“The world will not evolve past its current state of crisis by using the same thinking that created the situation”

Albert Einstein
Abstract

The primary research goal of this Graduate Terminal Project (GTP) was to take on environmental and economic issues by designing and examining the introduction of an eco-industrial park (EIP) in eastern Alachua County, Florida on Plum Creek’s 17,000 acre Windsor Tract. The primary objectives were to 1.) select a mixture of industries and agriculture that have the potential to work with one another and the surrounding lands and 2.) study the resource flows and exchanges that have the potential to develop between these industries. Mapping the potential resource flows and exchanges between the chosen industries influenced the overall site planning decisions of the EIP design. By identifying the resource flows and exchanges it allowed for the most efficient site design possible. The methods used to design this EIP can be applied to any site where resource efficiency is paramount to the design and function of the development.

The research approach for this GTP was a mixture of both a qualitative and action based research. Primary and secondary research activities were conducted in order to gain a complete understanding of the scope of design and concepts that would be employed in the Eco-Industrial Park development. Mixed methods were utilized and included field research, expert interviews, and case study analysis. Findings and analysis from these research tasks allowed for an understanding of similar projects whose success could be drawn upon during the design stage. Secondary research consisted of an in-depth literature review. The materials that were reviewed provided insight into understanding how EIPs came to be and how they have evolved over time. This research provided a base understanding of eco-industrial development and influenced the overall design of this project.

This GTP is the culmination of my deep interest in the subject of eco-industrial design. The design of a resource efficient eco-industrial park by looking at resource flows and how they relate to the landscape was undertaken. It is intended that designers draw from the ideas and methods discussed in this GTP and apply them to their own projects to create sustainable developments with "intelligent landscapes" now and for the future.
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Chapter 1: Introduction and Methodology

Project and Site Background

This graduate terminal project (GTP) builds upon work developed in the 2011 fall semester design exploration on agri-urbanism for Plum Creek’s Windsor Tract of 17,000 acres in eastern Alachua County, Florida. Plum Creek is a firm in the timber industry with land holdings across the United States. Professors Martin Gold and Dr. Mary Padua were approached by Plum Creek to lead a group of students in a studio setting to envision master plans for the Windsor Tract in northern Florida. This was part of the envision Alachua process where the community was engaged in a series of workshops to discuss future economic, environmental, and community opportunities for lands in Alachua County owned by Plum Creek. A mixture of architecture and landscape architecture students were split into teams to each create their vision for the site development. The group that I worked in synthesized a master plan called Cyclos: Ecological Renaissance; it was a “closed-loop”, net zero community in a compact development form located in the northeastern portion of the study area where State Road 26 and US 301 intersect. A closed loop or zero waste development is one in which the resources used come from within a defined system and are cycled through in a manner similar to nature (Barraclough n.d.). Natural systems operate in closed loops where water energy and nutrients are perpetually cycled and reused close to the source (Barraclough n.d.). My work focused on the infrastructure component and the creation of a water treatment facility that also...
served as an environmental educational facility and recreational park. This facility covered 100 acres and my design proposed to cleanse all of the daily waste water (sewage effluent) from the 20,000 residents and workers through a 3 step process over a period of 40 days involving aerobic and anaerobic processes. My GTP expands from this infrastructure development concept. My research begins with Plum Creek’s objective to bring industry and proposed new development to eastern Alachua County and this research project focuses on applying “landscape infrastructure” and sustainable principles for the development of an eco-industrial park. It is a technological and land use exploration with the research goal to find industries and agriculture that can work with one another at the Plum Creek property through energy, water, and resource exchanges. Through these exchanges not only will the industries be economically efficient, but also minimize environmental impacts.

Figure 1-2: Study Area Location (Source: 2011 Agri-Urban Studio)
Ideas discussed in this GTP also build from my time spent while working and studying in China. It appears that China’s concern for environmental degradation has called for a new mandate which may place them at the forefront of eco-industrial development. During the duration of my stay I was able to interview experts in the field of industrial ecology and visit a Chinese chemical plant in Shanghai that employs sustainable waste management practices (refer to Appendix B for interview questions). These experiences have helped to inspire my exploration on sustainable practices focused on infrastructure.

Introduction

As our society pushes into the future we are continually facing the new challenge of improving the environment in which we live. Today we find ourselves faced with such daunting issues as climate change, resource depletion, energy shortages, water and air pollution, and ecological degradation to name a few. Sometimes this list may seem insurmountable. However, as humankind continues to advocate for sustainability new technologies are being created to help take on these issues. Eco-Industrial design is poised to help reign in the waste we face today. It is now possible to shape our cities, industries, and economies in a way that not only mimics natural ecological systems but also works within these ecological systems and contributes to ecosystem services. We are approaching a time when it will be imperative that we recognize the mistakes of the past and take measures to protect our planet for the future. Many of the problems we face today began during the industrial revolution, which will be discussed in Chapter 2, with the rapid industrialization of the western world. We cannot reverse all of the
damage that was done during this period of expansion, but we can use new technologies and our newfound understanding of ecosystems to create a future that works not against but with our environment.

Currently environmental protection is ignored at the expense of economic development. With sustainable development and design this does not have to be the case. Sustainable development, as defined by Sustainable Seattle (n.d.), is “economic and social changes that promote human prosperity and quality of life without causing ecological or social damage.” By this definition, anything that is considered to be sustainable should not hinder economic growth (El-Haggar 2007). Sustainable development looks to lower costs and improve the environment simultaneously. Therefore, it can be concluded that sustainable development isn’t just a concept that should be pushed by environmentalists and policy makers, but should be embraced by industries, the business community, and society as well (El-Haggar 2007). One basic model for sustainable development is built on three pillars; economic, environmental, and social.

![3 Pillars of Sustainability](https://ees2001.wordpress.com)

Figure 1-3: 3 Pillars of Sustainability (Source: ees2001.wordpress.com)
Today, it is possible to create and sustain a circular economy to ameliorate the above mentioned problems. This is evidenced in China’s plan for a circular economy that was created by The Standing Committee of the 11th National People’s Congress (NPC) and signed into law by President Hu Jintao in August 2008 (Lai, Tian & Chen 2011). In Towards the Circular Economy, a report by McKinsey and Company (n.d.) produced for the Ellen MacArthur Foundation a circular economy is defined as “an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and business models.”

![Circular Economy Diagram](source: McKinsey n.d.)

The concept of a circular economy cannot be traced back to one person in particular; rather it grew organically out of multiple schools of thought. John T. Lyle contributed to the concept of in the 1970’s with his idea that all systems, from agriculture
onwards, could be orchestrated in a regenerative manner. In other words, that processes themselves renew or regenerate the sources of energy and materials that they consume. This is termed regenerative design (McKinsey n.d.). Industrial Ecology (IE), the study of material and energy flows through industrial systems, also plays an important role in the circular economy. Industrial Ecology focuses on connections between designated firms within an ‘industrial ecosystem’. The approach aims at creating closed-loop processes in which waste serves as an input, therefore eliminating the notion of undesirable by-products (McKinsey n.d.). Lastly, the concept of cradle to cradle (C2C) design helps to bolster a closed loop, circular economy. The concept of C2C, perfected by chemist Michael Braungart together with architect Bill McDonough, is an approach to the design of products and systems that is based on bio-mimicry. Bio-mimicry uses nature as a model to study and emulate natural forms, processes, systems, and strategies to solve human issues (McDonough & Braungart 2002). C2C models human industry on nature’s processes, viewing materials as nutrients circulating in healthy and safe metabolisms. It suggests that industry must protect and enrich ecosystems and nature’s biological metabolism while also maintaining a safe, productive technical metabolism for the high-quality use and circulation of organic and technical nutrients (McDonough & Braungart 2002). This concept will be discussed in depth in Chapter 2.

An eco-industrial park will be explored as the base for implementing a circular economy. It has the potential to be a viable answer to many of the aforementioned environmental issues that stem from the industrial revolution. In its basic form, an eco-industrial park (EIP) is a network of firms and organizations,
working together to improve their environmental and economic performance (Cushman n.d.). Planners and researchers of EIPs, such as Marian Chertow and Ernest Lowe, have used the term ‘industrial ecosystem’ to describe the type of symbiotic relationships that develop amongst participating firms. These relationships include flows of energy, resources, information, materials, and infrastructure. Ernest Lowe at Indigo Development, a leading consulting firm on EIP issues, provides the following definition: “An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues, including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only. The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impact” (Cushman n.d.). Although there are many differing definitions, this is the definition that is generally accepted by scholars and the US government alike. Therefore it will serve as the definition for the purpose of this GTP.

**Research Questions and Goals**

The goal of this GTP is to take on environmental and economic issues by designing and examining the introduction of an eco-industrial park in eastern Alachua County, Florida. The site will be a closed loop system that includes energy and water efficient design, which will create economic development in the community and will serve as a catalyst for the development of a proposed adjoining agri-urban concept. It will become a destination for research and investment. This system has the potential to
become a model for future new town development or the retrofitting of existing development. This eco-industrial park also has the potential to influence future land development in Alachua County and elsewhere. By anchoring a community with a green industrial core and infrastructure it will encourage others to develop in a similar manner which would have an overall positive impact on our environment. That being said, the primary research question this project aims to answer is: How can resource flows shape the landscape and planning decisions for the selected site? This primary research question leads into secondary research questions that will also need to be answered through this GTP. These include: What combination of industry and agriculture will work with the lands of the proposed site? And, what is the resulting structure of industrial ecology that takes place on site based on the chosen mix of industry and agriculture?

**Assumptions**

Because this GTP is based on work undertaken during the fall 2011 semester studio that explored the new development prototype, agri-urbanism, my working assumptions are based on the agri-urban community’s target residential population of 20,000. The Eco-Industrial Park will serve the community of 20,000 by providing products and resources, educational opportunities, recreational opportunities, and employment. Predicted waste quantities, such as waste water, sewage, domestic waste, and organic waste will be derived from that assumption. Based on the 2011 fall semester work, this GTP also assumes the site has the ability to provide enough agricultural resources and waste streams to support a closed loop system. This is further discussed in later chapters.
Methodology

At the onset of this GTP a research strategy or combination of research strategies had to be determined. Linda Groat and David Wang lay out categories of architectural research in their book *Architectural Research Methods* (2002). It was through reviewing the table presented by Groat and Wang that the research methodology approach for this GTP was decided upon.

Through review of the above table it was decided that the research strategies for this GTP would include a qualitative and action research based approach. Primary and secondary research
was conducted in order to gain a complete understanding of the scope of design and concepts that would be employed in the Eco-Industrial Park development. The primary research included mixed methods to obtain the information needed to complete the project. The forms of collecting primary research data that were used included field research, expert interviews, and case study analysis. This type of research allowed for an understanding of similar projects whose success could be adapted during the design stage. Secondary research consisted of an in-depth literature review. Review materials included books, articles, web-pages, and studies among others. The materials that were reviewed provided insight into how EIPs came to be and how they have evolved over time. This began with a look at the industrial revolution and moved into the evolution of the EIP, worldwide EIP development, EIP guidelines, cradle to cradle design concepts, and the future of the EIP. This research provided a base understanding of eco-industrial development that influenced the overall design of this project’s eco-industrial park. (See Figure 1-6)

By using a mix of qualitative and action research strategies, knowledge that was gained through primary and secondary research was analyzed and synthesized to develop the design concept for this GTP. By looking at what was done in the past and analyzing the successes and mistakes made in previous developments, a holistic design approach was implemented for the EIP site in eastern Alachua County.
Summary

This GTP explores how an eco-industrial park can be used as the foundation for development on Plum Creek’s 17,000 acre tract in eastern Alachua County, Florida. An extensive literature review provides background information to the reader on the history and evolution of the EIP as well as technologies and techniques and is applied to the design and planning of this project. Through the literature review, goals and objectives for the EIP design were set.
These goals and objectives influenced a program matrix that served as the basis for the creation of a master plan for the site; it incorporates design elements uncovered during the primary and secondary research. Through literature review, case study analysis, and field research different types of industries and agricultural activities were selected to work with the proposed lands of the site. Potential energy, resource, and water flows were evaluated and mapped based on the selected industries and agricultural activities. This again, influenced the final master plan.

The paper concludes with a discussion of the economic feasibility of a project of this magnitude, as well as a discussion as to what opportunities there are for further exploration and research regarding this project. Lastly, insight into the knowledge and lessons that were learned as a result of this GTP are discussed.
Chapter 2: Literature Review

Introduction
As discussed earlier a literature review; a secondary research activity to gain a complete understanding of eco-industrial parks was undertaken. It was important for this GTP to grasp the drivers behind the development of EIP sites, why there is a need for them, and how these sites will function in the future. Concepts that are discussed in the literature review influenced the overall design and concepts pertaining to the east Alachua County design site. While this is an overview of all the information that was synthesized for this GTP, the following is intended to give the reader a base understanding of eco-industrial parks and the design language that will be used for this project.

The Industrial Revolution
When the Industrial Revolution began in the mid 18th century, so did the negative effects on the environment. The economy shifted from primarily manual labor and draft-animal based towards a machine based manufacturing economy. It was set off by the mechanization of the textile industry, the increased use of fossil fuels in engines, and the development of iron making techniques (Beck 1999). These three innovations are attributed as the key to rapid industrialization that took place during the mid 1700’s through today (Bond et al. 2003). The innovations that took place during the first industrial revolution set a series of events in motion that would forever change our landscape. Agriculture became more mechanized, which created less demand for human labor.
As the economy transitioned from agriculturally based to machine based the populations of cities began to swell. Natural resources were needed to build these cities and so began rapid extraction and deforestation. Many families moved off of the farm and into urban areas seeking employment. This led to a shift in the cultural and social dynamic that was very different from the earlier centuries. As a new middle class of industrialists and working class in the mills and factories of cities grew as well (Hartwell 1971). This new class of worked fueled the demand for goods which required natural resources and fossil fuels to create.

The innovations and social changes of the 18\textsuperscript{th} century led to the second industrial revolution, which began around 1850 and lasted until 1914. The inventions of the second industrial revolution differed from the first in the fact that they were considered to be the first generation of inventions solidly based on science and technology. That fact would go on to shape the future of all innovation. This period was considered to be one of the most fruitful and dense in innovation in history (Mokyr & Strotz 1998). This point in time also bared witness to one of the largest periods of economic expansion in history. Workers saw a significant climb in their wages between 1813 and 1914 (Crafts & Mills 1994). The inventions of processing steel, refining petroleum, industrial chemicals, electricity, and the assembly line would forever change our world. It can be argued that these inventions had the largest effect on our landscape of any other inventions, previous or after. It was during this period that the negative effects on our environment from industrialization began to increase at an exponential rate. The second industrial revolution marked a major turning point in the Earth's ecology and humans' relationship with their environment. This period dramatically changed every aspect

Figure 2-1: Industrial Revolution
(Source: wikispaces.com)
of human life and lifestyles and the environment in which we lived (McLamb 2011). Because of the mechanization of industry through the use of fossil fuels and the speed of the assembly line, resources were being increasingly exploited at a rapid pace never before seen. Soil erosion, water and air pollution, loss of forests and wetlands, the depletion of natural resources and population growth would continue on until environmental regulation of the 1970’s began to take place. These regulations included the Environmental Policy Act, Clean Air Act, Water Pollution Control, and the Endangered Species Act to name a few. Rachel Carson was among the environmentalists that helped to bring environmental issues to the general public through her globally acclaimed 1962 book, *Silent Spring*. In it she raised important questions about humans’ impact on nature. From this book the public and industry would begin to realize the need for sustainable production and development (McLamb 2011).

**Evolution of the EIP**

Citizens began to realize the toll that progress and industry had taken on our environment. Calls for change began to spring up from the general public. As resources began to dwindle and international environmental incidents became more commonplace, such as the 1967 oil tanker Torrey Canyon running aground off the southwest coast of England, the 1969 oil spill from an offshore well in California’s Santa Barbara Channel, and the 1971 conclusion of a law suit in Japan that drew international attention to the effects of decades of mercury poisoning on the people of Minamata the public demanded tangible change from industry and big business. (McCormick 1995). With the increase in environmental degradation and depleting resources the idea of eco-industrial parks as an answer was eventually set forth.
EIP sites are able to deal with the major issues of resource depletion, environmental degradation, and economic factors all at the same time through the concept of industrial ecology, as explained previously in Chapter 1. Making one industry’s waste another’s raw materials is one of the most important goals of industrial ecology. An efficient way to accomplish this goal is through an eco-industrial development. These EIPs are a group of clustered facilities that minimize energy and material waste through agreed upon exchanges with each other. (El-Haggar 2007) The objective of the proposed EIP is to conserve natural resources by attempting to reach 100% utilization of all waste on site.

According to El-Haggar (2007) Eco-Industrial Parks aim at achieving economic, environmental, social, and government benefits as follows:

- **Economic:** Reduce raw material and energy cost, waste management cost, treatment cost, and regulatory burden, and increase competitiveness in the world market as well as the image of the companies.
- **Environmental:** Reduce demand on finite resources and make natural resources renewable. Reduce waste and emissions to comply with environmental regulations. Make the environment and development sustainable.
- **Social:** Create new job opportunities through local utilization and management of natural resources. Develop business opportunities and increase cooperation and participation among different industries.
- **Government:** Reduce cost of environmental degradation, demand on natural resources, and demand on municipal infrastructure, and increase government tax revenue.
Kalundborg Case Study

Ironically, the world’s first EIP was not planned and sprung up organically in Kalundborg, Denmark in 1972 (Ehrenfeld & Gertler 1997). It may not have come to be as a direct response to the environmental movement; however it did take root to contest issues of resource depletion and cost savings. The modern planned EIP grew through the lessons learned by studying Kalundborg. Kalundborg is a city of 16,300 residents, located 68 miles west of Copenhagen.

The development of industrial symbiosis in Kalundborg, Denmark began with the need to save limited supplies of ground water. Because of this, a project to use surface water from Lake Tisso for a new oil refinery was implemented. The City of Kalundborg took the responsibility for building the pipeline while the refinery financed it. Starting from this initial collaboration, a number of other collaborative projects were subsequently introduced and the
number of partners gradually increased (Ehrenfeld & Gertler 1997). The five main companies involved in the industrial symbiosis include a power plant (Asnæs), an oil refinery (Statoil A/S), a biotech and pharmaceutical company (Novo Group), a producer of plasterboard (Gyproc Nordic East), and a soil remediation company (Soilrem A/S). All of the by-product exchanges between firms evolved independently into a complex web of symbiotic interactions. (Jacobsen 2006)

As illustrated in Figure 2-4, the various material flows among the companies are based either on water, solid waste, or energy exchanges. In this system, wastewater and cooling water from the refinery are reused at the power plant: the wastewater for secondary purposes, the cooling water as feeder water for the boilers producing steam and electricity, and also as input water for the desulfurization process. The desulfurization process in turn produces industrial gypsum used in the production of plasterboard at the co-located Gyproc factory, thereby partly replacing the use of natural gypsum. The cogenerating power plant also produces heat for the town of Kalundborg and steam for the Novo facility and the Statoil refinery. The Novo facility is only supplied with steam from the power plant, whereas the refinery has production-related in-house steam generation capacity. In addition, heated cooling water from the condensation process at the power plant is piped off to a nearby fish farm, thereby increasing the efficiency in the farm, as the heated cooling water ensures full-scale production of the fish throughout the year. Finally, solid by-products such as fly ash from coal combustion, sludge from public wastewater treatment, and biomass from biogenetic fermentation at the Novo facility are recycled in various ways. In total, industrial
symbiosis in Kalundborg counts approximately 20 different by-product exchanges in operation (Jacobsen 2006).

These 20 different exchanges of water, solid waste, and energy have been quantified into real measurable economic and environmental results. The below bullets illustrate some of the many savings achieved at the Kalundborg IS site.

- The companies have reduced overall water consumption by 25% by recycling water and by letting it circulate between individual partners. A total of 1.9 million cubed
meters of groundwater and 1 million cubed meters of surface water are saved on a yearly basis.

- The partners have reduced their oil consumption by 45,000 tons per year, corresponding to a 380-ton reduction of sulfur dioxide emission on a yearly basis.
- The Asnæs Power Station provides up to 200,000 tons of gypsum to BPB Gyproc yearly. This makes up the majority of the company’s annual consumption lowering the need to mine natural gypsum for the production of their plasterboards.
- Yearly CO2 emission is reduced by 240,000 tons by the on-site participants.
- 30,000 tons of straw are converted to 5.4 million liters of ethanol yearly.
- 150,000 tons of yeast slurry from the pharmaceutical company is used to feed 800,000 pigs.
- Heated water from the Asnæs Power Station is sent to 57 nearby fish ponds that produce 200 tons of trout and salmon a year.

**Economics**

- Total site investment of US$75 million
- Annual revenues due to cost savings of US$12 million
- Return on investment in 5 years
- Accumulated revenues as of 1998: over US$160 million

Source: (Cushman n.d.) and http://www.symbiosis.dk/en

Kalundborg was the first example of quantifiable results through an industrial symbiosis exchange and provided its proponents with empirical evidence to justify the development of new planned EIP sites. Through the study and research done at the Kalundborg IS site scientists and academics were able to take lessons learned
from the facility and apply them to the next generation of planned EIPs.

**Eco-Industrial Park Development in the United States**

Although industrial symbiosis had been studied since its discovery at the Kalundborg site, the concept of eco-industrial parks was not formalized until 1993 by a group including Ernest Lowe from Indigo Development and researchers from Dalhousie and Cornell Universities (Cushman n.d.). This was in response to President Clinton’s July 1993 executive order 12852 establishing the President’s Council on Sustainable Development (PCSD). The vision of this council was the following; “Our vision is of a life sustaining Earth. We are committed to achievement of a dignified, peaceful, and equitable existence. A sustainable United States will have a growing economy that provides equitable opportunities for satisfying livelihoods and a safe, healthy, high quality of life for current and future generations. Our nation will protect its environment, its natural resource base, and the functions and viability of natural systems on which all life depends” (President’s Council on Sustainable Development 1999).

The council found that the promotion of EIPs would be central to a green and sustainable circular economy. Because of this they formed an active task force on EIPs as a key element for building a sustainable economy. The PCSD designated four EIP demonstration sites in: Baltimore, Maryland; Cape Charles, Virginia; Chattanooga, Tennessee; and Brownsville, Texas. The Environmental Protection Agency and the Department of Energy committed financial and intellectual resources towards exploring
gains that could be derived from EIPs (Mitchell & Bahl n.d.). By the fall of 1996 there were over 17 EIP projects in the United States that were in the development phase and two that already had their first tenants. Additional research conducted by the EPA was done to identify regulatory strategies to encourage the development of EIPs. The following strategies were identified during this study as being important (Peck 1998):

- Modification of existing regulations.
- Reforming existing permitting and reporting processes.
- Moving toward performance based regulation.
- Promoting the use of facility wide permitting.
- Using market based approaches, such as emissions trading.
- Utilizing voluntary agreements such as covenants.
- Implementing manufacture extended waste liability regulations, which will impact the design, production, use, reuse, and recycling of products.
- Promoting technology diffusion (sharing of technology information) within and between industrial sectors.
- Providing opportunities for technology development and commercialization.
- Providing technology development grants specific to industrial ecology applications.

Regarding the role of universities in the implementation of EIP development El-Haggar (2007) states “University and research institutes have also supported the development of EIPs extensively in cooperation with local and federal governments. It is important to develop a partnership among different stakeholders with universities and research institutes to develop innovative
techniques and guidelines for industrial parks to follow. EIP concept, methodology, and strategies should be included with the educational system within colleges and universities.” What the author did not touch on is the role that universities can play in a developed EIP. EIPs foster an environment that is suitable for research related relationships between the university and the functioning industry and agriculture on site. This is evidenced in sites such as the Catawba Eco-Complex which is an EIP venture between the local government, Appalachian State University, and Industrial stakeholders. This case will be studied further in Chapter 3.

The development of EIPs can occur through various entities; the private sector, public sector (local government, port authority, community development agency, or a university), or a combination of both; as the Catawba Eco-Complex was. The first generations of eco-industrial parks were primarily developed by the public sector as demonstration and research zones (Environmental Protection Agency 1996). As these projects have come to maturation it has been demonstrated that EIPs can be profitable to the private developer. When deciding between public or private ownership of an EIP there are several important issues to look at before the onset of a project. These issues are the availability of public land sufficient for the development, the availability of industrial bonding capability and public support to pass bonds, access to developers willing to take a position in innovative projects, and the ability of the economic development agency to take major responsibility for the EIP development process (Environmental Protection Agency 1996).
After looking into these 4 points a community can determine what route of private/public ownership a proposed EIP development should take. Public and private ownership each have their own unique advantages. Public ownership advantages are capital and direct incentives to companies locating within an EIP. The advantages to private ownership are land availability and land assembly along with the ability to take the lead role in development where public agencies can fall short. Regardless of park ownership it is important to have strong private/public cooperation in the development of these projects. Traditional industrial parks require coordination between both sectors and an EIP is even more likely to require a closer partnership between the two for a community to realize all of the benefits of a potential EIP (Environmental Protection Agency 1996).

According to the *Fieldbook for the Development of Eco-Industrial Parks* (1996), put out by the EPA, “An EIP developer is challenged to manage the design and development process and to recruit companies to the EIP. Managers of an operational EIP face three challenges: maintaining the community of companies; managing the EIP property, administration, and support functions; and ensuring the future viability of the EIP.” Therefore, choosing the correct industrial and agricultural mix to support the sites industrial ecology is very important from the onset of the project. It is imperative to the success of the EIP that park management recruit an anchor tenant; this will be discussed in depth in Chapter 5. However, having flexibility in the design and infrastructure is equally as important as the park grows and the industrial ecology evolves.
An EIP requires two different types of management entities: the property management company (PMC), which is responsible for the maintenance of the property, recruiting firms, negotiating leases, managing lease revenues, interacting with the public, maintaining infrastructure and providing support services, and the community self-management system (CSMS), which is an association or trust of companies who own their sites to handle functions that the companies share joint responsibility for. (Environmental Protection Agency 1996).

**Eco-Industrial Park Development in China**

As interest grows in the concept of eco-industrial parks, projects are beginning to take off all over the world. This is evidenced in China’s plan for a circular economy that was created by The Standing Committee of the 11th National People’s Congress (NPC) and signed into law by President Hu Jintao in August 2008 (Lai, Tian & Chen 2011). The Chinese circular economy initiative was developed as a strategy for reducing demand on their resources as well as the damage to natural environments. China’s top-down approach to the economy implemented sustainable development to use resources in an eco-efficient manner in order to improve the quality of life of citizens within natural and economic constraints. The circular economy model includes both cleaner production techniques and industrial ecology strategies. This is applied in reality through eco-industrial development (El-Haggar 2007).

In 1997, the United Nations Environmental Programme (UNEP) published a special edition on EIPs in their Industry and Environment publication. This was China’s first exposure to the concept of eco-industrial parks. The State Environmental
Protection Administration (SEPA; the predecessor of the Ministry of Environmental Protection) began to promote the development of EIPs with an emphasis on industrial symbiosis. This would be promoted as an alternative to the prevailing end-of-pipe pollution control approach, which had proven to be both costly and ineffective in China. One of the original purposes for China’s national environmental regulator, SEPA, was to tackle the issue of industrial development zones as pollution havens and enhance the environmental management of industrial parks (Shi, Tian & Chen 2012). In August 2001 SEPA approved China’s first National Trial EIP in Guangxi. As of November 2011 there were a reported 15 National Demonstration EIPs and a total of 60 National Trial EIPs. Among them, 48 are mixed industrial parks and 11 are sectorial industrial chemical and petrochemical industries, and one National Trial EIP is a resource recovery park. (Shi, Tian & Chen 2012)

Due to an extensive network of proven EIP developments in China, in operation for over 10 years, much can be learned from the Chinese. Analysis can be conducted on the success of their programs through an examination of the guidelines set for EIP development. Although China’s political environment is different than that of the United States, analysis of their EIP projects and their success could be useful.

**EIP Guidelines**

The following is a summary of EIP development and planning guidelines that were produced by Ernest Lowe at Indigo Development based in Northern California. Indigo Development is a leading EIP consulting firm in the United States and has been working on research and design in the EIP field for over 20 years.
Since Mr. Lowe is considered to be one of the preeminent experts in the field of eco-industrial park research and design and these guidelines have been endorsed by foreign governments as well as many of his peers, I utilized his guidelines for this GTP exploration.

Lowe’s work established four main characteristics that can be observed in successful eco-industrial projects. When evaluating EIPs, these four characteristics should be present in a well-functioning development. 1.) The first and most important characteristic is that an eco-industrial park is a complex of integrated industry, nature, and society. Without the integration of all three an EIP development cannot fully succeed. 2.) Second, an EIP must be designed to achieve the maximum use of resources and minimum discharge of waste through the exchange of by-products and wastes, use energy and waste water in a cascading and circular manner, and infrastructure should be reduced on site due to the sharing of infrastructure among the tenants of the park. 3.) Third, the EIP must ensure the steady and sustainable development of the industrial park through the application of modern administration, policy and new technology such as sharing information, saving water and energy, re-circulation and reuse, environmental monitoring and a sustainable transportation technique. 4.) Lastly, it must be evidenced that through constructing and operating a park’s infrastructures, the environmental conditions of companies in the park will reach a level in which industrial ecology is established. These four characteristics lead into six governing principles that should be followed in the planning and design of an EIP.
• The natural ecosystem principle: Eco industrial parks should be connected with the regional natural ecosystem to maintain its eco-functions as much as possible. To fulfill the requirement of sustainable development, the existing industrial park should rearrange its industrial construction, reform its traditional industrial technique, dramatically increase the efficiency of resource utilization and decrease waste generation and environmental protection pressure. When choosing the site for a new park, people should give full consideration to the local ecosystem capacity and minimize the bad influence to the surrounding scenery, culture, regional ecosystem and global environment.

• The Eco-efficiency principle: Carry out clean production when designing the park, constructing infrastructure and buildings, and in the operations of the park. In its most basic form, decrease resource consumption and waste generation.

• Life cycle principle: Intensify the life cycle administration of the raw materials before they enter into the park as well as products and waste after they leave the park, in order to minimize the negative environmental effects. Encourage the use and production of products, which need low consumption of resource and energy, are benign to the environment and safe to use, and can be recycled, reused and safely disposed of.

• Regional development principle: Integrating the eco-industrial park with regional development and the characteristic of the local economy. Strengthening the
connection between the eco industrial park and the community through training, education, developing local industry and employees’ residence construction. Integrating the design of eco industrial park with the plan of local economic development and letting it be harmonic with the plan of regional environmental protection.

- Hi-tech/high benefit principle: Broadly using modern bio-technique, eco-technique, energy savings technique, water saving technique, recycling technique, information technique, advanced production administration and environmental administration criteria.

- Attention to software and hardware principle: Hardware refers to the construction plan of projects including industrial facilities, infrastructures and service facilities. Software includes the establishment of environmental administration system, construction of information support system and enactment of preferential policy, which can allow the eco industrial park develop in a healthy and sustainable way.

Source: (Lowe 2003)

By following these characteristics and principles one would have a baseline for the evaluation or design of an eco-industrial park. When it comes to evaluation, it is very important to start with a baseline so all sites can be looked at the same way.

**Cradle to Cradle**

The current framework of the industrial system is the design and manufacture products out of raw materials that serve their life-
cycle in a very linear fashion. Valuable resources are extracted and turned into something more valuable to then be sold at a profit. Products are designed, manufactured, sold to the user, and when used up... shipped off to a landfill. This is known as cradle to grave design (McDonough & Braungart 2002). In the United States, more than 90 percent of materials extracted from the earth to make finished products become waste almost immediately (McDonough & Braungart 2002). This system of extraction, production, and land filling cannot be sustained indefinitely, as we will eventually run out of resources. Even the current model promoted of reduce, reuse, and recycle is not a sustainable practice. This is termed by McDonough and Braungart (2002) as “eco-efficiency.” Eco-efficiency is a reduction strategy; however, it does not get down to the root of the problem. It only makes the problem “less bad”. Every time something is recycled it diminishes the overall quality of the resource (McDonough & Braungart 2002). Therefore, recycling is only prolonging the depletion of resources. It does not address the issue head on by changing the model entirely. In the book, Cradle to Cradle by McDonough and Braungart, they suggest there is a 4th R on the list; regulate. Their belief is that regulation is important to add to the list because without it nothing would be implemented. El-Haggar (2007) takes the 4 Rs a step further by proposing the addition of 3 more. His list known as the 7Rs Rule consists of reduce, reuse, recycle, recover, rethinking, renovation, and regulation. This GTP serves to cause a shift in thinking to move from the eco-efficient model to a more sustainable one.

McDonough and Braungart (2002) propose the model of eco-effectiveness as an alternative to the status quo. Eco-Effectiveness is the use of intelligent and healthy materials,
designing human industry that is safe, profitable, and regenerative, while producing economic, ecological, and social value (Braungart n.d.). In other words, eco-effective designs use materials that can be returned to either the earth or back into the industrial system without causing harm to the environment or lowering the value of the material. The inputs of these eco-effective designs must then fit into one of two categories, being either a biological or technical nutrient. A biological nutrient is a material or product that is designed to return to the biological cycle, being consumed by micro-organisms in the soil or other animals. An example would be biodegradable packaging. Whereas a technical nutrient is a material or product that is designed to return back to the technical cycle from which it came, without degradation of its properties. An example of a technical nutrient is a sturdy plastic computer case that can continually circulate as a computer case after multiple reuses. (McDonough & Braungart 2002)

Figure 2-7: Eco-Efficiency vs. Eco-Effectiveness
(Source: http://divergentmba.wordpress.com)
There are three tenets of the cradle to cradle design concept. They are waste equals food, use current solar income, and celebrate diversity. (McDonough and Braungart 2002) The tenet of waste equals food is based on the fact that waste does not really exist in nature. This is because each organism’s processes contribute to the overall health of the eco-system. When natural things decompose they become food for other living things. Industry can model their metabolisms after nature to allow materials to flow as nutrient cycles being taken up by a biological or technical metabolism. In theory, there is no real waste.

Another tenet, use current solar income, is the idea of using renewable energy sources. Trees and plants use sunlight as food,
humans can be just as efficient. Energy can be collected directly from the sun through solar panels or through other means such as wind power. Wind power is created by thermal flows fueled by the sun and therefore an example of using solar income. The last tenet is to celebrate diversity. Natural ecosystems are extremely diverse relationship webs. These webs thrive on the complex diversity that exists within them and the mutual relationships among organisms in the ecosystem. Each individual system could not sustain itself without these relationships. A diverse ecosystem is a healthy ecosystem. Humans can model industrial ecosystems after ones found in nature. When designers celebrate diversity, they tailor designs to maximize their positive effects on the particular niche in which they will be implemented (McDonough et al. 2003).

The most advantageous sustainable designs draw information from and fit within local natural ecosystems. This follows the idea that “all sustainability is local”. If a designer truly understands the local ecosystem then one can design a site or product that functions within that system to enhance the local landscape. This concept is known as Green Engineering. Practitioners of green engineering draw from local and available energy and material flows to enhance interconnectivity between industry and landscape (McDonough et al. 2003). McDonough et al. (2003) go on to describe the 12 principles of green engineering. A designer should use these 12 following principles as a model to create a design that works within a local ecosystem and is therefore sustainable:

Figure 2-9: NASA Sustainability Base; Designed by William McDonough using C2C tenets (Source: http://www.mcdonoughpartners.com)
Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.

It is better to prevent waste than to treat or clean up waste after it is formed.

Separation and purification operations should be designed to minimize energy consumption and materials use.

Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.

Products, processes, and systems should be “output pulled” rather than “input pushed” through the use of energy and materials.

Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.

Targeted durability, not immortality, should be a design goal.

Design for unnecessary capacity or capability (e.g., “one size fits all”) solutions should be considered a design flaw.

Material diversity in multi-component products should be minimized to promote disassembly and value retention.

Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.

Products, processes, and systems should be designed for performance in a commercial “afterlife”.

Material and energy inputs should be renewable rather than depleting.

Source: (McDonough et al. 2003)
The concept of cradle to cradle design is integral to the creation of a circular economy. Without the consideration of how a design can fit into the local ecosystem a true and fully functioning closed loop system cannot exist. Therefore when designing for true sustainability, C2C concepts must be integrated to achieve the maximum return on inputs. This will prevent the depletion of precious resources and put an end to the degradation of our natural environment.

Summary
The concept of the eco-industrial park has been developing since the late 1960’s. It gained prominence in the early 90’s during the 1992 Rio de Janeiro Earth Summit and President Clinton’s 1993 President’s Council on Sustainable Development. As evidenced in the complete literature review the EIP is the base for implementing a circular economy. Because of a diminishing environment and diminishing natural resources implementing EIPs and a circular economy worldwide is the answer to many of the most important issues we will face in the future. Across the globe the EIP concept is being embraced, maybe nowhere more than in China. By choosing this, we are moving in a more sustainable direction however the EIP concept has still not been perfected and maximized.

Although there are already around 100 functioning eco-industrial parks across the globe, there still has not been one designed with a completely closed loop system (Industrial Ecology Wiki n.d). The key to closing the loop is to not only design an EIP that maximizes throughputs, but the goods that are being produced on site must be designed and manufactured with the idea that they have to be returned to the biological or industrial metabolism. Through this
idea of cradle to cradle design waste could be eliminated and the loop truly closed. This is why the proposal for an EIP based on cradle to cradle design in east Alachua County, Florida will be unique. It would be the only site of its kind to work with the local ecology in a closed loop system with a net-zero negative impact on the local environment.
Chapter 3: Case Studies

Introduction
Case studies were undertaken for this GTP to support the overall design decision making process. Lessons learned from each case study were applied to the overall design of the Eco-Industrial Park site. These particular case studies were selected to support the goal of a closed loop cradle-to-cradle system. In sticking with the tenets of C2C design it was important to choose case studies that could easily be applied and would work with the character of the site.

This chapter presents three different case studies, each one providing different lessons for the overall design of the site. The first case study is of the Catawba County Eco-Complex. This development was chosen because it is an excellent example of a functioning EIP in the United States. It is a joint public and private venture that has proven to be a success. The second case study is of the Herman Miller Greenhouse. This facility, designed by William McDonough (co-author of Cradle to Cradle), is a combination of office and factory space. It was designed with the tenets of C2C design; making it resource efficient and a pleasant space to work. The third case study undertaken for this GTP was that of a natural water treatment system at the Shanghai Chemical Industrial Park. Because water treatment and quality are so important to this project it was important to draw lessons from a successful project.
Research for the three case studies was conducted through several different avenues. Literature was reviewed for each of the three separate case studies. In addition to the literature review, interviews and field research were also conducted to gather more in-depth information on the projects. This gave added insight to the projects that could not be gained from a traditional literature review. The following is a synthesis of the three different projects and how they apply to the GTP design site.

**Case Study 1: Catawba County Eco-Complex**

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Catawba County Eco-Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>4017 Rocky Ford Rd, Newton, NC 28658</td>
</tr>
<tr>
<td>Date Planned:</td>
<td>Development of the site began with the Blackburn Resource Recovery Facility (Landfill) in 1998</td>
</tr>
<tr>
<td>Construction Completed:</td>
<td>Construction on this site is ongoing as new partners are continually recruited</td>
</tr>
<tr>
<td>Construction Cost to Date:</td>
<td>Unknown</td>
</tr>
<tr>
<td>Size:</td>
<td>805 acres</td>
</tr>
<tr>
<td>Consultants:</td>
<td>CDMSmith retained for engineering, architecture, landscape architecture, and sustainability consulting. Tetra Engineering retained for green energy consulting.</td>
</tr>
<tr>
<td>Client/Developer:</td>
<td>Catawba County</td>
</tr>
<tr>
<td>Managed By:</td>
<td>Catawba County</td>
</tr>
</tbody>
</table>

**Context:** The Catawba County Eco-Complex is an eco-industrial park located in Newton, North Carolina approximately 42 miles northwest of Charlotte, North Carolina. Newton has 12,650 residents and is the county seat of Catawba County. It is in the process of transitioning from a traditionally textile and furniture manufacturing city to a diversified manufacturing and service economy with an interest in high tech industries. The Eco-Complex is about 4 miles outside of the city limits of Newton.
Surrounding properties are primarily farmlands; however there is a large Target distribution center directly to the north of this site which employs over 550 people. There is highway access 2 miles to the east along US highway 321, an important route in western North Carolina. Located several miles to the southeast is an Apple Inc. Data Center that is a LEED platinum certified building. The Apple facility provides itself with 60% of their energy needs through a 100 acre solar array and a 5-megawatt biogas powered fuel cell instillation. The solar development is the world’s largest privately held solar array. Apple has expressed interest in future cooperation with the Eco-complex and is currently working with county to find ways to develop a relationship. It was said that the Eco-complex was one of the main reasons Apple decided to locate the data center in Catawba County.

Site Analysis: The main use of the 805 acre site is as a county run landfill and has been in use since 1998. When the decision was made that the site would be turned into an eco-complex over 100 acres of landfill property were planted with energy crops. These crops consist of soybeans, canola, and sunflowers and are planted on a rotational basis. The development is bounded by farm land and has over 4 miles of road built on the property for

Figure 3-1: Location of Catawba County Eco-Complex
access throughout the site. Rocky Ford Road bisects the property into north and south portions.

**Project Background and History:** The idea for converting the landfill site into an EIP came from site Director Barry Edwards. He became aware of an EIP project that was developed at Rutgers University through a presentation by someone from the EPA and was intrigued with what the landfill could do with their gas and heat energy resources. He began with reaching out to local universities through presentations about the possibilities of EIP development. Professors at North Carolina State and Appalachian State University were interested in the concept of an EIP and joined Mr. Edwards on investigation trips to the site at Rutgers University. At Rutgers they were able to witness heat energy from electricity generation being used to heat greenhouses. The heat energy was a by-product that would have had no worth in the past. It was from there that they decided to map out the possibilities for by-product exchange at the Blackburn Landfill site. The site’s industrial ecology grew from these early meetings into what is now witnessed as the Catawba County Eco-complex. Because of the close relationships formed during the early stages of program development participation from the universities was very high. These relationships manifest themselves today in the form of research taking place on the site, conducted by the universities in conjunction with the county.

**Design Development:** To get from conception to a built EIP development, Mr. Edwards stated that the most important thing was getting the county board officials committed to making this a reality. In order to accomplish this he had to work with everyone; from the government officials, to the professors, to the design
consultants. In his opinion, “the government will make the right decisions if they have the correct and pertinent information in front of them.” Because of this, much time was spent on developing knowledge, plans, and gathering correct and accurate information to make political decisions. When the county was on board then site construction began. One component of the program was built at a time and it continues to develop this way today.

**Program Elements and Industrial Ecology:** The industrial ecology formed at the Catawba County Eco-Complex stems from the anchor tenant; the Blackburn Landfill. Other site industries decided to co-locate because of the unique opportunities the site presented to each one. Many different components have resulted on the site and the industrial ecology web continues to grow as more companies decide to locate in the development. A gas-to-energy facility consisting of 3, 1-Megawatt generators, which burn methane, a landfill byproduct, compliments the activities of the Blackburn Resource Recovery Center. These generators produce enough electricity to power approximately 1,400 average sized homes and serve to provide energy for the other industries on the site. A high-tech wood products facility employing 115 people is located at the eco-complex. Its byproduct of wood waste is being used by a co-located wood pallet recycling and manufacturing firm. Other byproducts of wood shavings, bark, sawdust, and other wood wastes produced by the wood products facility and the pallet company will be sent to an impending component, a bio-energy facility, in the future. This proposed bio-energy facility is a wood gasification energy facility that will use the byproducts and biomaterials from the wood products firm, the pallet company, and the county to generate electricity, steam, and heat energy. The Bio-Energy Facility will house a newly constructed wood-fired

![Figure 3-2: Pallet One Factory at Catawba County Eco-Complex (Source: http://www.catawbacountync.gov/ecocomplex/index.asp)](http://www.catawbacountync.gov/ecocomplex/index.asp)
gasifier and steam production plant that is expected to produce 3 megawatt hours of electricity and 15,000 pounds of steam per hour. A natural gas fired boiler, with similar steam output, will serve as a backup to the main wood-fired steam production plant (Edwards n.d.). Another program element participating in the site’s crops are planted in the landfill’s buffer zones. The buffer zones are required and would otherwise sit unutilized. Previous to the planting the buffer zones were actually costing the county dollars to maintain because of the mowing that needed to take place. The crops produced on these lands are then used by the co-located Biodiesel Research Facility. This research facility is a partnership between the county and Appalachian State University and consists of a LEED certified 7,260 square foot processing and research center and an 800 square foot chemical storage facility. Graduate students from ASU are using the feedstock energy crops grown on site to research which types of crops are capable of producing the highest quality biodiesel. The biodiesel produced at this site is then in turn used to power county and university vehicles. There is also a greenhouse demonstration and research facility located on 1 acre of landfill buffer land. This is a cooperation between the county and North Carolina A&T State University, where the university is doing research on extending crop growing seasons. There are several other proposed components that will take place on the site to enhance the IE as well when they come online. A bio-solids processing facility will replace the existing Regional Sludge Management Facility, with byproduct exchanges between the other energy producing facilities. A bioreactor landfill on the site will use gray water residuals from the Bio-solids Management Facility that are then injected into the existing landfill to create a bioreactor landfill. And lastly, an algae research facility in conjunction with Appalachian
State University is proposed for the site. Research at this facility will be an extension of the biodiesel research already taking place in the development (Edwards n.d.).

![Diagram](http://www.catawbacountync.gov/ecocomplex/index.asp)

**Figure 3-4: Catawba County Eco-Complex Industrial Ecology** (Source: http://www.catawbacountync.gov/ecocomplex/index.asp)

**Maintenance and management:** Site maintenance and management is taken care of by Catawba County. The county maintenance workers come out to the site regularly to take care of issues such as grass clipping and infrastructure maintenance. A team of 2 workers are responsible for the entire site at a cost to the county of $75,000 annually. The management of the site is administered by the county under Director Barry Edwards. He has a staff that works under him to ensure the Eco-complex runs in the approved manner. Mr. Edwards is also responsible for recruiting new firms to co-locate on the site and fostering the EIP exchange relationships.
Criticism: Several criticisms of the Eco-complex have come up over the years since development started. However, the amount of issues with the Eco-complex has been relatively low. With increasing truck traffic, bringing in more resources to the site, there has been an increase in noise and debris pollution.
Neighbors of the site have complained of finding debris blown off of trucks on their private property. Another complaint levied by local farmers was that the government should not be participating in biodiesel production. It was their opinion that private enterprise should be the only ones involved in this type of research and production.

**Significance and Uniqueness:** What makes this project significant is the proven ecological gains that have developed over time in and around the EIP site. Since the development of the EIP started in 1998, Catawba County has gone from the middle of the pack in terms of recycling per capita to number one in the state of North Carolina. By providing the county residents with an example of eco-efficiency and through community outreach the citizens have gotten on board with the idea of sustainability in everyday life. The county had one of the largest waste streams in North Carolina before development of the EIP and now they are the lowest in waste in the state. This can all be attributed to the Eco-complex. At the rate they were going, a new landfill would have been needed every 8 years at the cost of 12 million dollars. Because of the Eco-complex, Catawba County has not yet needed a new landfill over 15 years later. Cost to citizens for waste disposal has not gone up over this period either, where waste disposal price has been increasing across most of the United States. What makes the project unique to others like it is the county places a direct monetary value on every waste that enters or is created at the EIP. This value can be positive or negative. By doing this it allows firms to understand the cost of their waste streams and the value of by-products that were previously being land filled at a cost. This has promoted private industries to take a look at their practices and see how they can participate in by-product

![Figure 3-6: Landfill at Catawba County Eco-Complex (Source: http://www.catawbacountync.gov/ecocomplex/index.asp)](http://www.catawbacountync.gov/ecocomplex/index.asp)
exchanges with other local industries to lower overall waste. Catawba County will even assist small firms in identifying uses for their waste streams instead of sending it off to the landfill.

**Limitations:** The Eco-Complex has several limitations that will be tested by time. With energy sufficiency being a development goal, as more companies choose to co-locate on this site will the energy produced on site be enough to fulfill all their needs? Because the evolution of the site is continuing there is no knowing how the industrial ecology web will work out. If one of the private enterprises decides to leave the complex what does that do to the IE web and other co-located firms? More growth at the site and time will be needed for further evaluation.

**General Lessons:** From the onset of this project, Barry Edwards (Eco-Complex Director) sought to develop a concept that could be replicated elsewhere. Through analysis of this site it was determined that many of the aspects of the Catawba County Eco-Complex can be transferred to other similar properties. Numerous components of this project are seen in the proposal for the EIP development on the Plum Creek property. Some of these include the use of land on site to grow crops that will be used in co-located industries, joint research facilities with local universities, and onsite energy production. It was also proven at the Eco-Complex that joint public and private cooperation can be successful in EIP development. It is important to consider that cooperation is key in this sort of development. When relationships are formed with local governments, universities, and the developer a better overall development will occur. This type of cooperative relationship helps to foster the exchanges that will take place on site. It was also discovered that informing the public
is a very integral part of the process to meet the goals of an EIP. In a public/private development the public needs to be involved as well. This is accomplished over time through changing the way society functions at a methodical pace so people can change their behaviors to become more sustainable along with the EIP.

Case Study 2: Herman Miller Greenhouse

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Herman Miller Greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>10201 Adams St. Holland, MI, 49424</td>
</tr>
<tr>
<td>Date Planned:</td>
<td>Discussions for site began in 1992</td>
</tr>
<tr>
<td>Construction Completed:</td>
<td>1995</td>
</tr>
<tr>
<td>Construction Cost to Date:</td>
<td>$14,400,000 (land purchase not included)</td>
</tr>
<tr>
<td>Size:</td>
<td>Building: 290,000 square feet, land area: 180 acres</td>
</tr>
<tr>
<td>Consultants:</td>
<td>William McDonough + Partners, Architect; Pollack Design Associates, Landscape architect; Owens-Ames-Kimball, Contractor; E Source, Environmental building consultant; Soils and Structures, Structural engineer; Van Dyke &amp; Associates, Interior designer</td>
</tr>
<tr>
<td>Client/Developer:</td>
<td>Miller SQA, subsidiary of Herman Miller Inc.</td>
</tr>
<tr>
<td>Managed By:</td>
<td>Miller SQA</td>
</tr>
</tbody>
</table>

Context: The Herman Miller Greenhouse is a C2C designed furniture manufacturing and office facility located in Holland, Michigan. Holland Michigan is home to over 250,000 residents and is on the shores of Lake Michigan. Over 3,300 people in this area are employed by Herman Miller, with 700 specifically at the Greenhouse site. The Herman Miller Greenhouse facility is bounded on 3 sides by varying forms of residential lands. The most intense being a residential neighborhood development on the north side. The Gerald Ford Freeway bounds the east side of the site which allows for easy highway access for shipping. Included on the same site as the Herman Miller Greenhouse is the
Herman Miller Midwest distribution center. Other surrounding land uses include light industrial and commercial. LG Chem Power Inc. has a nearby facility that is responsible for making lithium-ion batteries for electric vehicles. The Black River lays directly to the west of the site and flows into Lake Michigan. Because of this proximity, storm water treatment is important for the Herman Miller site.

Site Analysis: The Herman Miller Greenhouse is 290,000 square feet and the total acreage of the site is around 180 acres. The building is a single story structure that was designed to follow the natural contours of the site and therefore work with the land by reducing cut and fill. The constructed wetland cleanses the facility's storm water before it makes its way to the Black River and eventually into Lake Michigan. Before Herman Miller, the site was previously used as an industrial site and needed to be cleansed before the Greenhouse facility was constructed. Through this, the restoration of natural ecosystems took place. The Herman Miller Company opted for a natural landscape using mostly native plants that eliminate the need for regular mowing.
herbicides, and fertilizers. This also helps to lower the facility’s overall operating costs and reduces groundwater contamination. After the prairie and wetland ecosystems were restored employees witnessed the return of wildlife to the site. Parking at the site is organized along the access road in order to limit paved surfaces and is hidden from view by large berms newly planted with forest (Building Green 2004).

**Project Background and History:** Herman Miller has been dedicated to sustainability since 1992. It created an internal group of over 300 employees from all departments of the company named the Environmental Quality Action Team. This team works together to figure out ways to improve environmental performance within the company. It was at the same time this group was formed that the idea for the construction of the Greenhouse began to take shape. William McDonough, from McDonough and Associates, was contacted to create the new facility. Herman Miller reached out to McDonough because of his expertise with C2C design concepts and they wanted to implement these concepts into the design of the new facility. McDonough proposed a C2C based design that would allow for clean air, natural light, open spaces, and views to nature through all windows; all while being energy efficient and cleansing water on site. It was thought from the onset of the design that this would have a positive effect on the employees of the facility. The site would become a study in worker productivity, as research has been done to prove its effectiveness (McDonough & Braungart 2002).

**Design Development:** The design development was spearheaded by the architects, McDonough and Associates, however many consultants were brought in on this project. Three
areas of concern were identified as being critical to the success of the project: occupant comfort, health, and communication; integration of the exterior landscape; and maximum use of day lighting. Employees and members of the community were engaged in the design from the onset. This was established through a three day charrette that included members of the community and the workers that would be using the building itself. This began a spirit of communication, cooperation, and continuity between the design team and the users that would last through the completion of the project (Building Green 2004).

**Program Elements:** The building design provides openness on the inside and to the outside world. This was intended to foster open communication inside the building. There are as few doors and walls in the facility as possible and many amenities such as open conference and meeting rooms promote teamwork and cooperation between employees. There is an interior “street”, that runs the length of the building that not only allows for easy movement, but it is also ventilated with filtered fresh air and filled with interior greenery. The exterior windows look out to the prairie landscape ecosystem which, together, gives the occupants a feeling of being outdoors. Day lighting is used not only for the interior “street,” but also for the factory area. Natural lighting is plentiful from skylights and roof monitors. Lights in the building only turn on when the sensors detect that it is needed, also saving on energy consumption. Ventilation rates exceed code for enhanced indoor air quality. Additionally, careful selection was made of non-offgassing materials and finishes. The most noisy subassembly operations have been moved outside the building. Other noisy operations were shifted about to minimize noise impacts as well as to optimize the interior space. Additionally, the

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Figure 3-9: Interior “Street” at Herman Miller Greenhouse (Source: http://www.mcdonoughpartners.com)
Greenhouse building has a fitness center, including a full-sized basketball court (Building Green 2004).

**Maintenance and management:** The maintenance and management of the facility are all conducted by the Herman Miller Company. The facility supervisors were informed about the new building form and function through informational teaching sessions run by the designers of the building. There was also an open house provided for all workers to inform them on their new environment (Building Green 2004).

**Site Plan:**

![Figure 3-10: Herman Miller Greenhouse Site Plan (Source: http://www.mcdonoughpartners.com)](http://www.mcdonoughpartners.com)
Significance and Uniqueness: The US Department of Energy conducted surveys of employees before they moved into the new facility and after to see if there would be any measurable differences in perception, health, and productivity. Workers were asked to rate their comfort and satisfaction with a wide range of ambient, aesthetic, social and functional features of the environment as well as their behavioral, physical, social, and psychological experiences. It was determined that there were increases in on time shipment, efficiency, quality, profitability and productivity. The data shows that the new, green building was associated with overall with higher quality of work life than the old building, and that it had a more positive impact on perceived work performance and job satisfaction. Multiple workers who left the company for employment elsewhere returned and stated a large reason was the positive work environment (Heerwagen 1998).

Criticism: Some have hypothesized that the measured increases in production are due to a “halo” effect with being in a new building. In the DOE study this was largely shot down due the fact it wasn’t seen across all variables. The workers’ perceptions and experiences were not all consistently positive. For numerous outcomes, the non-daytime workers actually showed a more negative response to the new building compared to the old one (Heerwagen 1998).

Limitations: It is unsure if the same positive effects would be witnessed in all industries. Additional like surveys would have to be done for firms moving out of old facilities and into new ones such as the Greenhouse designed by McDonough and Associates. It is also unclear if a building in a different region would see the same environmental performance as the case
study. Different environments will affect the building performance in different ways.

**General Lessons:** From the research conducted by the DOE and analyzed by other scholars it was concluded that the building does perform better than traditional industrial developments. It lowers costs, increases productivity, and performs better for the environment. It is suggested that the buildings on the design site for this GTP follow the Herman Miller Greenhouse model. This will not only serve the environment better, but also fit in with the stated goals and objectives of the GTP and the tenets of C2C design. By following this model it will create a more holistically designed EIP that is site sensitive.

### Case Study 3: Shanghai Chemical Industrial Park Natural Water Treatment System

<table>
<thead>
<tr>
<th><strong>Project Name:</strong></th>
<th>Shanghai Chemical Industrial Park Natural Water Treatment System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong></td>
<td>201 Mu Hua Road, Shanghai, China, 201507</td>
</tr>
<tr>
<td><strong>Date Planned:</strong></td>
<td>August 2005</td>
</tr>
<tr>
<td><strong>Construction Completed:</strong></td>
<td>2006</td>
</tr>
<tr>
<td><strong>Construction Cost to Date:</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Size:</strong></td>
<td>73 acres</td>
</tr>
<tr>
<td><strong>Consultants:</strong></td>
<td>AECOM was project lead in engineering and landscape architecture. Tongji University and University of California, Berkeley participated in project research.</td>
</tr>
<tr>
<td><strong>Client/Developer:</strong></td>
<td>Shanghai Chemical Industry Park Development Company Ltd.</td>
</tr>
<tr>
<td><strong>Managed By:</strong></td>
<td>Shanghai Municipal People’s Government</td>
</tr>
</tbody>
</table>

**Context:** The Shanghai Chemical Industrial Park (SCIP) occupies 29.4 square kilometers of land southeast of Shanghai on the edge of Hangzhou Bay. Effluent from an on-site wastewater treatment
plant discharges into the Natural Water Treatment System that eventually flows into the Bay. The system was implemented to further cleanse industrial wastewater before it reached the ocean. The site includes a constructed wetland that was retrofitted from old aquaculture ponds and canal systems. Polished wastewater provides a source of clean water for on-site water features, is reused in various industrial processes, and further protects the ecology of the coastal zone of Hangzhou Bay. The system improves both financial and environmental aspects of SCIP's operation. Other objectives of the site include recreational and scientific research opportunities as well as wildlife habitat. As one of the first facilities used for natural treatment of industrial wastewaters in China, the SCIP NTS serves as a model for similar industrial operations throughout China and Asia.

Site Analysis: The NTS occupies an L shaped configuration totaling 73 acres of land along the north east corner of the SCIP. The existing elevations are between 3.4 and 7 meters above sea level. The majority of the SCIP site is occupied by abandoned
aquaculture ponds. A large tidal canal enters the site from the east about 700 meters from the southern tip of the site. The main existing infrastructures on the site are large electrical towers which deliver electricity to the SCIP facilities. Aquaculture ponds are separated by berms and access roads. The eastern border consists of a large retaining wall which separates the sea from the SCIP site. The northern border consists of 20 meters of planted green-buffer between the NTS and a small village.

**Project Background and History:** The project began with the implementation of the original industrial wastewater treatment plant (WWTP), located within the SCIP. It is operated by Sino-French, a foreign water engineering firm. The WWTP has been adapted to the industrial wastewaters that it receives and includes numerous measures to protect the local ecosystem from pollution. The influent is divided into organic and inorganic waste streams. It was decided that to further treat the water a NTS would be added to the site to completely cleanse organic waste streams before entering the bay. Presently, up to 25,000 cubic meters of organic waste can be treated by the NTS on a daily basis.

**Design Development:** The design team began by identifying the NTS’ objectives. Three main objectives for the system were identified during this research process. The primary design objective of the SCIP Natural Treatment System was to improve water quality of the WWTP effluent to meet China’s national standard of surface water quality. The second objective was to design the NTS to comply with the government’s environmental quality standard for groundwater and soil quality. Lastly, the design team set the objective of preventing toxic compounds from accumulating in groundwater, soils, surface waters, and

Figure 3-12: Tidal Canal, Photo taken at site
organisms to the most feasible extent possible. Therefore the team intended to outperform even the government standards. Site analysis and research was performed by the AECOM team in conjunction with Tongji University and UC Berkeley. From that research the AECOM design and engineering team stepped in to develop the complete NTS.

**Program Elements:** The research uncovered that the best way to treat the industrial wastewater of the SCIP was to create a NTS with three different components. This was selected based on consideration of technical feasibility, capital cost, management and maintenance requirements, and reliability. It was decided that the preferred strategy was a trickling filter along with the integration of a COD degradation pond and a free flow constructed wetland area. The free surface wetland area is the largest of the three components on site covering 22.02 hectares with only 3.45 hectares of open water. A planting scheme for the wetland was developed by the environmental engineers at AECOM. Other adjoining program elements to the site are a visitor center, 580 meters of boardwalk and piers, access roads and parking, a bird observation tower, and research wetlands.

**Maintenance and management:** For the purpose of maintenance and management it was determined that the Sino-French Water Development Company would take responsibility for monitoring and operation of the NTS. This is because of the direct relationship that the NTS has to the WWTP that was already run by Sino-French. This ensures that the NTS is integrated effectively into the existing wastewater management system at the SCIP. Having a single party responsible for the performance and
upkeep of both helps to optimize the performance of the Natural Treatment System.

**Site Plan:**

Composite Landscape Concept
Preferred Alternative

Figure 3-13: Concept Sketch of Site Master Plan (Source: AECOM)

Figure 3-14: Site Master Plan (Source: AECOM)
Figure 3-15: Site Planting Plan (Source: AECOM)
**Significance and Uniqueness:** What makes this project so significant and unique is that it was one of the first constructed wetland industrial waste water treatment facilities in Asia. It has served as a model for multiple other similar projects since its design and implementation in 2006. Testing performed by the government and AECOM several years after the project was built proved that performance levels of the NTS were even higher than predicted by the design team and universities. The site has helped to establish in Asian cultures that natural processes can be just as effective, if not more, in water cleansing as man-made ones are.

**Limitations:** In China and other nations where land is scarce an NTS may not always be applicable. Because so much land is needed to build the large areas of constructed wetland (for water cleansing), areas where large tracts of land are not available may not be suitable for this type of development.

**General Lessons:** The use of constructed wetlands to treat municipal and industrial waste streams is gaining in popularity. It has proven to be an effective alternative to traditional man-made water cleansing solutions. It is often less expensive and has a lower environmental impact than that of traditional choices. Constructed wetland parks not only cleanse wastewater but also provide many opportunities for learning, recreation, and wildlife habitat. Because of this, it is proposed that industrial wastewater on the GTP design site is to be cleansed in a constructed wetland such as the SCIP NTS. This not only fits in with the character of the site but also within the tenets of C2C design.
Summary

The case studies presented above play an important role in the overall design and character of the EIP site as well as in the designer's overall learning and comprehension process. Lessons learned from each individual case study were applied to the design site. Through case study research one can gather and synthesize information that leads to a more complete site that is integrated with the goals and concepts of the design that were set forth from the onset of the GTP. The lessons taken from the case studies will be discussed further in the design chapter (Chapter 7) regarding how they influenced the overall site design and cohesion.
Chapter 4: Study Area

Introduction

The site selection for this GTP stemmed from work that was done in the Plum Creek Agri-Urban studio that took place in the Fall semester of 2011. The project was brought to the studio by the Plum Creek Company as part of their Envision Alachua community outreach exploration. This program, ran by the Plum Creek Company, was intended to involve the community and its stakeholders in the exploratory stages of developing their property in east Alachua County. Our studio was charged with producing master plan concepts for the Plum Creek property known as the Windsor Tract. These master plans involved a community based on agri-urbanism. As part of the studio a site visit took place where the students had the opportunity explore the site first hand. Notes and photos were taken and questions were asked of the Plum Creek employees to gain a better understanding of their utilization of the land and silviculture practices. This GTP stems from the studio exploration and takes a look at what developing an eco-industrial park on the site would mean to the overall land planning of the development.

Context

The site consists of 17,000 acres of timber property located in east Alachua County Florida. Alachua County is found in north central Florida. The site is roughly 7 miles east of the city of Gainesville and proximal to the rural towns of Windsor, Melrose, and Hawthorne. Directly to the west of the property is Newnans
Lake which is one of the largest bodies of open water in Alachua County. Most surface water on the site works its way through wetlands and flows west towards Newnans Lake or flows south through Lochloosa Creek. The site is bounded on the other three sides by State Road 26 on the north, State Road 20 on the south, and US 301 on the east. A CSX railroad runs along US 301 on the east side of the property. Other than the timber lands, the site is covered by natural wetlands and has several creeks flowing through it. The site has the ability to function as a wildlife link, providing movement of wildlife between Payne’s Prairie Preserve and the Newnans Lake Conservation Area.

Figure 4-2: Site Context
Although site is located in a rural area Gainesville is only 7 miles away. Gainesville is the county seat of Alachua County and has over 125,000 residents. It is also the home of the University of Florida, which may provide for cooperation opportunities between the eco-industrial park and research entities. The university is looking to expand alternative energy and agricultural research which would lend itself to the proposed EIP development. Gainesville also has a regional airport which has the ability to provide convenient access to the EIP site from outside the community.

Figure 4-3: Water Shed Analysis (Source: 2011 Agri-Urban Studio)
Site Analysis

The site visit allowed for firsthand experience in understanding the scope and characteristic of the property. After the site visit was completed an in depth GIS analysis was undertaken. This analysis looked at several different scales. First, the county scale was looked at to understand how the site fit into the context of the county as a whole. Factors that were taken into consideration include proximity to infrastructure, population bodies, water bodies, parks, and energy sources.

Figure 4-4: Alachua County Resource Map, created in GIS
Once the site was understood from the county scale an analysis of the Plum Creek property was undertaken. The goal of this analysis was to identify the most appropriate location for the development of an eco-industrial park. Multiple factors were taken into consideration during the analysis to find the most suitable areas for development. First, upland (highest elevation) areas were identified as the most appropriate for eco-industrial development. Also, proximity to highways and rail networks was an important factor of locating the EIP development. Lastly, constraints to development were considered. These included wetlands and water bodies, the 100 year floodplain, and Florida managed lands. Through this GIS analysis the most suitable lands for EIP development were identified (see figure 4-6). Three areas, of at least 200 acres of contiguous land, were identified as suitable for development of an eco-industrial park. The entire built environment of the EIP falls within one of these identified lands. Most of the agricultural practices take place outside of the direct EIP site but occur on the Plum Creek property.

Figure 4-5: Plum Creek Property Exploration (Source: http://www.envisionalachua.com)
Figure 4-6: Site Analysis; Site Selection Map, created in GIS
EIP Site Selection: SWOT Analysis

A SWOT analysis was conducted for each of the three different sites to determine which one is best suited for the EIP. This type of analysis looks at the strengths, weaknesses, opportunities, and threats of each different potential EIP location. By taking an in-depth look at these four different categories insight to each location was gained. Variations were noted in the advantages and disadvantages of each site. Through performing the SWOT analysis the most advantageous EIP site selection became clear.

Site 1

Site 1 has a unique set of advantages and disadvantages that were discovered during the SWOT Analysis. This location was chosen as the EIP site by the Cyclos master planning team, described in Chapter 1. During previous work, it was chosen primarily because of its proximity to the proposed agri-urban development and its location along the CSX rail line. These advantages were also confirmed for this location through the SWOT analysis. Its location along the far eastern boundary of the site also keeps the industrial sites away from the proposed wildlife corridor. The main disadvantage to the site when compared to the other two is the elongated shape of the property. A more compact parcel of land is ideal for fostering exchanges between co-located industrial firms. The elongated parcel shape is dictated by the wetland directly to the west. It was decided that all wetlands on site would not be disturbed by any proposed development, therefore constricting the parcel shape. Figure 4-5 illustrates the SWOT analysis for Site 1.
Site 2

The second site that was considered for the location of the EIP is in the center of the Plum Creek property along County Road 1474. The largest advantages of this piece of land were that it would allow for a compact EIP development to foster exchanges, has a direct connection to Windsor and the proposed agri-urban development, and there is a low occurrence of wetlands on site to design around. The largest hindrance to development is its proximity to the proposed wildlife corridor which would run along the western edge of the parcel. The affect that the industrial sites could have on wildlife movement along this corridor would have to be mitigated through design measures such as forested buffers and possibly sound barriers. Figure 4-6 illustrates the SWOT analysis for Site 2.
The last site that was analyzed is located near the town of Hawthorne, but not directly connected to the largest swath of Plum Creek lands. It functions as an outparcel to the main timber producing lands owned by Plum Creek. This location away from the rest of the timber properties also provides for a unique set of advantages and disadvantages as well. The site is also compact like Site 2; however it is more broken up by wetlands on the property than the other two sites being considered. Its proximity to Hawthorne can be seen as an advantage and disadvantage. It is close to a population base that could provide employees to the EIP, but the development may meet objections from locals who do not want to see this type of growth in their town. Like Site 1 it is located along US301 and the CSX rail line, but would not have a
relevant connection to the proposed agri-urban development. Figure 4-7 illustrates the SWOT analysis for Site 3.

**SWOT ANALYSIS: SITE 3**

**INTERNAL**

**STRENGTHS**
1. Upland Site
2. Access road already in place
3. Large swath of wetlands for compact development

**OPPORTUNITIES**
1. Proximity to town of Hawthorne
2. Along State Road 20, Up 301, and CSV Rail line
3. Proximity to other industrial land uses
4. Direct road access to Gainesville

**EXTERNAL**

**HELFUL**

**WEAKNESSES**
1. Abundance of wetlands and large amount of site falls into 102 year flood zone
2. Noise and small pollution to Hawthorne
3. Loss of farmland producing lands
4. Distance to Agri-Urban development and agricultural lands

**HARMFUL**

**THREATS**
1. Wetlands on site, extra measures to mitigate water pollution from runoff and industries will need to be made
2. Development objections from Hawthorne

Figure 4-9: SWOT Analysis: Site 3

**Functional Diagrams**

After the SWOT analysis, functional diagrams for each site were produced by printing out a base map that identified each site’s boundaries and the wetlands on the site. Bubbles representing approximate acreage for each of the proposed industries (discussed in the following chapter) were used as templates and spatially arranged within each site as a way to explore functional relationships and understand ways that each site could be organized. The average acreage for each industry was based on examples of similar industrial sites. How each of the industries relates to one another was also considered in the placement of...
each bubble in this exercise. As the bubbles were placed on each site it became evident which site was the most beneficial for developing an EIP.

![Figure 4-10: Alternative Functional Diagrams](image)

**Summary**

Analysis of wetlands, topography, 100 year flood plains, and infrastructure was performed for each site and it was determined that the best site for the design of the EIP was Site 2. Site specific design was able to begin with the final selection of the site for the EIP determined. The next step in the design process was to solidify what type of industries will occur in the eco-industrial park based on the selected site and its surrounding lands. This step is discussed in the following chapter.

The GIS site analysis, SWOT analysis, and functional diagrams lead to the identification of the most suitable site on the Plum Creek property for eco-industrial park development. It was within the boundaries of Site 2 that the EIP master plan was designed. In order to design a holistic master plan for the eco-industrial park the GIS, SWOT analysis, and functional diagrams were paramount in the decision making process.
The overall site analysis along with the industrial resource flow matrices, discussed later in Chapter 7, were the two biggest factors in siting the industries in the final EIP master plan.
Chapter 5: Industrial and Agricultural Members

Introduction

The selection of interrelated industrial and agricultural uses is paramount to the success of an eco-industrial park. It is through this examination of uses that the site's symbiosis begins to take shape. This step in the design process was critical for maximum integration between all site facilities. This GTP takes a close look at all of the possible industrial and agricultural activities that could take place on the site and then evaluates the relationship flows of inputs and outputs to determine the best industrial and agricultural mix for the site. Important questions that were evaluated are:

- What are the potential synergies on this site?
- How can renewable energy benefit the EIP members?
- How do these relationships influence the overall site landscape?

For this GTP all activities on the site fall into the following categories: Energy Providers, Treatment and Recovery, Primary Processor of Inputs, Secondary Processor of Inputs, and Agricultural Activities. After discussing the proposed site EIP categories, their symbiotic relationships and flows will be further examined and mapped.
Energy Providers

As discussed in Chapter 2 it is important that an EIP have an industry that will serve to anchor the development. It is through this anchor that the rest of the development can take shape and the exchange web can begin to grow. For this site, it is proposed that the anchor tenant be an energy provider. This is important because it is an anchor that can provide low-cost energy and steam to many members of the EIP, thus providing the first of many incentives for companies choosing to locate within the EIP.

Because this EIP development is based on the principles and tenets of C2C design it was important to select an energy provider that fell within these guidelines. The tenet of “use current solar income” was followed while selecting the energy provider. After the site analysis revealed that solar and wind may not be the most efficient types of renewable energy for the selected site it was determined that the main energy provider should be a Biomass Energy Facility with several other offshoot bio-fuel energy providers. This choice will lead to research opportunities and integration with programs at the University of Florida as well.

Biomass

Biomass energy is energy created from plant material and animal/human wastes. It is the oldest form of renewable energy; in use since our ancestors first learned how to create fire. If we are to transition to a future of clean energy, biomass should play a critical role as a renewable resource. As indicated earlier, biomass is renewable because it is an energy source that comes from the sun and can regenerate in a relatively short period of time. Through the process of photosynthesis the sun’s energy is captured in plants by converting carbon dioxide and water into a
complex compound. Captured energy is released when organic material is burned and turned back into carbon dioxide and water. It is through the process of burning the organic material that biomass energy can be harnessed by humans for storage and use. Biomass is burned in a gasifier which in turn creates biogas. The biogas is then used as the energy source to heat water in a boiler that creates steam. This steam is then used to turn turbines that generate electricity. (see Figure 5-1)

Beneficial types of biomass for energy use include energy crops such as switch grass, food crop residues such as wheat straw and corn stalks, sustainably harvested wood and forest residues, and clean municipal and industrial wastes (Union of Concerned Scientists 2010). By using wood and forest residue as a major input the biomass facility would take advantage of the pine that is currently being grown on site while maintaining the biological integrity.
The first commercial biomass plant went into operation in the US in 1998 at the McNeil Power Station in Burlington, Vermont. This station is capable of generating over 50 MW of power from local wood waste products. That is enough power to provide electricity for around 50,000 households on a yearly basis (Rutgers University 2001). Because of the site’s current use as a timber practices it is proposed that a facility such as the McNeil Power Station be the anchor tenant of the EIP site. By producing energy derived from the sun a biomass energy facility is in line with the C2C design concept as well as works with the other agricultural aspects of the site.

Biofuels

Other offshoots to a biomass energy facility are important to the industrial ecosystem of the site while providing more opportunities for research as well. These other suggested offshoots are all related to biofuel production and use similar natural and agricultural inputs as a biomass energy facility. Another form of biogas can be produced on site in an anaerobic digester. An anaerobic digester uses micro-organisms to break down biomass, usually sewage and animal manure as well as dead plant and animal material, to produce methane gas. The methane gas is captured and then used as a power source, such as replacing traditional petroleum based fuels in vehicles with bio-methane. Along with the proposed anaerobic digester an ethanol and biodiesel production facility is also suggested for the site. Ethanol is alcohol made through the fermentation process of carbohydrates commonly found in crops such as corn and sugar cane. It increases octane levels while also promoting more complete fuel burning that reduces harmful tailpipe emissions.
such as carbon monoxide and hydrocarbons. Recently ethanol has also been produced from cellulosic biomass. This is derived from non-food sources like trees and grasses which lend itself to the site as well. Biodiesel, on the other hand, is a renewable fuel for diesel engines derived from natural oils like soybean, canola, and sunflower oils (McIntire 2006).

Summary
In summary, the anchor tenant for this site is to be a biomass energy facility. The biomass facility was chosen as the anchor tenant because of the current land uses of the site and the need to generate power on a large scale to power the EIP and agri-urban development. This facility will have the capacity to provide inexpensive renewable energy to all of the co-located EIP industries as well as the surrounding community. Adjoining facilities producing biofuels are also suggested as secondary energy producers on the site. These include an anaerobic digester and an ethanol and biodiesel production facility. As learned from the Catawba County Eco-Complex case study, these facilities will have the ability to produce enough biofuels to power not only the vehicles on the site, but also possibly county and university vehicles with inexpensive resource efficient fuels. With the implementation of these three facilities it will provide ample energy sources and research opportunities within the EIP, also witnessed in the Catawba County Eco-Complex. The Eco-Complex promotes on-site energy research with over 6 universities. Relationships such as these should also be fostered on the Plum Creek site.
Treatment and Recovery

The following category deals with treatment and recovery of water and other resources on the site. Because the objective called for all resources on the site need to be returned into the biological or technical metabolisms to function as a C2C development, infrastructure to assist in this process was critical to develop. Waste water management is the largest issue in this category. The management of waste water includes both sewage effluent and storm water runoff from the built environment. A resource recovery facility is also proposed as the main vehicle to return the technical resources back into the metabolism. And lastly a composting and fertilizer component is suggested for the design site. Through the composting process biological materials can be reintroduced into the metabolism as soil amendments and fertilizers.

Waste Water Treatment

Waste water treatment is the next most important design issue. How the water is treated on this site is vital to the success of the EIP. Because the goal of this site is net-zero waste, figuring out the best practices for water usage and cleansing needs to be implemented in the design from the onset. Water cleansing is a two pronged issue; both sewage water and storm water need to be considered in the design. However, the approach to cleansing each type is very different. The following section will discuss how this design will be handling each type of water cleansing issue. Along with the cleansing of sewage and storm water, water cascading will take place on site. This is where gray water from one industry can be used in another industry before needing to be cleansed, saving on the overall number of gallons of water used.
from the potable water supply. This will be discussed more in depth while explaining the water resource flows later in Chapter 6.

**Sewage Water**

The model used for the sewage treatment in this EIP is based on work that I did in the Fall 2011 Plum Creek Studio. A 100 acre constructed wetland water treatment facility was designed to naturally treat all of the sewage effluent on the site. Not only is the constructed wetland intended to clean the water of the proposed eco-industrial park and surrounding community, but also serve the community as a center for learning and wildlife watching. The constructed wetland water treatment facility will be discussed in greater detail in Chapter 7, the design chapter.

**Storm Water**

The second water issue that needs to be addressed on the design site is how to deal with storm water. Because there are so many impervious surfaces in a traditional industrial park, the way that storm water is dealt with is that water is drained into sewage pipes, ditches, and canals to move the water away from the site as quickly as possible. This traditional school of design and engineering not only has ramifications regarding pollution, but also is often the more expensive method. Because the pollutants picked up by fast moving storm water do not have the opportunity to settle out it is most often carried directly into the surface and ground water systems; flowing straight into wetlands, rivers, and lakes. This leads to a myriad of ecological problems including algal blooms, altered pH levels, loss of wildlife habitat, and high levels of toxins in our water supply. It is also very taxing on water treatment facilities to deal with sewage effluent as well as storm water.
Regarding the cost; because the traditional industrial park usually uses more built structure for the purpose of water conveyance this adds to the cost of infrastructure. Traditional infrastructure is one of the most costly aspects of a development. In most instances it is less expensive to deal with the storm water in a more natural way, known as Low Impact Development (or LID). LID is a type of storm water management that aims to repair hydrological and ecological function in developed watersheds. It mimics natural hydrologic processes by making green space function to control storm water at its source. These functional vegetated areas create a designed system that incorporates natural processes to manage and cleanse the storm water before being returned to the water cycle (Sarte 2010).

This cost savings was proven by the use of LID practices during the redesign of the Ford River Rouge Auto plant in Detroit Michigan by William McDonnough. Because of new regulations from the Clean Water Act the plant, addressing the issue the traditional way, would have had to invest in new concrete pipes and a water treatment plant to cleanse the storm water from their factory site. This was estimated at a cost of $48 million. Instead, William McDonnough designed a factory that treated the water using natural systems and saved Ford as much as $35 million in infrastructure costs (McDonough & Braungart 2002).

Figure 5-4: LID Bioswale use in Parking Lot (Source: http://www.water-research.net)
The Ford River Rouge plant can be used as a model for bridging the built environment of the site with LID storm water management. If the buildings in the eco-industrial park are designed in the same fashion as the Ford plant it will cleanse the water and save real dollars. The new Ford plant removed impervious surfaces by fashioning it with a green roof capable of holding 2 inches of rainwater and porous parking lots that can absorb and store water as well. The storm water then seeps into a constructed marsh where it is cleansed by plants and other biota. From the marsh the water works its way down to the Detroit River through swales planted with native plants that continue to polish the storm water until it is fully clean. This process slows the water by 3 days allowing it to reenter the water cycle cleansed. As discussed above, this was around $35 million cheaper than the traditional way (McDonough & Braungart 2002). If water on the eco-industrial park site is cleansed in this fashion it will be better
for the environment, save money, and follow the goal of creating a true C2C eco-industrial development.

**Resource Recovery Facility**

In C2C design, products are manufactured in a way in which they can be disassembled and put back into the technical and biological metabolism. The resource recovery center is the vehicle to how the technical and biological pieces are gathered and reintroduced into the metabolism. An example of this would be a C2C designed chair being returned to the resource recovery center when the customer is done using it. The center would then disassemble the chair into its technical and biological parts. The technical pieces, mostly metal parts, would then be sent back to the furniture manufacturing company to be reused in the design of a new product. Thus the technical piece’s value is never diminished and can cycle in this system perpetually (McDonough & Braungart 2002). The resource recovery center can then send the biological material, such as the fabric upholstery of the chair, to be composted for use in the agricultural sector as a soil additive or it can be used as an input in the earlier discussed biomass energy facility. Used oils from local restaurants and industries can also be collected at this center for re-use in biofuel production.

**Composting and Fertilizer Facility**

A composting and fertilizer facility can have direct relationships with both the water treatment and resource recovery components. Byproducts from these two facilities will be the inputs to make the compost and fertilizers used on this site. Solids taken out of sludge during the waste water treatment process can be used to make fertilizers and biological materials left over from industrial production on the site will be compostable due to the C2C design.
mandate. These will then in turn be put back into the biological metabolism through application on the agricultural fields that supplement the input demand for industries on site. This step in the IE process is a large contributor to keeping the circular economy in motion; otherwise soils may become depleted over time.

EIP Industries: Primary and Secondary Processors of Inputs

A vast number of industrial uses were researched to compile a list of potential candidates for the EIP site. The industries had to meet three different criteria to become a candidate for membership in the EIP. First, because this site has the objective of producing only cradle to cradle certified products to attain the goal of a net-zero waste EIP, the selected industries must manufacture products that fall within the definition of C2C design and certification. This would be a product that at the end of its life cycle can either be returned to the biological or technical metabolism, as explained in earlier chapters. These types of industries were identified by researching what different C2C certified products are already on the market and selecting from these established manufacturers. Second, each selected industry that manufactures C2C products must also have the potential for finished product and byproduct exchanges with other co-located industries. Lastly, the industries must be able to take advantage of local agricultural uses by using those resources as their primary inputs or the resource ‘waste’ residues as secondary inputs. This begins to shape the web of industrial ecology on the site. The industrial uses and agricultural uses were researched in conjunction with one another to identify which ones work best with
each other and the site in general. The C2C tenets of waste equals food and celebrate diversity were the drivers behind the industrial and agricultural selection process.

**Primary Processors**

For the purpose of this GTP a primary processor of inputs refers to an industrial entity that takes raw natural resources and turns them into a finished product. The finished product or byproducts produced from a primary processor of inputs can then be the input to a secondary processor later somewhere along the industrial ecology web. Through research of plausible industries that fit with potential and actual local agricultural practices it was determined that the best Primary Processor industries for this particular site are a wood products manufacturer, packaging, bio-plastics, textiles, and food production. Each of these industries uses raw resources from the land to manufacture their finished products. This does not mean, however, that they are unable to use recycled materials in any of their production. In fact at times they do, but their main inputs are not generally recycled materials. The exchange flows between entities will be explained in further detail in later sections.

**Wood Products Manufacturer**

The wood products manufacturer is proposed as a member of the EIP due to the current primary land use on the site being forestry. All 17,000 acres of the Plum Creek property are in forestry and the state of Florida has over 15.6 million acres of timberland in total (Florida Forestry Association n.d.). Because of this, the mill would be in an optimal location to take advantage of its proximity to the input of raw timber. This closeness also works to keep the
carbon footprint of the EIP site low because the resources do not travel far to reach their destination. Due to population growth, demand for industrial timber is expected to double by the year 2020 (Abuyuan et al. 1999). Because of increased demand by ecologically minded firms, opportunities for certified sustainably harvested wood exist on this site and fit within the stated goals of the EIP. It is recommended that the wood products manufacturer develop a diversified manufacturing base to take advantage of the demand for sustainably sourced products and the relationships between other members of the EIP. There are by-product exchange opportunities between the wood products manufacturer and other proposed EIP members including the paper mill and the biomass energy facility which will be discussed later in the chapter.

**Packaging**

Packaging makes up over 50 percent of the volume in the municipal solid waste stream (McDonough & Braungart 2002). There is opportunity for a firm that creates alternative packaging products to take advantage of relationships with other sustainably minded firms co-located in the EIP. These other companies will be looking for ways to cut down on waste and a packaging firm has the ability to help them meet their goals. One example of an alternative to traditional packaging is cellulose based packaging. This product is made from plant crops that are biodegradable. Agricultural inputs are used in the manufacture of these ‘bio-containers’. Sugar cane fibers are a prime example of an input that will be grown on site and used to make this type of packaging. The sugar cane scraps left over after the manufacturing process can be sent to the biomass facility for use in electricity generation, serving a dual purpose to the EIP. After

![Figure 5-7: Assortment of Biodegradable Packaging](http://begreenpackaging.wordpress.com)
use, this type of packaging can be returned directly to the biological metabolism. Used containers can be returned to the Resource Recovery Facility where they can then be sent to composting for use in the agricultural fields. This follows the site goal of creating no waste. The use of this type of eco-packaging will assist in facilitating a sustainable image of the companies and their products that have located within the EIP as well.

**Bio-Plastics**

A bio-plastics firm is also proposed to complement the other EIP members. Bio-plastics are organic based plastics derived from biomass and are therefore biodegradable (Cereplast n.d). This type of firm specializes in producing bio-plastic resin. The resin is then in turn sold to other industries that use it to manufacture plastic molded products. Bio-plastic firms lend themselves to exchanges with firms that manufacture auto parts, among others. An example of this type of exchange is the Ford Motor Company purchasing bio-plastic resin to create plastic dash boards installed in their Ford Fiesta model that are biodegradable after use (Impact Lab 2011). This type of exchange works to further enrich the industrial ecology web.

**Textiles**

Textile companies are also capable of producing products that after use can be fully reintroduced into the biological metabolism. In the early 1990’s the originators of cradle to cradle design, William McDonough and Michael Braungart, were asked to create a compostable upholstery fabric. The fabric they produced was a combination of plant and animal fibers: wool and ramie. The fabric trimmings left over from the production process were able to be
used as mulch in local gardens, returning the product to nature (McDonough & Braungart 2002). A company producing textiles such as these is proposed as a member of the EIP as it has the opportunity for multiple exchanges with other firms in the EIP and the surrounding environment through the composting center.

**Food Processor**

Because of the agricultural practices taking place on and around the Plum Creek property a food production facility is also proposed as the final primary processor. Plant and animal products can be processed and packaged at this facility before being sent to market. This creates the opportunity for by-product exchanges among other EIP members, the agricultural sector, and a direct relationship with the packaging firm. A close relationship between the food processor and the farmers would be mutually beneficial; with the farmers providing locally grown inputs and the food processor providing livestock feeds made from the by-products of the production process.

**Secondary Processors**

Secondary processors of inputs are industries that use primary processor’s outputs and by-products to produce finished goods. These exchanges can either be completed through direct exchange with co-located firms or through obtaining inputs from the resource recovery center. Therefore, to complete the circular economy of the EIP a resource recovery facility is needed. After looking into the proposed primary processors and the potential agricultural uses, complimentary secondary processors were chosen for the site. The secondary processor industries

![Figure 5-9: Food Processing Facility](http://foodmatters.tv)
recommended for the site include carpet and wood flooring, paper mill, furniture, auto part manufacture and other specialty cottage industries.

Flooring
A flooring company specializing in carpet made of plant and animal based fibers as well as flooring produced from sustainable woods is proposed as a secondary processor on the EIP site. By producing natural carpeting and flooring the firm positions itself to have many exchange flows between other firms located in the EIP. It will also have a direct relationship with the resource recovery center because once the flooring is used by the consumer it can be returned to the resource recovery center to be broken down and then returned to the flooring company for reuse in production. This allows the product to continue to cycle in the technical metabolism without its overall quality being reduced over time.

Paper Mill
The proposed paper mill is a direct response to the earlier discussed timber use on and around the Plum Creek property. It is also strategically in conjunction with a planned primary processor; the wood products manufacturer. A paper mill is able to take manufacturer. Wood scraps and sawdust from the wood products manufacturer can be used as the inputs for the pulping process of paper production. Recycled material from the resource recovery park can also be introduced into the paper production process as an alternative feedstock. Plant fibers that are proposed to be grown on the site, such as kenaff, will also be used as inputs for pulping as well. Kenaff has been widely researched as an industrial paper fiber because of its qualities as a renewable
resource. The other advantage kenaf has as a paper fiber is that it has lower lignin content than traditional tree fibers. This means the paper would require very few chemicals for bleaching because kenaf is naturally whiter (Abuyuan et al. 1999). The growing of kenaf on the Plum Creek property will be discussed in more depth in the section regarding planned agriculture on the site.

**Furniture**

Furniture designed and built with sustainability in mind is a growing industry in the United States. As consumers become more sustainably minded, the demand for these types of products continues to rise. According to the article “Consumers want green furniture options” by Kathleen McLaughlin (2008) a study showed that although 46% of consumers were interested in green furniture options, only 4% purchased green furnishings. This was attributed to there being a low number of options even though customers were willing to pay 10% more for green products. This provides evidence of a difference between the supply and demand for green furniture options and therefore provides opportunity for an EIP member producing such products. Furniture is being designed in a way that all of the parts can be returned to the technical and biological metabolism after use. It is important that the market fill the demand for such products by continuing to manufacture products that engender these ideals. Because of this, a green furniture company is proposed for the site. The planned firm has the opportunity for many exchanges with other EIP firms; including the wood products manufacturer, the textile firm, and the resource recovery center among others. The resource recovery center will also play an important role in relation to the furniture firm because used furniture that is returned there is broken down and returned to the furniture company for reuse.

Figure 5-11: Skylight, Herman Miller Greenhouse Furniture Factory
(Source: http://www.mcdonoughpartners.com)
There is also opportunity for the furniture company to take advantage of the agricultural inputs being grown on site as well.

**Auto Parts**
As the cost of petroleum continues to rise, alternative materials are continually being explored. This is evidenced in the car part manufacturing industry. Currently, as much as 10 percent of car parts that are typically made from petroleum plastics can now be made from soy-based polyurethane foams or bio-plastics. Car seats made from the soy-based foam take considerably less energy to produce than traditional seats. Also, while the soy is growing it can take in CO2 that helps to shrink the site’s carbon footprint. Scientists at Ford are also experimenting by mixing mushroom roots together with other plant matter, like wheat straw, and putting the mixture into car part shaped molds. These parts will be 100% biodegradable when introduced into production vehicles. These mushroom parts have the potential to change how car parts are manufactured as we know it (Impact Lab 2011). This is why a car part manufacturing firm is suggested for the site as well. It fits within the goals and ideals of the EIP development while enriching the web of industrial ecology as well.

**Cottage Industries**
Other small cottage industries that can take advantage of by-product exchanges are also promoted for this site. These types of industries come from a broad range of backgrounds, but produce small-scale natural and sustainable products sourcing their inputs from the site. Businesses that have the potential to be included in this type of EIP are personal hygiene, cleaning supplies, candle makers, and other green industries to name a few. Space for these types of companies will be provided for in a business
incubator where the business can grow and eventually move into larger permanent facilities in the EIP. A business incubator can provide these businesses with access to financing, marketing, other business services, and collaboration among businesses within the incubator and EIP, and access to emerging technical opportunities (Abuyuan et al. 1999).

Agricultural Activities

Agricultural activities play a major role in the EIP’s industrial ecology. Without agriculture or working landscapes fulfilling the resource needs of the energy providers and primary producers on the site the industrial ecology web would not be able to sustain itself. By producing the resources needed by industry on the site it allows for the completion of a true functioning circular economy where biological and technical resources are returned to metabolisms based on the tenets of C2C design. The types of agriculture that are proposed for this site were selected in conjunction with the development of which industries were to be located on the site. A holistic approach was used to find industries and agriculture that could work with one another and the land of the selected site. Therefore only agriculture that can be grown successfully on site and can be used by the co-located EIP industries was selected. When research of potential agriculture was initiated it was assumed that the agricultural types would fall into three different categories; energy, food, and industrial. As the web of industrial ecology began to grow the categories began to blur with multiple crops being used in all 3 different categories. Although this blurring was found, for the purpose of this GTP the
crops will be broken down into the three aforementioned categories.

**Energy**

Energy crops grown on site are not only important as sources of energy production but also for providing research opportunities. The crops that fall into the energy category and that can be successfully grown on this site are canola, soybeans, sunflowers, algae, corn, and sugar cane. These crops will be the inputs for the ethanol and biodiesel facility. Corn and sugar cane can be used through the fermentation process in ethanol production and the oil extracted from canola, soybeans, sunflowers, and algae can be used in biodiesel production. The by-products from this type of biofuel production can then be used by other co-located industries, the anaerobic digester, or the biomass energy facility. Research, in conjunction with universities, can be done at the site on these energy crops to identify which variety produce the best biofuels, crop yields in the north Florida climate, sequester the most carbon, and emissions testing.

**Food**

Types of agriculture that have a direct relationship to the food industry are also suggested for this site. These varieties of agriculture include fish farming (aquaculture), the raising of livestock and poultry, and wheat production. They were not only selected for their relationship solely to the food industry but also because of the other resulting by-product exchanges that will enhance the web of industrial ecology on the site. By-products that come from the production of these types of agriculture can be used in the energy and industrial sectors.
Industrial
The last category of agriculture is related to the industrial sector of the EIP. These crops are direct inputs into co-located industries on the site. They first enter into the industrial sector through a primary producer and the by-products can then either go to a secondary producer or the energy sector. The suggested industrial crops are timber (which is currently grown on the design property), ramie, kenaf, bamboo, and bulrush. Each one of these crops can be used in an industry that is found in the EIP. This further serves to foster exchanges between the co-located firms.

Summary
As evidenced above it is paramount to the success of the development to get the correct mix of co-located industries and agricultural activities involved in order to begin the web of exchanges between entities. If it is possible to plan and recruit certain industries from the onset of a project, that work with the surrounding lands, the EIP will have a higher success rate. This was explained by Barry Edwards, director of the Catawba County Eco-Complex, during the interview conducted with him regarding the Eco-Complex case study. Although one of the difficulties of executing a development such as this is recruiting firms, if certain firms are targeted from the onset of the design process they often are more willing to engage in this type of development.

After the industrial and agricultural mix of the site is decided it is important to look at the resource flows. This will allow for the most efficient site design to accommodate for resource movement in the development. Chapter 6 discussed the types resource flows
and exchanges that can take place in the proposed EIP development.
Chapter 6: Mapping Resource Flows

Flows Through Co-located EIP Members

A characteristic that differentiates industrial ecology from other environmental management systems is the focus on mapping resource flows through industry, agriculture, and the environment. Materials-flow accounting (MFA) can be used to quantify all resource flows in and out of a system. This is done by setting a system boundary and tracking specific resources as they flow through the industrial ecology system. In the case of this GTP the boundary is the eco-industrial park location. By tracking the resources at each step in the EIP exchange process, quantification of resource use and by-product exchanges can be completed. There are multiple advantages to materials-flow accounting. The balance between inputs and outputs can be examined through MFA. This can serve as an overall indicator of and industry’s sustainability. Tracking of resource flows can also serve to identify hidden flows or leaks in a system and help to identify new resources and by-products that are being left unutilized. MFA is a helpful technique in visualizing symbiosis of industries on the site. By mapping materials flows it provides opportunity to identify additional symbiotic exchanges. The following section does not attempt to provide detailed, quantitative analysis of resource flows; it is intended to identify and map the resource flows on the site in a legible method which the reader can understand (Abuyuan et al. 1999).
The first step in the process of flows mapping was to produce the list of the industries and agricultural activities that were proposed for the site. This was done by creating a spreadsheet that broke down all 17 industrial and 15 agricultural activities that will take place on the site. Then a simple comparison analysis was done to identify industries and agricultural activities that have the potential for exchange based relationships. The same was done by listing industries on both axes to identify relationships that could take place between the co-located industries.

### Potential Industry and Agriculture Exchange Analysis

<table>
<thead>
<tr>
<th>Industries</th>
<th>Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Energy Facility</td>
<td>x x x x x x x x x x x</td>
</tr>
<tr>
<td>Anaerobic Digester-Biogas</td>
<td>x x x x x</td>
</tr>
<tr>
<td>Biofuel Facility</td>
<td>x x x x x</td>
</tr>
<tr>
<td>Water Treatment</td>
<td>x x x x</td>
</tr>
<tr>
<td>Composting and Fertilizer</td>
<td>x x x x x x x x x</td>
</tr>
<tr>
<td>Resource Recovery</td>
<td>x x x x</td>
</tr>
<tr>
<td>Wood Products</td>
<td>x x x x</td>
</tr>
<tr>
<td>Packaging</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Bio-plastics</td>
<td>x x x x x</td>
</tr>
<tr>
<td>Textile</td>
<td>x x x x x</td>
</tr>
<tr>
<td>Food Production</td>
<td>x x x x x x x x x x x x</td>
</tr>
<tr>
<td>Carpet/Flooring</td>
<td>x x x x</td>
</tr>
<tr>
<td>Paper Mill</td>
<td>x x x x x</td>
</tr>
<tr>
<td>Furniture</td>
<td>x x</td>
</tr>
<tr>
<td>Auto-parts Manufacturing</td>
<td>x x x x x x x x</td>
</tr>
<tr>
<td>Cottage Industries</td>
<td>x x x x</td>
</tr>
<tr>
<td>Livestock Feeds</td>
<td>x x x x x x</td>
</tr>
</tbody>
</table>

Figure 6-1: Table showing potential for industrial and agricultural exchanges
Resource flows fall into 3 different categories of flows. The categories are energy, water, and biomass flows. Energy flows consist of electricity, biofuels, and steam. Water flows generally cycle through the system as treated potable water, gray water (water used by industry), and treatment water (water that has gone through the cycle and needs to be cleansed). Biomass flows largely enter the system as raw materials. This can either be in the form of agricultural products or as commodities such as metals. As the materials cycle through the site, at each step, they are broken down into by-products that can then be used by other co-located members. The next step in the flow mapping process was to identify potential exchanges between co-located industries.
and agricultural activities and how they fall into each of the three flow categories.

**Energy Flows**

As explained above energy flows on this site consist of electricity, biofuels, and steam. Each one of the industries was examined to see which type of energy flows could take place amongst one another. After identifying the type of energy needs of each individual industry they were categorized to determine how energy could cascade through the EIP to use it most efficiently.

Creating electricity on site to provide inexpensive green energy for all EIP members is a stated goal of this GTP. This is implemented through the biomass energy facility serving as the anchor industry to the EIP site. Electricity produced in large quantities at the biomass facility will be utilized by every co-located member. This begins the flow of energy on site, not only with the creation of electricity, but also of steam that will be captured and used by the other EIP members in a cascading and circulating fashion.

Industries were categorized by their consumption of steam to produce finished goods and what they use the steam for in production. These two things have a direct relationship with one another as some industrial processes are more steam intensive than others. The primary users of steam energy on site are the paper mill, food producer, and packaging. These industries receive their steam directly from the biomass facility where it is produced in the largest abundance. After use it is cascaded down to other industries that use less quantities of steam.

Steam energy used by the paper mill is to be reused in the industrial energy sector. Because biofuels (bio-diesel and ethanol)
and the anaerobic digester use steam in a similar fashion it makes sense that it is cycled from the same source. Steam is sent to biofuels producers from the paper mill. After use, that steam can be sent to the anaerobic digester which in turn can be cycled back to the biomass facility completing the cycle of use and reuse. Also, within the energy sector other forms of energy are produced for use on the site. Methane gas produced by the anaerobic digester can be sent to the biomass facility for use in electricity generation when biomass is not in abundance. This will allow the biomass facility to run at full capacity even during times of the year when there is less biomass being produced. Fuel produced by the ethanol, bio-diesel, and anaerobic digester will also be used for vehicle consumption on site. This serves to keep the site energy self-sufficient.

Food production is also a primary user of steam directly from the biomass facility. It can be cycled down for use by textiles and carpeting/flooring industries because they both consume less steam energy than what is used in food production. Steam in food production is mostly used in the cooking and cleaning processes. The textile and carpeting/flooring industries mostly use the steam in the dying process. Because of this they were linked together for using steam energy from the same source.

Packaging is also a major user of steam energy from the biomass facility. In the packaging industry steam can be used in the molding and sterilization process. Because of this, it can be cascaded down and used by bio-plastics and auto-parts manufacturing. In bio-plastics production the steam is used in sterilization and in auto-parts it is used in small amounts in the finishing process. The bio-plastics industry is also a large producer of steam and therefore a good resource for the wood
products and furniture industries. The wood related industries use steam in the wood bending process among other things. After use by these industries it can be cycled back to the biomass facility to begin the cycle over again. Figure 6-3 depicts the energy flows within the EIP development.

Figure 6-3: EIP Energy Flows Map
Energy Flows Listed

Biomass

Sends: Electricity to all members of EIP. Steam is sent to Food Production, Paper Mill, and Packaging
Receives: Steam and methane gas from Anaerobic Digester and steam from Textiles, Carpet/Flooring, Wood Products and Furniture

Food Production

Sends: Steam to Textiles and Carpet/Flooring
Receives: Steam from Biomass

Textiles

Sends: Steam to Biomass
Receives: Steam from Food Production

Carpet and Wood Flooring

Sends: Steam to Biomass
Receives: Steam from Food Production

Packaging

Sends: Steam to Bio-plastics and Auto Parts Manufacturer
Receives: Steam from Biomass

Bio-plastics

Sends: Steam to Wood Products and Furniture
Receives: Steam from Packaging

Auto-Parts Manufacturing

Sends: Steam to Biomass
Receives: Steam from Packaging

Wood Products

Sends: Steam to Biomass
Receives: Steam from Bio-plastics

Furniture

Sends: Steam to Biomass
Receives: Steam from Bio-plastics

Paper Mill

Sends: Steam to Biofuels
Receives: Steam from Biomass

Biofuels

Sends: Steam to Anaerobic Digester and fuel to vehicle consumption
Receives: Steam from Paper Mill

Anaerobic Digester

Sends: Steam and methane to Biomass and fuel to vehicle consumption
Receives: Steam from Biofuels
Water Flows

Water consumption and use on this site is an issue that needs to be dealt with in a very careful manner, particularly given the impact on the Florida aquifer. Keeping with the goal of a closed loop system, water will need to be cycled throughout the site, cleansed on site, and use kept to a minimum. Industrialization has brought on contamination of ground and surface waters as well as the substantial depletion of aquifers, leading to saltwater encroachment (Abuyuan et al. 1999). Because the Florida aquifer is such a fragile system, measures to design the EIP to reuse and recycle water supplies in a cascading fashion between co-located members became very important. To create a system in which water is cascaded the quality of the water needed by each cluster member was evaluated, as was the quality of the wastewater after use. As discussed above, the type of water will fall into three categories; potable water, gray water (water used by industry), and treatment water (water that has gone through the cycle and needs to be cleansed). Using this classification, opportunities for water reuse were identified and the water flows were able to be mapped. It is assumed that the EIP will need to draw some water from the aquifer; however this will be kept to a minimum through site design and water cascading.

In this scheme, only industries requiring cleansed potable water as input can draw from those supplies from the waste water treatment center. These include biofuel production, biomass, the paper mill, agriculture, resource recovery, furniture, textiles and food production. Water leaving biofuel processing facilities would contain nutrients and residual organic material from the fermentation process. This mixture makes an ideal input to the anaerobic digester, where it can be used to dilute solid biomass
and slurries to approximately 15-25% solid material before digestion. After the organic material has been digested and converted to biogas, the remaining liquids contain only high concentrations of inorganic nutrients. This liquid can be applied to agricultural fields as an organic fertilizer (Abuyuan et al. 1999).

Gray water left over from industrial processes can be reused in other industries that don’t need to draw from the potable supply. By reusing the water in this fashion it will lower overall consumption at the EIP site. Uses can include washing machinery, the cooling process, and flushing systems. The co-located members that can take advantage of this gray water are composting, anaerobic digester, carpet/flooring, packaging, bioplastics, auto-parts, wood products, and biomass. After the gray water is used and contaminates added to the supply it must be returned to the waste water treatment facility for cleansing before it can enter the EIP site water cycle once again. By cycling this water and treating it on-site it will reduce the need for groundwater extraction and the negative impacts on the aquifer.

Aquaculture also plays a role in the water treatment process. During the treatment process, water that has gone through the primary phase of treatment to remove solids is sent to the aquaculture facility. By the fish using nutrients contained in the water it assists in the cleansing process before the water is sent back to the treatment facility for secondary treatment in the algae lagoons. Figure 6-4 depicts the water flows within the EIP development.
Figure 6-4: EIP Water Flows Map

Water Flows Listed

Water Treatment Center

Receives- Water to be treated from Carpet/ Flooring, Packaging, Auto Parts Manufacturing, Resource Recovery, Wood Products, Textiles, Composting, and Agri-urban core


Biomass Energy Facility

Receives- Potable water from Water Treatment Center and gray water from Agricultural Lands

Sends- Gray water to Carpet/ flooring and Packaging
Anaerobic Digester
**Receives:** Gray water from Bio-diesel and Ethanol
**Sends:** Gray water to Composting and Agricultural Lands

Bio-diesel
**Receives:** Potable water from Water Treatment Center
**Sends:** Gray water to Anaerobic Digester

Ethanol
**Receives:** Potable water from Water Treatment Center
**Sends:** Gray water to Anaerobic Digester

Composting and Fertilizer
**Receives:** Gray water from Anaerobic Digester and Food and Animal Feed
**Sends:** Water to be treated to Water Treatment Center

Resource Recovery Center
**Receives:** Potable water from Water Treatment Center
**Sends:** Water to be treated to Water Treatment Center

Wood Products
**Receives:** Gray water from Furniture
**Sends:** Water to be treated to Water Treatment Center

Packaging
**Receives:** Gray water from Biomass
**Sends:** Water to be treated to Water Treatment Center

Bio-plastics
**Receives:** Gray water from Paper Mill
**Sends:** Gray water to Auto-Parts Manufacturing

Textiles
**Receives:** Potable water from Water Treatment Center
**Sends:** Water to be treated to Water Treatment Center

Food and Animal Feed
**Receives:** Potable water from Water Treatment Center
**Sends:** Gray water to Composting

Carpet and Wood Flooring
**Receives:** Gray water from Biomass
**Sends:** Water to be treated to Water Treatment Center

Paper Mill
**Receives:** Potable water from Water Treatment Center
**Sends:** Gray water to Bio-plastics

Furniture
**Receives:** Potable water from Water Treatment Center
**Sends:** Gray water to Wood Products
Organics and Biomass Flows

Because of the agricultural activities that take place on the site, organic materials will be in constant supply to be used as industrial inputs. Plants processed through industrial systems are reduced down into different components. Industries extract the components they want and are left with the others. These are known as by-products. It was stated earlier, that the by-product of one industry can be the input of another. It is through this by-product exchange that the site’s industrial ecology grows. These by-products can then be processed further to provide fuel energy, food for other animals, or a form of organic material that can easily be reapplied to and reabsorbed by the land. Another form of exchange that can happen on the site is that of finished product exchange; where the finished market product of one co-located industry may be an input of another industry. It is these types of organics and biomass flows that contribute to the overall health of the site IE.

Plant inputs and residues from harvesting and food processing can be processed by the anaerobic digester, ethanol producer, bio-diesel, packaging, bio-plastics, or composting facility. Human and animal residues will go to the anaerobic digester or to aquaculture. Trees harvested from the site will go to the wood products facility to be processed. About 50% will be extracted as
high value lumber and sold to the market, or used by the co-located furniture and wood flooring companies. The other 50% will be chips, scraps, and shavings which can go to the paper mill or the biomass energy facility. The herbaceous fiber crops of kenaf, ramie, sugar cane, and bamboo will be processed, and the extracted fiber will be made into paper, while the other woodier parts of the plants can be used by the biomass facility to create electricity (Abuyuan et al. 1999).

Biofuels produced by the energy sector can be used by farm and other EIP vehicles and any not used by the EIP and agricultural practices can be sold to market. Lignin from the ethanol producer can be processed into binders used in production of plywood and fiberboard, and furfural can be incorporated into resins, adhesives, and protective coatings for wood. Silage, from fermentation in the ethanol production process, can be incorporated into fish and animal feeds, or used in the anaerobic digester to produce methane. Biogas from the anaerobic digester can be used by the EIP vehicles as well or it can be used at the biomass facility to create electricity as well. Digestate, another product of anaerobic digestion, is a quality feedstock for composting. The nutrient-rich liquid fertilizer from the digestate can be applied directly to fields in lieu of non-organic fertilizers and the composted materials can be applied directly back to farm lands to increase productivity and close the nutrient loops (Abuyuan et al. 1999). The following is an extensive list that shows all of the organics, biomass, and finished product flows that will take place on the site by breaking out all of the inputs, outputs, and by-products. Figure 6-5 depicts the Organics and Biomass flows within the EIP development.
Organics and Biomass Exchanges

Biomass Energy Facility
- **Inputs**: Biomass Energy Facility receives agricultural scraps from all industrial production
- **Outputs**: Electricity is produced for entire EIP
- **Byproducts**: Boiler ash to go to composting facility for soil amendment

Anaerobic Digester
- **Inputs**: Animal wastes come from livestock and food production, human bio-solids come from waste water treatment plant
- **Outputs**: Biogas is produced from methane that can be used to power vehicles or can be used directly in gas turbines at the biomass facility to produce electricity
- **Byproducts**: Digestate left over from production can be used in soil amendment and fertilizers at the composting facility. Also it can be used by the packaging and bio-plastics firms as a filler for structure in plastics

Figure 6-5: EIP Organics and Biomass Web
**Bio-Diesel**
- **Inputs**: Agricultural inputs of algae, canola, soybeans, and sunflowers.
- **Outputs**: Bio-diesel used to power vehicles
- **By-products**: Seed meal can be used as livestock feed, biomass feedstock, or soil amendment at the composting facility

**Ethanol**
- **Inputs**: Agricultural inputs of sugar cane and corn stover
- **Outputs**: Ethanol used to power vehicles
- **By-products**: Lignin can go to wood products facility for use in making flexible wood, textiles as a dye, and auto-parts manufacturing for use in injection molding. Black syrup can be used in bio-plastics production. The silage and protein can go to animal and fish feeds and the anaerobic digester.

**Waste Water Treatment**
- **Inputs**: Takes in waste water from all EIP facilities to be cleansed
- **Outputs**: Cleansed water for industrial and agricultural use. Also algae, bulrush, sugar cane, and bamboo will all be used in the water cleansing process and can be used as inputs by co-located industries
- **By-products**: Bio-solids can be used in anaerobic digester and for use in fertilizers. Nutrients in the water can be used by fish farm. Polyhydroxyalkanoates can be used as input in bio-plastics production.

**Composting and Fertilizer**
- **Inputs**: Receives biodegradable and organic wastes from co-located industries, resource recovery center, waste water treatment, and agricultural lands
- **Outputs**: Compost, fertilizers, and soil amendments are produced for the surrounding agricultural lands
- **By-products**: Waste materials not used in composting process can be sent to biomass energy facility

**Resource Recovery Center**
- **Inputs**: Used and discarded biological and technical nutrients that need re-introduction into the cycle of industrial ecology
- **Outputs**: Recovered materials that can be used as inputs by co-located industries; including the bio-plastics, carpet and flooring, paper mill, furniture, auto-parts manufacturer, and composting facilities.
- **By-products**: Organic waste materials not used by co-located industries can be sent to biomass energy facility

**Wood Products**
- **Inputs**: Timber, bamboo, sugar cane, ramie, and kenaf are all agricultural inputs grown on site. Lignin form ethanol production is used to make some wood products more flexible
- **Outputs**: Finished wood products. These can include pieces for furniture production and board-feet used in wood flooring
- **By-products**: Saw dust and scraps can be used in paper mill and packaging. All other tree trimmings and scraps can be sent to biomass energy facility
Packaging

- **Inputs**: Agricultural inputs of bulrush, sugar cane, bamboo, wheat, and kenaf. Whey waste from cheese production at food processor can be used to make plastic membrane liners.
- **Outputs**: Biodegradable packaging that can be used by every co-located member to package their own finished goods
- **Byproducts**: Organic waste materials can be used in composting process or can be sent to biomass energy facility

Bio-plastics

- **Inputs**: Agricultural inputs of algae, kenaf, canola, corn, soybeans, and sunflower. Black syrup from ethanol production. Polyhydroxyalkanoates from the waste water treatment plant.
- **Outputs**: Biodegradable bio-plastic resin that can be used in injection molding.
- **Byproducts**: Seed meal and scraps can be used as livestock feed, biomass feedstock, or soil amendment at the composting facility

Textiles

- **Inputs**: Fibers are produced from bamboo, kenaf, ramie, wool and other animals raised on-site. Hides from the livestock can also be used to make leather in the textile factory. Dyes can be produced from algae grown at the waste water treatment center and from lignin leftover after the process of making ethanol
- **Outputs**: Textiles made with all natural fibers that can be returned to the biological metabolism after use. The furniture company would have a need for such textiles
- **Byproducts**: Biodegradable scraps can be sent to composting center or be used by biomass energy facility

Food Production

- **Inputs**: Agricultural inputs of algae, sugar cane, bamboo, wheat, canola, corn, soybeans, sunflower, livestock, and fish. Seed meal and silage can be used to make animal feeds at the food production facility
- **Outputs**: Finished food products to be sent to market
- **Byproducts**: Animal waste and food residues can be used in anaerobic digester. Food residues can also be used to produce animal feeds. Other organic biomass can go to biomass energy facility

Carpet and Wood Flooring

- **Inputs**: Fibers to make carpeting. These can be fibers made of kenaf, ramie, bamboo, or wool; or produced from bio-plastics. Wood flooring will be made with board-feet from the wood products facility. Also, recovered carpet and wood flooring can be repurposed from the resource recovery center
- **Outputs**: Finished carpeting and wood flooring products
- **Byproducts**: Biodegradable scraps can be sent to composting center or be used by biomass energy facility

Paper Mill

- **Inputs**: Agricultural Inputs of sugar cane, bamboo, kenaf, and ramie can be used to produce paper. Sawdust and scraps from the wood products facility will be used to produce paper as well. Collected paper from the resource recovery center can also be to make recycled paper stock
Output: Finished paper products sold to market
Byproducts: Cellulosic fibers can be used in textile, carpet, bio-plastics, and ethanol production. It can also be used in the biomass energy facility

Furniture
Inputs: Wood pieces come from wood products facility, metals come from the resource recovery center, textiles and leather for upholstery come from the textile company, and plastics come from bio-plastic resin made at the bio-plastics facility
Outputs: Finished furniture made of sustainable products
Byproducts: Biodegradable scraps can be sent to composting center or be used by biomass energy facility

Summary
From carefully studying all of the potential resource flows that could take place on the site the web of industrial ecology was mapped. Through this process it was determined that this site has the potential for over 100 unique resource exchanges. As a comparison, the Kalundborg case discussed in Chapter 2 had 20 mapped byproduct exchanges. The potential for resource exchanges on this site is enormous if the site is designed to maximize these resource exchanges.

Before any design work could be done it was important to map out all of the different types of exchange flows that could take place between the co-located firms and agriculture. Over 100 potential unique resource exchanges were identified through this process. These exchanges shaped land use decisions in the master planning stage. Each type of flow, whether it was an energy, water, or biomass flow, was examined to find the best fitting resource exchanges for the site. It was imperative to have an understanding of the industrial ecological web that will take place on-site before making long term design decisions. By mapping out the exchanges it allowed for a better and more efficient final master plan.
The following chapter presents a discussion of the master plan development and how it functions regarding the resource flows through the site.
Chapter 7: Design

The previous chapters examined the potential industries and agriculture that could take place on the site and the resource flows that would stem from these selected industries. Through a careful look into these industries and the examination of the web of industrial ecology that would grow out of resource flow exchanges between these industries the site master plan was designed. The following chapter walks the reader through the design process for the EIP master plan and explains the site program.

Industrial Resource Flow Matrices

The first step that was taken after mapping out the resource flows was to examine what these flows mean and how they can be translated to site design. This was done through creating a set of matrices that allowed the designer to 1.) Determine the ranking of importance of each industry to the site’s web of industrial ecology; and 2.) Determine the strongest resource exchange relationships among the industries. Knowing which industries have the strongest relationships master planning decisions could begin. Industries with strong relationships are sited near each other to foster exchange and reduce waste that would if located apart.

The following matrices rank the importance of the resource exchanges among the industries on a scale of 0 to 2. 2 being a strong relationship, 1 being a moderate relationship, and 0 is no relationship between the industries. From the outset, these exchanges were broken into the three categories of exchange discussed in Chapter 6 (energy, water, and biomass). The color
coding in the matrices is related to the four categories of site industries that were discussed in Chapter 5. The red industries are the energy providers, the green industries are the treatment and recovery facilities, the purple industries are primary processors, and the blue industries are secondary processors.

**Industrial Resource Flow Matrix by Exchange Type**

![Energy Flow Matrix](image)

**Figure 7-1: Energy Flow Matrix**

![Water Flow Matrix](image)

**Figure 7-2: Water Flow Matrix**
Analysis of the matrix count totals led to the determination of which industries were most important to the web of industrial ecology and therefore the functioning of the site. The biomass energy facility and water treatment facility emerged as the two highest ranking industries, which confirms and validates the decision to make the Biomass facility the anchor tenant for the

**Figure 7-3: Biomass Flow Matrix**

**Figure 7-4: Matrix Totals**
EIP. As discussed in earlier chapters, the anchor tenant is the initial source for the web of industrial ecology and all site resource exchanges stem from this tenant. Figure 7-5 ranks the industries in order of most important to the site to least important.

<table>
<thead>
<tr>
<th>Ranking of Importance</th>
<th>Exchange Matrix Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Biomass Energy Facility</td>
<td>43</td>
</tr>
<tr>
<td>2 Water Treatment</td>
<td>27</td>
</tr>
<tr>
<td>3 Anaerobic Digester- Biogas</td>
<td>18</td>
</tr>
<tr>
<td>4 Composting and Fertilizer</td>
<td>18</td>
</tr>
<tr>
<td>5 Bio-plastics</td>
<td>17</td>
</tr>
<tr>
<td>6 Biofuel Facility</td>
<td>16</td>
</tr>
<tr>
<td>7 Wood Products</td>
<td>15</td>
</tr>
<tr>
<td>8 Food Production/ Farm Feeds</td>
<td>15</td>
</tr>
<tr>
<td>9 Furniture</td>
<td>14</td>
</tr>
<tr>
<td>10 Textile</td>
<td>13</td>
</tr>
<tr>
<td>11 Paper Mill</td>
<td>13</td>
</tr>
<tr>
<td>12 Resource Recovery</td>
<td>12</td>
</tr>
<tr>
<td>13 Packaging</td>
<td>12</td>
</tr>
<tr>
<td>14 Carpet/ Flooring</td>
<td>12</td>
</tr>
<tr>
<td>15 Auto-parts Manufacturing</td>
<td>10</td>
</tr>
<tr>
<td>16 Cottage Industries</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 7-5: Ranking Industries by Importance to Site’s Industrial Ecology

The matrices allowed the designer to take a look at the most important exchanges that would take place on site. This was done by looking at the matrix totals and taking note of which industries scored the highest in terms of exchanges among them. The following figure, 7-6, illustrates the most important industrial relationships on site. It was this list that served as the basis for siting of industries within the EIP. Industry pairs with high scores were located close together in the EIP to foster resource exchanges.
By analyzing the resource exchange flows, program components and their exchanges were considered in the spatial arrangement for the comprehensive master plan. It allowed for a master plan design that took these exchanges into consideration when siting each industry. This allowed for the most resource efficient design possible for a selected site and helped to achieve this GTP’s goals and objectives to use the resource flows for EIP site planning decisions. The following illustrates how these matrices influenced the overall design.

**Functional Site Diagram**

After the industrial resource flow matrices were completed a functional site diagram was produced. This diagram, which was discussed in the site analysis chapter (Chapter 4), served to figure out placement of the industries on the design site. The final spatial arrangement was driven by the Industry Relationship Score Matrix.
(Figure 7-7). This would allow for a resource efficient design. Several different industrial arrangements were explored until the most beneficial placement was revealed. The following figure is the functional diagram that illustrates the most efficient industrial arrangement that could be determined for the site. From this diagram the final site master plan began to take shape. Streets were laid out to connect the industries to each other, the surrounding land uses, and the agri-urban core developed for the Cyclos master plan. The master plan and program were developed further from this idea.

Figure 7-7: Functional Site Diagram
Siting of the EIP

As discussed in Chapter 4, a series of steps were taken to identify the most appropriate location for an EIP. This included looking at 3 different locations, their strengths and weaknesses, and how the industries would fit into the selected lands. Through this process a boundary for the EIP was chosen. To re-orient the reader and provide the context for the eco-industrial development site, refer to Figure 7-8. It shows the relationship of the EIP development to surrounding site features such as the urban core development.

Figure 7-8: EIP Location on Plum Creek Lands
The next step in the process was to take a look at how the EIP would fit within its selected site. This was done through the re-examination of the site analysis at an enlarged scale. In order to design with the land the two main driving factors behind the siting of the EIP were looking at the topography and the wetlands were locations. An important part of this GTP design was to design with sensitivity to the land. The highest elevations on the site were used to locate the center of the EIP. This allows for best storm water practices to be implemented into the design. The EIP was also nestled into the wetlands along their eastern border without encroaching upon any of them. This also allows the storm water management system to utilize the natural wetland for further cleansing and conveyance away from the EIP site. Figure 7-9 illustrates the factors that drove the siting of the EIP.

Figure 7-9: EIP Site Analysis
Site Master Plan

The site master plan is the culmination of all the research and flow mapping that went into this GTP. Each industrial site and the program that was developed for this 381 acre EIP was driven by the preceding work. Figure 7-10 is the complete Eco-Industrial Park Master Plan that was designed through this process. Pithlochoco Eco-Industrial Park, a name derived from the site’s original inhabitants, was chosen for the name of the development. The meaning is “place where canoes are made”. It was selected to honor the first inhabitants of the site because they lived as one with the land as this Eco-Industrial Park strives to do.

Figure 7-10: Eco-Industrial Park Master Plan
Figure 7-11: Eco-Industrial Park Site Diagram
Circulation

Circulation is an important part of any design project. Different modes of transportation were taken into consideration while working out the EIP's circulation. Questions addressed were: Who are the users of this site and how are these users accessing the site? The EIP's location is in the center of the Plum Creek lands. This allows access that is equidistant to employment bases in the urban core, Hawthorne, and Windsor. Reducing the miles and trips traveled and generated by employees was considered in the siting of the EIP. Also, providing trail systems for employees who choose to walk, jog, or bike into work was paramount to the siting and design of the EIP. The below figure illustrates the site's overall circulation plan by breaking it down into different categories. These categories begin to explain how a user would traverse the site and what type of access would be provided to certain areas of the EIP.

Figure 7-12: Eco-Industrial Park Circulation Diagram
Site Character

The character of the site is very important to the overall performance and aesthetic of the EIP. The desired impression for the visitor is one of high performance. This includes both the built and landscaped environments. In this case high performance means a place that is mutually beneficial to humans and the natural world. The site’s buildings and landscape are to leave as little impact on the land as possible.

As discussed in earlier chapters the buildings are all to be designed in the C2C fashion. This means that they minimize water and energy use, provide lots of natural light, provide views and connections to the world outside of the building envelope, bring in fresh air, and have an open layout. All of these factors contribute to the efficiency, health, and happiness of the employee working inside. In following Robert Thayer's ideals set forth in his book, “Gray World Green Heart”, the site’s buildings are not to be hidden by the landscape, but showcased (Thayer, 1993). The intention is not to hide these industrial processes. It is to show that these processes are taking place on site, but they are working with the site’s ecological systems to eliminate waste and pollution. Figures 7-13 through 7-15 are intended to give the reader a feeling of the general character of the buildings in the EIP.

Also discussed in Chapter 5, the plantings and site design adjacent to these building are to use LID techniques to reduce storm water runoff and cleanse the water before it reaches the natural wetlands on the east side of the EIP development. These techniques include but are not limited to bio-retention, green roofs, and permeable paving. The open lands on the EIP site are to take on a naturalistic feel and be planted with native species to provide...
habitat for a variety of wildlife that may make the EIP development their home.

**Enlarged Nodes and Site Program**

In order to fully explain the complete master plan it was determined that 2 areas of the site should be examined in detail. Two areas of the EIP were chosen and were enlarged to highlight the center of the EIP and the Water Treatment Center Wetland area. These enlarged areas are intended to demonstrate the important features and general program of the master plan. It was important to look at the site master plan at this scale to understand the details and features of the EIP site. The following figure (7-16) shows the two enlarged nodes and ways they fit into the overall site.

![Figure 7-16: Eco-Industrial Park Enlarged Node Location](image)
Eco-Industrial Park Center

The first enlargement node represents the central portion of the EIP. After the Industrial Resource Flow Matrices were produced it was determined that the biomass facility would be at the center of the eco-industrial park because of its strong relationship to many of the co-located industries. The central location would facilitate resource exchanges among the co-located members.

The main road loops around the biomass facility to provide site access to all of the EIP members. All of the primary roads on the EIP site are considered to be eco-streets. They are to be made of photocatalytic cement. This type of cement cleans the surface of the street and removes nitrogen oxide gases from the surrounding air through a catalytic reaction driven by UV light. Because of this
reaction the streets actually absorb the pollution that comes from a vehicle’s exhaust. The eco-streets are also outfitted with bike and walking lanes and have planted bio-swales to collect and cleanse storm water runoff. Figure 7-18 illustrates the eco-streets in detail.

![Eco-Street Section](image)

**Figure 7-18: Eco-Street Section**

This location is also important to the EIP’s storm water management system. Along with the eco-street bio-swales two storm water creeks on either side of the biomass facility collect the rain water runoff, help to filter the water through natural processes, and carry the runoff to the storm water pond adjacent to the biomass facility. This pond also serves to hold the water used in the cooling process for power generation at the biomass facility. The pond is planted with water cleansing plants which help to remove pollution before the water continues its way to the natural wetlands directly east of the EIP site. The following photomontage represents the relationship between the industrial sites in the EIP and the storm water collection features. The trail network on the site also provides users access to the storm water features which serve the EIP as an amenity.
Another important feature of the EIP is the two parks that are available to employees of the eco-industrial park. The first is a boardwalk that creates a semi-circular ring around the biomass facility’s storm water pond. This allows for access over the water and was designed as a “broken” circle. The broken circle design of the boardwalk is intended to represent the effect that humans have had on natural cycles of ecosystems. Humans are responsible for breaking these circular cycles by destroying ecosystems through traditional development. This eco-industrial park attempts to reverse the trend of breaking ecosystems by being one with the land and working within the natural systems taking place around it. The second park, which is located south of the broken circle boardwalk, is the C2C Park. The form of the C2C park is a complete circle to represent the positive relationship that the eco-industrial park has with its surroundings. The circular design of the park relates to the tenet of cradle-to-cradle design.
that all resources must be returned to the technical or biological metabolisms. Therefore the use of resources is circular.

As discussed in earlier chapters the buildings in the EIP are to be designed in the C2C fashion to promote employee health and efficiency. Not only do these high performing buildings promote the health of their employees, but also the health of the surrounding environment. By outfitting many of the buildings on site with greenroofs this helps to assist in storm water management, make the buildings more energy efficient, and provide habitat for flora and fauna. The following photomontage represents the type of greenroofs that are intended in the EIP design. These greenroofs, planted with sedums, will provide habitat for many creatures, where traditional roofs would not have.

Figure 7-20: Greenroof Habitat
Pithlochoco Wetland Water Treatment Center

The model used for the sewage treatment in this EIP is based on work that I did in the Fall 2011 Plum Creek Studio. A 100 acre constructed wetland water treatment facility was designed to naturally treat all of the sewage effluent on the site. Not only is the constructed wetland intended to clean the water of the proposed eco-industrial park and surrounding community, but also serve the community as a center for learning and wildlife watching. The constructed wetland also stimulates the local economy by attracting visitors from not only the state, but all across the country. A similar facility in south Florida, Green Cay, has had over 1,000 visitors daily that come from all over the world. Figure 7-21 shows the wetland water treatment center in detail.

Figure 7-21: Pithlochoco Wetland Water Treatment Center
The facility has the ability to cleanse all of the daily waste water (sewage effluent) from the residents and workers on the site as well as the industrial waste water coming from the EIP. This occurs through a 3 step process over a period of 40 days involving aerobic and anaerobic processes. The primary treatment process takes place in water treatment buildings including treatment silos and tanks. For secondary treatment the water is pumped into an off-site aquaculture facility in the EIP where it is further cleansed by plants and fish that use the nutrients left in the water after the primary solids are removed. From there it is pumped back onto the site and held in an algae pond where secondary treatment is finished. Algae grown in these ponds can also be harvested and used to make biofuels and other products on site. In the end, the water is released into the constructed wetland for tertiary treatment. Plants used to cleanse the water can be harvested and used by other co-located industries as well.

Figure 7-22: Marsh Boardwalk and Heron Rookery
By the time the water works its way through the two free flowing cells it will be clean enough to drink. However, most of the cleansed water will be pumped onto the nearby agricultural lands to support the agricultural inputs of the connected eco-industrial park. Any leftover water will be reused by industries within the EIP. The entire constructed wetland is just under 100 acres and is nestled between natural wetlands on the site. This water treatment facility is designed to allow the visitor to experience the natural and constructed part of the wetlands. There are two constructed wetland water treatment cells. Cell one covers 22 acres and cell two is 18 acres. These cells are designed as places where the visitor will be able to see many different types of wildlife along the boardwalk path system. The boardwalk paths are a half – mile and one mile. These different segment lengths offer the visitor a choice for the duration of their visit and variety of experiences. The plan considered the wildlife corridor that links the site to Paynes Prairie. It is anticipated that many of the species in this corridor will expand their home ranges into the habitats in the proposed constructed wetland. Some of these species are herons, osprey, eagles, fish, alligators, deer, gopher tortoises, fox, and many more. The south Florida constructed wetland habitat example even has a resident bobcat. The trail connections and wildlife boardwalk will serve the community and the workers in the EIP with recreation opportunities. By providing active outlets for workers in the EIP it follows the principles of C2C design.
As explained above, the design objective was also to create a learning experience and center for research excellence. The proposed design program includes an on-site Wetland Education Center as well as didactic signage throughout the boardwalk system. Throughout the constructed wetland, visitors learn about three different things: 1) the water cycle (natural and treatment); 2) the local wildlife; and 3) the local cultural heritage of the Native Americans who originally inhabited this land. Recently, archaeologists and anthropologists discovered that the Newnans Lake area was inhabited by the Seminole tribe for over 5,000 years. In 2000, over 140 Seminole canoes and other artifacts were found, providing the evidence needed to become designated for the National Park Service’s National Register of Historic Places. The designs of various elements of the constructed
wetland are inspired by this archaeological discovery and the story of these people.

Summary

The site design was driven by an extensive look at the potential resource flows that would take place within the EIP. Each industry was sited to maximize the exchanges that would take place between co-located members. This allowed for the most resource efficient design possible. The final Eco-Industrial Park master plan is the culmination of the study of site resources and ways they could be optimized within the EIP.
Chapter 8: Conclusions

The exploration, research, and design of an eco-industrial park on Plum Creek lands located in eastern Alachua County, Florida elevates many positive issues. This GTP demonstrated the breadth of industries that could coexist on this property and the types of exchanges that could take place between those industries. These exchanges in turn affected the overall location of the industries in the proposed site master plan. This is evidenced in figure 8-1, illustrating the design process of this GTP.

![Design Process Diagram](image)

Figure 8-1: Design Process Diagram
It serves as a prototype for industrial ecology that could develop into an ideal EIP. Over 100 different opportunities for resource exchanges between co-located EIP members were found. It was also determined that an EIP of this magnitude would employ over 1000 people directly and indirectly create an additional 1500 jobs locally. In my research it was discovered that, in the United States, these exchanges were often more difficult to foster than in theory. This is due in part to the technical, financial, organizational, and legal issues any proposed EIP would be challenged by in moving forward. The following is a preliminary discussion of the feasibility of an EIP being developed on this site and the lessons that were learned through this GTP.

**Feasibility**

It is a challenge for any EIP development to become a reality. As mentioned above, these include technical, financial, organizational, and legal. Challenges recruiting companies to participate and creating effective exchange systems can be problematic. Regarding the technical aspects, exchanges among industries can be infeasible or not fully understood, and information on exchanges is not always available at the time of development. Financially, exchanges may be economically unsound or too risky for firms to be willing to take on. Organizational exchanges may prove difficult due to corporate structure or worry about corporate espionage. Lastly, legal concerns over liability may prevent even proven exchange processes from taking place in the US. (UNC Institute for The Environment 2008) These issues all need to be overcome and a common or civic goal will need to be established among potential developers before an EIP development can succeed.
Further Study

This GTP provides a vision for the type of EIP development that could take place on Plum Creek’s Windsor Tract. The next logical step in the process would be to develop a full feasibility report. The feasibility report would need to address the following points before a development should go forward on the site.

- An examination of the economic conditions and business opportunities in Alachua County; a study of the types of industries that may be attracted to the property was undertaken for this GTP process however more local economic factors need to be considered. These include population distribution, household incomes and education levels, sectors of employment, etc.
- Options for financing; private, public, or a combination of funds needs to be examined. Are any state or public incentives available for this type of development?
- An environmental impact study and analysis would also be critical for the feasibility study.

A feasibility study would serve to inform the surrounding communities. By having the community engaged, support for the EIP development could be gained. This type of report would need the expertise of multiple and variable disciplines to be completed. People with backgrounds in business and economics, environmental engineering, government and finance, anthropology, and landscape architecture could all contribute to a feasibility report for this site.

Another opportunity for further study would be the calculation of savings in dollars and pollution rates that could be achieved by
developing an EIP as opposed to a traditional industrial park development. Researchers with an environmental or economics background may be interested in undertaking such a study.

Educational Experience

The completion of this GTP has proven to be a valuable learning experience for the author. Through the background research and design it became clear that the development of an eco-industrial park in the United States is an extremely complicated process. In theory it will be very beneficial to implement these types of high performing industrial sites, but in reality they are difficult to achieve. This is because of the many different factors discussed above, including economic and political factors among others. This is most likely why there are currently few examples of successful EIP sites in our country. However, as witnessed at the Catawba County site, when executed correctly there can be many benefits for the co-located firms, the community, and the environment. Coordination between many entities is essential for creating an EIP development. Agencies that should be involved in this process include planning departments, county commissioners, development agencies, industrial members, and community members. Because of the different backgrounds of each of these groups they each bring different opinions and values to each individual project. It is important to have the support of every one of these groups to execute a successful EIP development.

Contributions to the Profession

The research conducted for this GTP proved it is difficult to find materials about site design based on resource flows. But, as
resources become more scarce design can result in more efficient use of these resources. One would achieve this by looking at the flows of a site and designing with these in mind from the onset of a project. This will be the base to move us toward the eco-effective society described in *Cradle to Cradle*, green urbanism, and the emerging field of “smart” or “intelligent” landscapes.

This project can serve as a model for designing sites that consider research on resource flows and exchanges. Additionally, projects such as these can serve as a motivator to bring allied professions together. Because executing a project of this magnitude would take expertise in many different fields it can serve as a base to bring different backgrounds together. Due to optimization as a fundamental component for EIP development, the landscape architecture profession is poised to take on the role of leaders in this field. Our education provides us with knowledge in many different arenas, placing Landscape Architects in position to lead major projects such as the one taken on in this GTP.
Works Sited


Appendix A: Plans and Flows
Appendix B: Interview Questions
Interview with Tian Jinping, expert and professor of Industrial Ecology at Tsinghua University in Beijing China. Answered questions received November 14, 2012.

Q1: How and under what circumstances were eco-industrial parks first initiated within your country? Who was responsible for the implementation of the first EIPs?

Re: Please find the information in these publications.


Q2: How does your country’s political economy affect the coordination (or willingness for coordination) of firms located within an EIP?

Re: this is very complicated question. China has many laws and policies both from central government and from local government, either from environmental protection sector or from other sectors, such as NDRC, MIIT, MOFCOM, and MOST. Along with the strict legislation and administration on environmental protection and resource conservation, the consciousness of stakeholders has also been greatly improved, which is very helpful to cultivate the coordination or willingness for coordination, especially for firms located with a local boundary, such as in an industrial park.

In the two most important laws, promotion law of cleaner production, promotion law of circular economy, the recycle and reuse of spent material is encouraged or mandatorily required. Coordination is the first step to build up the network of recycle or industrial symbiosis.
In the regulation files issued by the MEP, MOFCOM, and MOST to promote EIP development, there are guides and requirements for coordination, industrial symbiosis, information exchange, and other coordination-related matters.

Q3: What were the drivers that caused your country to seek EIP development strategies?

Re: you can find the comments in the references listed in the Q1.

Q4: What are the main goals and objectives of firms deciding to locate in EIP developments in your country? Why do they decide to locate in these developments?

Re: In some of the firms, EIP is viewed as an advanced idea toward the target of the sustainable development of an industrial park. Their understanding on EIP is similar as environmental protection. Firms must stay in the mainstream of environmental protection practice of the park, because they have no choice.

Q5: In your country, does each firm cultivate its own relationships or is it directed by a single local firm?

Re: I guess the relationship you mentioned is mainly focused on waste exchange relationship. Both happened.

Q6: In your country, do EIP firms pursue common strategic targets responding to the market and other stimuli?

Re: Definitely. The common strategic target is to promote the sustainable development of the industrial park by improving the efficiency and efficacy of materials and energy and reducing the generation of waste.

Q7: In your country, would you consider cooperation between EIP firms to be vertical (enterprises along the supply chain), horizontal (enterprises from just 1 industry), or diagonal (companies from different industries and stages of the production process take part)?

Re: You can find all the three types cooperation in most of China’s industrial park.

You can find some examples in following references.


Q8: What is the general duration of cooperation agreements between EIP firms in your country? long term (over five years), middle term (one to five years), and short term (less than one year)

Re: It is hard to answer. I have no general idea on this question.
Q9: What type of ecological performance factors have been positively influenced by EIP developments in your country and how? i.e. total amount of waste disposed, total amount of waste recycled, total amount of waste, total amount of raw materials, total mileage needed to purchase and distribute goods, and energy efficiency of all participating firms

Re: This is a very important question and a big question. We recently submitted several manuscripts to Journal of Cleaner production and ecological economics for consideration, on the performance assessment of China’s EIP.

Following is the abstract of one manuscript: " Chinese national demonstration eco-industrial park program has received particular consideration in the field of industrial ecology. The program has just passed its ten years anniversary. This article aims to assess the economic and environmental performance of the fourteen accredited sector-integrated national demonstration eco-industrial parks. A select group of ten metrics, including resource consumption, economic development, and waste emission, are applied to assess the performance by comparing the difference of metrics between reference years of EIP planning and accreditation. Our main findings include: (1) industrial added value of the fourteen EIPs increased by 46%; (2) for fresh water consumption, comprehensive energy consumption, total quantity of industrial wastewater generation, and solid waste production, most of the EIPs had an increase by 7%-24%, meanwhile, the weighted average intensity of the four metrics all decreased by 15%-25%; (3) for chemical oxygen demand and sulfur dioxide, the EIPs accomplished a double decrease both in total quantity of emissions and in the intensities respectively. Chemical oxygen demand emissions and its intensity decreased by 19% and 45% respectively. Sulfur dioxide emissions and its intensity decreased by 49% and 65% respectively. Further analyses of Chinese EIPs are also discussed".

Q10: Regarding EIP development in your country, are environmental factors or economic factors more important to firms?

Re: Both are very important to firms. The target is harmonizing both the environmental factors and economic factors.

In the following articles, we stated that EIP in China, “greening of industrial systems through diffusion of EIPs must be an integrated economic and environmental initiative rather than primarily an environmental program.”…… “Through the EIP program, economic competition has been effectively turned into incentives for improving environmental management and performance at the industrial park level”.


Q11: What types of government initiatives are in place to promote EIP development within your country? Does this generally take place at the local, regional, or national level of government?

Re: Please check the references listed in the Q1.

In China, many departments have variable initiatives or policy instruments to promote greener development of industrial park.

- MEP
- Instructive documents and standards for national demonstration EIP
- Title, green image
- NDRC:
  - Circular economy demonstration (2005), circulation retrofitting (launched in 2010)
  - Economic incentive driven (1.6 billion yuan and 2.2 billion yuan investment in 2010 and 2011 respectively)
- MIIT: resource saving and environmental friendly industrial parks, retrofitting (launched in 2010)
- Economic incentive and regulation driven
- MOFCOM: transition and upgrading program
- Ranking, pressure
- ETDZ oriented

Q12: Are firms in your country interested in a collaborative approach with other like-minded firms?

Re: As to I know, firms in industrial park are interested in collaborating with other firms. Because there are always chances to improve and resolve the environmental issues by cooperating with other companies.
Interview with Barry Edwards, Director of Catawba County Eco-Complex. Phone interview conducted October 30, 2012.

Were there any consultants involved in the design, planning, or building of this site as an eco-complex? i.e. architecture firms, planning associations ect… If so, who were the participants and what were their roles?

Did a landscape architect play any role in the design or development of this site?

What were the costs associated with the development of this site?

What was the process for the development of this site from idea to fruition? How did it come to be?

What were the key goals of the site from onset (social, economic, ecological)? Have these changed over time?

How were the co-located firms and uses on site developed? Who was responsible for the ideas and implementation and the growth of the industrial ecology on site?

What are the key design concepts of the site and did they influence form at all (placement of facilities and agriculture on the site)?

What is the cost of site management and are there any issues?

How is this site perceived and valued?

Are there any criticisms of the site and how it functions?

Were there any unique constraints to the design and implementation of this project?

How is the community served by this project? What is the social impact?

How many jobs has this development created for your county?

How is the environment served by this project and what is its contribution to sustainability? LID or LEED design?

Are there any underlying challenges or technological constraints for this development?

What is your vision for the site when it is fully built out? How many firms, what type of industries, ect?

What are the contextual influences on the site, major things surrounding the site that influence it? Any site specific history?

What makes this project unique and significant?
Appendix C: Work Completed During Fall 2011 Agri-Urban Studio

Work Credits p. 171-174: Bryant Cook, Brightman Thomas, Jennifer Frost, and Mia Requesens

Work Credits p. 175-176: Bryant Cook
“CYCLOS”: AN ECOLOGICAL RENAISSANCE
MASTER PLAN

KEY:
1 - URBAN CORE
2 - STORMWATER AND EDUCATION WETLAND
3 - WILDLIFE CONNECTIONS/ NATURAL FOREST
4 - EQUESTRIAN AREA
5 - VEGETABLES
6 - CHICKEN COOPS
7 - COW AND GOAT GRAZING
8 - GREENHOUSES
9 - GRAN FIELDS
10 - ECO-INDUSTRIAL PARK
11 - WASTEWATER TREATMENT FACILITY
12 - WASTE TO ENERGY FACILITY
13 - ORCHARDS
14 - WILDLIFE CONNECTIONS/ 100 YEAR FLOOD FLAND