>360</td>
<td>Small junk wood</td>
<td>Collected in dumpsters</td>
<td>Disposed off-site</td>
<td>(360)</td>
</tr>
<tr>
<td></td>
<td>Internal</td>
<td>n.a.</td>
<td>60</td>
<td>Large junk wood</td>
<td>Loaded onto logging trucks</td>
<td>Processed off-site</td>
<td>(60)</td>
</tr>
<tr>
<td></td>
<td>Internal</td>
<td>n.a.</td>
<td>250</td>
<td>Wood chips</td>
<td>Chipped twice, stored in composting yard</td>
<td>Applied as mulch</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Internal</td>
<td>n.a.</td>
<td>480</td>
<td>Firewood</td>
<td>Cut and grouped in cords&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Given to employees</td>
<td>480</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>1750</td>
<td></td>
<td></td>
<td></td>
<td><strong>1330 (420)</strong></td>
</tr>
</tbody>
</table>

All figures in cubic yards.

<sup>1</sup>The Arboretum pays a garbage hauler to take the small junk wood to a “stump dump.” It is not clear whether this material is re-used or simply fills up the dump.

<sup>2</sup>Again the Arboretum pays operators of logging trucks to remove the large junk wood which is processed in one of two ways: it is sent through a whole tree chipper and re-used as mulch and it is milled and later sold as wood products. IT MAKES NO SENSE THAT THE ARBORETUM PAYS FOR THIS. THE ARBORETUM HAS A VALUABLE RESOURCE.

<sup>3</sup>One cord is equal to 4.8 cubic yards.
into the soil. The Arboretum estimates that in 1998 they gathered about 100 cubic yards of leaves. In recent years, the Arboretum even began accepting leaves from Harvard Yard in Cambridge. Last year, 500 cubic yards were brought from the Harvard campus to the Arboretum, which allowed for a reduction in leaf disposal costs for Harvard and provided compostable material to the Arboretum.

Organic debris is collected at a composting yard on Bussey Street, located in the southwest portion of the Arboretum. It is about an acre in size and can hold up to 20,000 cubic yards of material. During the storm of 1997, the yard was filled to capacity, resulting in the disposal of some debris off-site. Soil and manure are also stored here, occupying roughly 20% of the space. The turnover time for the wood debris depends on the quantity and type of debris product needed, as well as the season. In the summer, well-ground debris, or mulch, is needed to prevent soil desiccation. The preparation of mulch does not require decomposition and thus, once ground, is ready for application. If allowed to decompose, wood debris can become a nutrient-rich fertilizer, but the preparation time is typically three months (Block and Goldstein 1998).

Processing organic residues is just one aspect of the Arboretum’s grounds maintenance. Flower beds dot the landscape, and are maintained with new flowers and soil, and by weed removal. In all corners of the Arboretum, new trees and shrubs are planted during the spring and fall. Dead plant material is replaced, while new species are planted to better represent ecosystems, provide educational opportunities, and improve aesthetics.

Pesticides are used to reduce weed growth and insect damage. Annual quantities are unknown, but over the past few years, the Arboretum has cut pesticide use by 85% through Integrated Pest Management (IPM) strategies that rely on natural predators to eliminate insect pests. Soil nutrient levels are supplemented through organic and synthetic fertilizers. Last year, the grounds team applied 500 pounds of synthetic fertilizer to newly seeded lawns. Recent cooperation with the city mounted park ranger corps has resulted in the transfer of horse manure to the Arboretum, and last year approximately 100 cubic yards were exchanged between the two entities.

In the summer, watering is essential to keep drought-sensitive plants healthy, but since only ten of the 265 acres are irrigated, water use is low relative to the large size of the Arboretum. In the past, the Arboretum drew from City of Boston water supplies, but high chlorine levels forced a switch to its own sources. Two wells exist on the property, one with a 300 gallon capacity and the other with a 600 gallon limit. Along with greenhouse operations, grounds maintenance uses about two million gallons each year, at a cost of $20,000.

Throughout the Arboretum is infrastructure that requires upkeep. Pedestrian trails weave through the forests and over bridges that span streams and roads. In every nook, signs are found. On the trails, wood chips are spread to give soft footing and prevent ponding. Water bars – usually in the form of

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railroad ties – are installed to keep soil in place. As bridges age, their wooden planks, concrete, and stone must be replaced. New England winters make the lifetime of signs especially short. For the Arboretum to thrive, this infrastructure must be maintained, and this requires the regular purchase of materials.

Greenhouses
The Dana Greenhouses are a collection of four greenhouses located in the northwest corner of the Arboretum, near the Center Street Gate. The trees, shrubs, vines, and perennials grown here are used in two ways: they are transplanted on the Arboretum grounds, or sold to the public. Of the 7,800 plants removed from the greenhouses last year, 800 were planted in the Arboretum. Hardwood trees made up half of this total, while the other half is a mix of conifers, vines, and shrubs. In the Greenhouses’ annual plant sale, about 3,500 trees, 2,800 shrubs, and 700 vines and perennials are purchased. Included in the sale are “surplus” plants from the in-house propagation. Because a certain mortality rate is expected, the number of plants initially grown exceeds the number of plants needed. When the actual mortality falls short of the expected mortality, a surplus results. Rather than incorporate the surplus into the planting plan for the grounds, the Arboretum sells the plants.

There are six primary inputs to the greenhouse operations. The first is soil. Approximately 25 cubic yards of “screened loam” is used each year. Added to this is a soil mixture that includes composted pine bark (65%), peat (25%), and rock minerals (10%). About 204 cubic yards of this soil mix is used each year. In the past, the greenhouse accepted compost from alternative sources, but high salt levels and weed seeds forced them to return to conventional suppliers that have the equipment to address these problems.

A second set of inputs is fertilizer, pesticides, and mulch. The greenhouses use about 100 pounds of nitrogen/phosphorous fertilizer each year. Unprocessed fertilizers, such as horse manure, are viewed with suspicion; they may contain salts, weed seeds, or other contaminants. Like the grounds maintenance unit, the greenhouses have dramatically reduced their use of chemical pesticides. The introduction of beneficial organisms as part of an IPM program addresses most pest management issues. Ground wood chips, or mulch, are provided free of charge by a local arborist company. The wood debris generated on the Arboretum grounds falls short of the demand from the greenhouses, so they have formed a beneficial partnership with an outside supplier. Unlike fertilizers and other composts, the quality constraints on mulch are less, perhaps due to its superficial application to plants.

A third input to the greenhouses is inorganic materials. Each year approximately 8,500 pots are used, 6,500 of which are purchased new, while the other 2,000 are reused. Another inorganic input is the plastic “bubble” material inserted between the exterior panes of the greenhouses. When filled with air, the plastic becomes an insulator with only marginal impacts on incoming solar radiation. Approximately 1,500 square feet of the material are used annually.
Water and energy represent the fourth input to the greenhouses. As discussed earlier, the Arboretum as a whole consumes about two million gallons of water per year. Energy use, namely heating, is a major concern for the greenhouses. When the sky is clear, solar energy raises the temperatures inside the greenhouses to the desired levels, generally around 70º Fahrenheit (F). In fact, sunny days make the greenhouses too warm. Temperature-controlled vents and fans release some of this heat to the external environment. Manual vents and shade cloth perform the same functions. But while high temperature is the problem during the day, cold is the problem at night, especially during the winter. It is estimated that the annual heating requirement for the four greenhouses – which total 6,240 square feet – is one million BTUs. Accounted for in this figure is the reduced temperature requirements (about 40º F) permitted in the winter in greenhouses with dormant species.

It is important to note that given the plants’ high demand for carbon dioxide input, it was assumed that carbon dioxide was injected into the buildings. However, according to the greenhouse manager, no artificial sources of carbon dioxide are used.

Massachusetts Audubon Society
While the Massachusetts Audubon Society has yet to break ground on the former Boston State Hospital site, the construction and future operations of the sanctuary play an important role in Green Triangle’s potential eco-industrial park dynamics. The following discussion highlights material flows and other components of the development plan that influence our analysis of eco-industrial park implementation. The Massachusetts Audubon Society’s vision for the sanctuary and its fit with the Green Triangle Coalition’s goals is also discussed.

Development Plans
The planned environmental education center will provide programs offering a broad range of opportunities for children and adults from the community to learn about and interact with the natural world. Physical facilities will include a one-story main building (7,500 square feet), to be constructed of wood and other natural materials and designed “to be well integrated into the natural environment” (Massachusetts Audubon Society 1995). The center will consist of an assembly room, exhibit area, and gift shop. Office space within the center will provide space for program, administrative, and advocacy staff, headquarters for the Boston Education Project, as well as additional space that can be rented by other Boston environmental groups.

The Boston State Hospital Urban Gardens, currently occupying 350,000 square feet of the Massachusetts Audubon Society’s property, are the oldest and one of the largest community gardens in Boston. The Massachusetts Audubon Society plans to renovate and oversee maintenance of the gardens as part of its overall development scheme. In cooperation with gardeners, the Massachu-
setts Audubon Society will improve the layout of the gardens, adding two storage sheds for tools and materials (375 square feet each) and walking paths. Renovation plans also include the construction of raised and other special garden beds designed for the disabled and elderly. In addition, the Massachusetts Audubon Society plans to address the gardens’ critical issues of water use and cost distribution by installing a series of faucets that can monitor usage.

Aside from one structure that will be renovated and operated as a caretaker’s facility, the Massachusetts Audubon Society has shown no interest in other buildings currently occupying the site. The State of Massachusetts is responsible for the removal of all unwanted buildings, structures, hazardous wastes, and other specifically identified materials on the site. There is no indication from the Massachusetts Audubon Society’s master plan of a proactive effort to re-use materials from the demolition of old buildings and roads on the property. In addition, while natural buffers have been identified as part of the development plan, there is no indication that the Massachusetts Audubon Society will incorporate other design-for-environment principles into its development plan.

**Vision for the Site**

The Massachusetts Audubon Society has been working closely with other Green Triangle Coalition members to ensure that its development plans for the site complement the coalition’s overall development goals as well as priorities identified by surrounding communities. Residents in the area have stressed a need for protection and enjoyment of open space, employment and job training programs, and environmental education.

The Massachusetts Audubon Society’s plans are instrumental in advancing the Green Triangle Coalition’s goal of increased environmental education. When complete, the environmental education center and wildlife sanctuary will be uniquely situated to serve as a major resource to Boston’s public schools, and will be the headquarters for the Massachusetts Audubon Society’s Boston Education Project. An estimated 48 elementary and high schools with over 23,000 students are located within two miles of the site. This represents almost 40% of Boston’s public schools and generally defines the initial service area for the site.

**Funding**

Massachusetts Audubon Society expects to raise approximately $6 million from individuals, corporations, and foundations to cover expenses associated with the project, as well as provide an adequate, permanent endowment for the staff and site operations. The Massachusetts Audubon Society will not have to charge entrance fees or rely on increased visitation to maintain and grow operations over time. This is an important factor to consider in evaluating options and constraints for eco-industrial park development.
Area Cemeteries
The materials in the cemetery of interest to our proposal for an eco-industrial park are grass clippings and organic debris, including leaves and other yard waste. The usefulness of these residuals will become evident in the discussion of our medium-term proposal.

Area Hospitals
Of primary interest from the area hospitals are food waste and organic debris from landscaping activities. The usefulness of these residuals also will become evident in the discussion of our medium-term proposal.

ECO-INDUSTRIAL PARK PROPOSAL
Our recommendations for the development of an eco-industrial park are divided into short, medium, and long-term objectives. We conceptualize the breaks in the time periods as follows:

- **Short Term**: goals that can be reached using existing practices and resources. The short-term effort consists of bringing together facilities that have had some communication in the past.
- **Medium Term**: proposals requiring additional planning, possibly new infrastructure, and some alteration of current operational paradigms. Involves broadening materials exchanges to include new participants.
- **Long Term**: involves fundamental redesign of infrastructure, rethinking of roles, relationships, and technologies in the process of development. Builds on linkages throughout the area.

**Short Term**
This time frame includes activities that can be undertaken immediately. In some cases, the materials that we propose trading are already exchanged in some form. Our focus is on integrating, planning, and formalizing relationships that have already begun to develop, as well as suggesting and introducing new and untapped opportunities for materials exchange given current resource availability. Before addressing opportunities for exchange of materials between firms, it is important to focus on the efficiency of resource use within each entity.

Opportunities for the Zoo include reducing water use and disposal and capturing more value from its manure waste stream. The Arboretum should also focus on residual stream value, in addition to realizing value from slight changes in operating procedures. Because the Audubon site is currently under development, we exclude consideration of its general operations from this short-term section. However, we do recommend ways in which materials used and generated during construction activities can be captured. Interaction between these facilities forms the basis for our medium and long-term strategies.

The Zoo can take advantage of net metering immediately. Net metering entails installing additional meters that monitor water return to the city system.
The additional metering allows the user to benefit from its own “treatment” of city water by adjusting disposal charges to reflect only the amount disposed. Current systems at the Zoo levy disposal charges equal to the amount of water that is withdrawn. Because of water lost through evaporation from the duck pond and other sites, water that runs off directly to the ground, and water that is consumed, charges grossly overstate the actual amount of water the Zoo sends back for treatment. Setting up a net metering system is simple, and should immediately result in cost savings for the Zoo.

From an industrial ecology perspective, however, net metering accomplishes a more important goal. This goal is to encourage more on-site treatment of waste streams. A good example of effective on-site water treatment is the Living Machine currently under development for treating runoff from the zebra and giraffe barns (a Living Machine is a waste-water treatment system that uses a series of tanks filled with plants, algae, and bacteria to break down waste naturally, without chemicals). Without net metering, the water treated in these systems would be charged for treatment by the city. Net metering should inspire a search for additional opportunities for living machines. In the short term, as the Zoo plans for expansion of its facilities and development of additional areas, incorporating living machines should be a priority. The Zoo should evaluate the possibility of having larger, more centralized “machines” that could become exhibits unto themselves. The Zoo’s mission is to put natural ecosystems and their inhabitants on display. The living machine is an interesting bridge between the human and natural world.

Another input that should be given careful consideration as the Zoo expands its facilities is energy. Eco-efficient designs often have short pay-back periods. Efficient lighting can create positive returns within two years. Facilities should be designed such that any excess heat is funneled back to a productive use such as heating another facility, keeping ice off watering troughs or keeping rocks in the lion dens warm.

While the Zoo has been leveraging returns from its manure for some time, we suggest a two-pronged approach to capture more value from this critical residual stream. An important concept to be addressed in the medium term section involves the creation of a new entity to manage this waste. In the short-term, however, the Zoo should consider packaging manure for sale directly to its visitors for use as a fertilizer. This concept has been pioneered and proven successful by the ZooDoo company of Memphis, TN. One option would be to contract directly with the existing operation. Benefits would include capturing ZooDoo’s established brand name and web space. Our recommendation, however, is for the Zoo to develop its own program, keeping material flows and financial benefits local.

Currently, the Arboretum grows many more trees and plants than it needs on an annual basis. Most of these plants are sold during its annual plant sale; others are given away. This plant growing program leads to two short-term possibilities for improvement. First, every year, 8,500 plastic pots are used in
the program, 2,000 of which are returned. Resource consumption could be lowered by increasing the rate of pot return. This could be accomplished by levying a pot deposit on top of each plant sale. This program would be extremely cost effective, reducing expenditures on new pots, and increasing revenues through unredeemed deposits. An important consideration in stimulating pot return is the environmental consequences embedded in the return action. Returning pots might increase fuel consumption (though it seems likely that Arboretum visitors would return pots during a trip they might have taken anyway) and it may be that pot purchasers individually put their pots to good use. Further study is needed to determine whether this program would yield net positive environmental and economic results.

The second idea generated by the Arboretum’s plant sale represents the first material trade suggestion. The Arboretum has demonstrated that it has excess capacity in its growing operation. We believe that appropriate planning for this capacity would enable the Arboretum to share its excess plants with the Zoo. If additional capacity were needed, it is likely that the Arboretum could accomplish the expansion at lower cost than the Zoo currently incurs when it purchases plants for landscaping and animal habitat. An effective trading program would require advance planning, as the Zoo develops new land and as the Arboretum allocates growing capacity. This joint planning effort is the first step toward broadening the cooperative relationship between these entities. Regular contact between the organizations will enable discussion of other potential synergies. Potential partnering opportunities include joint purchases of material inputs such as sand, loam, and gravel. Joint purchases that capture economies of scale will be cost effective, and may yield environmental benefits through a decreased reliance on transportation.

As noted above, it is the responsibility of the state to remove all unwanted buildings from the State Hospital Site where the new Audubon Facility is currently under construction. Most of these buildings are made of brick and concrete. Crushed brick is an excellent source of path material, while crushed concrete may be useful as road fill. Because the Zoo is in an expansion phase, and the Arboretum requires trail maintenance, both of these materials may have some value and should be exploited in the short term.

A final short-term activity that leverages joint resources and meets a variety of objectives is to build existing education and recreation programs in the area jointly. Instead of a Lena Park Summer Camp, children could come to the Green Triangle for a summer experience that includes activities and learning at each of the facilities. Introducing children to the notion that facilities in an area are inter-linked could be an effective way to build support for the eco-industrial effort. Children may also generate new ideas about how resources can be shared.
Medium Term
The previous section introduced potential material exchanges among Green Triangle organizations, given existing practices and resource constraints. This section describes our strategy for enhancing these short-term opportunities, and for creating new opportunities for exchanges.

To broaden the scope of the eco-industrial park, we first looked at constraints on material exchange opportunities. The following are problems inherent in the short-term proposals for the Green Triangle:

- **Quality of materials exchanged.** The Arboretum has had quality issues with shipments of organic material. Past exchange programs with municipalities often resulted in unusable materials containing salt, weed seeds, or other contaminants.

- **Specialization in operations.** Certain elements of organizations’ operations require specialized resources. For example, the Arboretum has specific requirements for the types of materials they can apply to plantings and landscaping. The Zoo requires special foods for its animals, and requires habitat-specific plants for exhibits.

- **Timing of materials exchanges.** Many materials with potential for exchange are available only during short windows of time, requiring rapid coordination and assessment of demand. For example, the Arboretum has a variable supply of excess plants at the end of the growing season that must be planted quickly to be used. On the demand side, input material demands vary due to seasonal needs.

- **Physical capacity constraints.** Many Green Triangle organizations, including the Arboretum and the Zoo, are limited in the expansion of operations beyond currently planned development. The Zoo formerly contracted with a company to exchange manure for fees and services. The Zoo was forced to buy out of that contract to reclaim land that had been used for temporary storage of the manure. The Zoo’s on-site storage capacity is currently limited to one dumpster dedicated to manure and clippings. The Arboretum has a one acre facility for storing organic debris. Future expansion of organic material exchanges will require off-site storage of residuals.

- **Scale constraints.** Given the relatively small quantities of material involved, costs of developing infrastructure to support trades may in some cases be prohibitive.

An industrial ecology perspective includes an examination of the industrial system within the context of a natural system. The advantage of this perspective is that potential opportunities are presented outside traditional bounds. We looked beyond the current actors in the short-term materials exchange process, and identified facilities such as hospitals, cemeteries, and the Franklin Park, which offered new opportunities without barriers such as quality concerns.
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**Anchor Proposal: Composting Facility**

We propose as a possible solution to system constraints the development of an anchor facility. As described by Chertow’s anchor-tenant model of an eco-industrial park, an anchor is a centralizing mechanism that can provide the increased scale and quality control necessary for system expansion.

Since organic residuals dominate the input and output cycles, a modern composting facility would be a powerful anchor. The composting facility would enable Green Triangle members to better coordinate and centralize the movement of organic residuals. The facility would convert organic residuals into mulch, fertilizer, wood chips, and other products that could be redistributed to Green Triangle members. Manure from the Zoo, for example, could be delivered to the site as an input to the production of mulch and fertilizers.

Such a facility would enhance short-term opportunities for exchange by overcoming factors inhibiting material exchange in the present state. The composting facility could offer a wider variety of mulches and fertilizers that cater to the quality and timing specifications of the Arnold Arboretum. A composting facility would have adequate storage capacity to overcome production problems caused by seasonal fluctuations in material inputs. Increased inventory also would more capably handle variations in demand among consumers of composting products. The facility would have the necessary equipment and capacity to incorporate junk wood from the Arboretum that is currently disposed of off-site. Not only would this increase the flow of residuals, but it also would eliminate off-site transportation and disposal costs.

Perhaps most importantly, the increased scale and scope of operations generated through the composting facility would create new cost-effective exchange opportunities. A composting facility would expand the types of materials exchanged, enabling other area facilities to enter the materials flow cycle. For example, hospitals in the area, as well as restaurants and concession stands that are planned for development, could contribute food residuals. A composting venture run by the Lower East Side Ecology Center (LESEC) in Manhattan processes restaurant residuals, including soiled paper towels. The success of this effort has prompted LESEC to look to expand collection from generators to include a cafeteria and green grocers in the area (Block and Goldstein 1998). In Boston’s Chinatown, the Asian Community Development Corporation is networking restaurants and food businesses for composting. The proposed composting program also could collect food residuals from elementary and high schools in the Green Triangle area. The Reeds Spring School District in Missouri is considering composting options to manage preconsumer food residuals and plate scrapings generated by only 2,300 students and staff (Ling 1999) – approximately one-tenth the number of students in a two-mile radius of the Green Triangle.
A composting facility broadens opportunities for involvement not only by facilities but also by area residents. An expanded collection effort could accept yard waste from the surrounding neighborhoods. Looking further, a food residual composting collection program could be initiated with area neighborhoods. Such efforts, along with the involvement of area schools, would advance one of the primary goals of the Green Triangle coalition: to promote environmental awareness and education.

Location of Anchor Facility
An opportunity for the development of this proposed anchor facility presents itself in the 175 acre area called the Boston State Hospital Site. The Audubon development plan covers only 65 acres of the site, leaving over 100 acres for further development. The Audubon Society recognizes compatibility of the area with other uses, stating, “We expect [our] development to be fully compatible with other site uses. Low-density development in abutting areas would be most compatible with [our] project in order to contribute to the buffer between our program activities and the noise and visual congestion of other development uses (Massachusetts Audubon Society 1995).”

Several proposals have been offered to develop the area, the latest suggestion being the construction of a supermarket. There has been opposition to the supermarket proposal from both the Mayor of Boston and organizations involved in the rejuvenation efforts of the Green Triangle area. They have stated a strong interest in developing the site within the context of the Green Triangle Coalition’s common goal of enhancing the area’s conservation, recreation, entertainment, and educational benefits.

A composting facility is consistent with the Green Triangle Coalition’s goals for the area. The anchor facility would enhance materials exchanges among participants in the EIP, helping to conserve the area’s natural resources. The project would offer additional employment for the local community. As the operations of the facility broaden to include material inputs from the surrounding community, there would be an increased sense of community involvement, and a sense of ownership in the success of the Green Triangle area. The increased involvement of the community would serve to educate the community on the interaction of industrial and natural systems.

The anchor composting facility would greatly benefit from the centralized location of the Boston State Hospital site. By maintaining the site within the Green Triangle, transportation costs to and from residual generators would be minimized, making smaller collections on short notice less costly. The site’s proximity to Green Triangle organizations provides ready access to a range of professionals who can lend expertise and help manage activities. The 100 acre site also would allow growth of the anchor facility as it expands its scale of operations.

The anchor facility would create even further opportunities for materials exchange by drawing in more tenant facilities. The following section discusses
a number of possible tenants that could benefit from the materials exchanges offered by the plan. These suggested facilities are well suited to expanding the EIP and advancing the goals of the Green Triangle Coalition.

**Centralized Landscaping Equipment Pool**

A landscaping equipment facility could be located adjacent to the composting facility, pooling the equipment needs of the composting facility and Green Triangle organizations. A well-managed and coordinated equipment pool shared among members could help reduce some of the redundancy in the types of landscaping equipment currently purchased by the organizations. Revenue generated from the equipment facility could go toward more costly equipment, such as a “tub grinder” for chipping wood, which individual organizations cannot afford to purchase.

A major hurdle in pooling equipment resources in the past has been concern over joint ownership, with the inherent problems of upkeep of equipment and the coordination of equipment use. The proposed facility would be responsible for the maintenance of the equipment, and could possibly even employ a staff of landscapers, as a need for such a service has been identified. General landscaping maintenance is not, and should not be, a core competency of the Franklin Park Zoo and other Green Triangle organizations. Centralized landscaping operations would provide efficiencies in cost, training, and specialization, reducing overhead of customer organizations through outsourcing.

An equipment pool would provide a more cost-effective and centralized mechanism for handling spent fuel and other equipment fluids in an environmentally responsible manner. The increased scale of operations and equipment maintenance would make processes such as recycling motor oils more standardized, decreasing the probability of smaller discharges throughout the area.

**Nursery and Garden Center**

A nursery and garden center located adjacent to the anchor facility could use composting products as input for its own production. Any production from the composting facility in excess of Green Triangle customer needs could be provided to the nursery for on-site use and for retail sale through the garden center. The nursery and garden center also could coordinate purchases with the Arboretum, Zoo, and other organizations to reduce costs through bulk ordering. Material residues, such as the Arboretum’s plastic pots, could be reused by the nursery. Green Triangle organizations involved in the composting program could receive credits that go toward the purchase of nursery and garden center products.

The combined facility would further the Green Triangle Coalition’s goals of education, recreation, and economic development. Visitors to the Audubon’s sanctuary, the Arnold Arboretum, and Franklin Park are likely to have a strong interest in nature, and horticulture more specifically. A nursery and garden
center would be a means of taking advantage of this customer niche to generate revenue. Visitors spending a day among trees, flowers, and wildlife may be inspired to develop their own green thumbs. In addition, the nursery and garden center could highlight the environmental benefits of ongoing material exchanges for marketing and educational purposes. Signs could be posted in the garden center identifying local products and explaining the production process. Unique fertilizer products such as “ZooDoo”\(^2\) could be sold through the garden center.

Locating these tenants as extensions of the anchor facility on the Boston State Hospital site creates further opportunities for energy and material exchanges among the co-located facilities. For example, the composting facility could capture heat created from the biological processes involved in composting and funnel this energy to the adjacent nursery and garden center to assist in heating. The garden center could lease landscaping equipment for transporting inputs and moving inventories.

**Farmers Market / Craft Fair**
A weekly or biweekly farmers’ market and crafts fair could take advantage of existing material flows while furthering the recreational and economic development goals of the area. Locally grown produce, especially from the Boston State Hospital Community Gardens, could be sold to visitors, local residents, and restaurants/eateries. The market and craft fair would draw visitors and local residents to the Green Triangle area, helping to enhance the image of a safe, friendly community.

**Restaurants**
Green Triangle development plans have identified a need for local eateries for visitors. The establishment of restaurants and concessions would enhance value for the area and could become an integral part of material exchanges. These facilities could purchase food from the proposed farmers’ market, or directly from community gardens. And as mentioned previously, restaurant food residuals could be material inputs for the composting facility.

**Challenges to Implementing Anchor-Tenant Proposal**
Primary challenges to developing and operating the proposed anchor-tenant model are ownership issues and the need for information systems. A number of ownership options are feasible for the composting facility and any co-located facilities. It could be operated independently of current Green Triangle Coalition members, purchasing organic residual inputs from surrounding organizations, and leasing landscaping equipment or providing landscaping services. Alternatively, the facility could be managed as a cooperative, with members receiving credits for contributed inputs going toward the purchase of products and equipment services.

\(^2\) For more information on ZooDoo products, see www.zoodoo.com.
An essential component of this proposal would be the establishment of an information and resource management system. For example, the coordination of landscaping equipment lending among participating facilities would need to be managed carefully. Material inputs for the composting facility would need to be tracked to manage fluctuations in supply caused by seasonal variance. Overall operations would require effective management of inventories, supply and demand forecasting, and the establishment of an accounting system to handle cost allocation among co-located facilities.

Information system resources that would be helpful to the development of this proposal would be an interactive database and/or internal web site maintained by the managers of the anchor facility. The status of operations could be updated on the web site, facilitating communication among Green Triangle members. Material and equipment orders, as well as anticipated supplies and demands, also could be coordinated through the web site. The site would provide easy access to information on shared materials, facilitating the planning process for current and future tenants. The Green Triangle Coalition also should work with Industrial Economics, Inc., located in Cambridge, Massachusetts, to share GIS data layers on Green Triangle area businesses that would be helpful in analyzing the growth potential of the proposed facility.

At this time, we feel that the Lena Park Community Development Corporation is in the best position to manage the proposed facility. They have many of the necessary technologies and business skills, as well as a strong interest in economic development and employment in the area. As a Green Triangle Coalition member, they would help insure that the development goals of the proposed anchor-tenant model complement the overall goals of the area.

Long-Term

In order to increase the connectedness among the EIP facilities, we propose the following, discussed in detail below:

- Use methane from organic decomposition in fuel cells to power trucks and buses travelling between the facilities.
- Convert underground conduits currently used for telephone lines, TV cable, and natural gas into conveyance systems for EIP residues.
- Create an on-line marketplace for buying and selling residues.
- Establish a contiguous greenspace that makes the EIP a single geographic unit that allows easy, pollution-free movement (namely, walking, biking, or roller-blading) and a greater sense of unity between the member institutions.

By adaptively reusing the existing infrastructure, and in some cases creating entirely new infrastructure, we hope to improve the efficiency of materials exchanges and introduce new residues to the system.
“Landfill gas” and Fuel Cells
Fuel cells are electro-chemical machines that convert the chemical energy of hydrogen-containing fuels into electricity. From an environmental standpoint, fuel cells are attractive because they produce no emissions and can use a range of source fuels. One such fuel is methane, which, in combination with carbon dioxide, is known as “landfill gas.” The anaerobic decomposition of organic matter, a major constituent in municipal dumps, produces landfill gas. The Green Triangle’s proposed composting center would act much like a landfill in this respect. In fact, because the “trash” at the composting center would be entirely organic, landfill gas production would exceed that from a typical municipal dump. According to the U.S. Environmental Protection Agency’s Landfill Methane Outreach Program, between 100 and 400 cubic feet of methane is produced per ton of trash (EPA 1999).

The landfill gas could be collected and transported via the Green Triangle Residue Conveyance System (RCS, see below) to the Gas Processing Center (GPC) where the methane, carbon dioxide, and other species will be separated. The Arnold Arboretum’s Dana Greenhouses would receive the carbon dioxide by the RCS, while the methane would undergo an additional chemical reaction to produce elemental hydrogen – the target species for the fuel cell – and carbon dioxide. Again, the carbon dioxide would go to the Arboretum, but the hydrogen would be sent by RCS to a fuel cell “refilling station.” The long term vision for the Green Triangle includes fuel cell-powered trucks transporting materials between the member institutions. Also, as the Green Triangle becomes a major tourist destination, fuel cell-powered buses could transport visitors between the Arboretum, Zoo, Audubon Society, the metro stop, and other area locations. Both the trucks and the buses would “refill” at this station, which would be centrally located.

In addition to creating new links within the Green Triangle EIP, the reuse of landfill gas has two important environmental benefits. First, both carbon dioxide and methane are greenhouse gases. By creating new sinks, the EIP would keep these gases from entering the atmosphere. Second, as anyone who passes a landfill knows, a pungent smell envelopes these facilities. Because methane is the source of some of this odor, the Green Triangle EIP would have a secondary, aesthetic, environmental benefit.

Residue Conveyance System
Miles of pipes, carrying telephone wire, TV cable, and natural gas, run under the Green Triangle area. The current push in technology toward wireless and satellite communication systems means that these wires and cables – and their conduits – may become obsolete. A zero emission Residue Conveyance System (RCS) is proposed that would use the obsolete underground pipes to move materials among Green Triangle facilities. Food waste, manure, and woodchips would be the primary residues carried through the RCS. A certain amount of retrofitting of pipes would be necessary. The existing telephone and cable lines

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1 The typical chemical breakdown of landfill gas is 50% methane, 39% carbon dioxide and 11% other (EPA 1999).
would need to be removed, and the pipes sealed with an inner sleeve or other methods to create a vacuum. Pumps would be installed to quickly move the material through the system.

Due to the long depletion time of natural gas, the pipes for this fuel will likely be in use for many decades. However, multiple use of the pipes is possible. The Gas Processing Center (GPC), introduced in the above section, would regulate the flow of natural gas, hydrogen, methane, and carbon dioxide through these pipes. It is expected that natural gas would predominate the flow and that the other gases would be conveyed at discrete times during the day. A limitation on the use of natural gas lines is that, unlike phone lines, they do not run everywhere, but are pervasive enough to allow for a comprehensive and easily expanded RCS.

Virtual EIP Marketplace
Transaction costs are an obstacle to increasing the efficiency and number of residue trades. First, a Potential EIP Participant (PEP) must search for facilities that produce the desired residues or, if the PEP has residues to sell, find a potential buyer. Second, the PEP must determine whether the quantities produced (desired) are sufficiently high to induce a transfer. Third, the parties must negotiate a price.

All of these steps and others can be eliminated through a virtual EIP marketplace. A NASDAQ-type system is envisioned, with all existing and potential Green Triangle participants on-line and able to determine the quantities and prices of available residues. An additional feature of the marketplace might be a “trigger” mechanism that releases stocks of purchased residues into the RCS at times specified in the transaction.

Contiguous Greenspace
Most of the Green Triangle facilities are directly adjacent to one another, but a key member, the Arboretum, and the metro stop are both located on the opposite side of Washington Street (see map). A swath of greenspace running from the Forest Hills Cemetery to the Arboretum would create several advantages. First, if all the natural elements of a park, including trees, shrubs and grass, are added to this connector greenspace, then the flows of organic materials through the Green Triangle will be increased. Second, the creation of new pathways means an opportunity for the reuse of construction and demolition material, such as crushed bricks, or the application of woodchips to create pathways. Third, if all the facilities are connected in a way that is attractive to pedestrians, bicyclists and rollerbladers, then fewer cars will be used to move between the Green Triangle destinations. And lastly, the contiguous greenspace will have the less tangible, but no less important, benefit of reinforcing the connectedness between facilities. By creating these physical links, EIP institutions may be less likely to view themselves as self-contained individuals and more as members of a self-reinforcing group.
CONCLUSION
The Green Triangle area represents a tremendous opportunity for the development of an eco-industrial park. The park, as proposed above, will enhance profitability of existing enterprises by reducing input needs and adding value to residual streams. The enterprises envisioned will dovetail with existing plans for community revitalization by creating jobs, and by fostering a sense of connectedness to the Green Triangle area. While existing efforts seek to instill the notion that facilities in the Green Triangle are related, the eco-industrial park plan adds substance to that notion. The park will demonstrate how entities can use each other to fulfill their own needs and to capture synergies that fulfill the needs of others outside of the individual “firms.” The eco-industrial park, under effective management, could become an entity in and of itself, providing an additional reason for people to visit the area.

On a more general note, our experience evaluating the potential for an eco-industrial park in an area targeted for revitalization has illustrated substantial value in combining efforts to increase efficiency and exchange materials among firms with redevelopment initiatives. The field of industrial ecology stands to benefit from the living laboratories that such regions provide, while redevelopment efforts can gain from a tool that graphically illustrates the interconnectedness among people, places, and organizations.

REFERENCES