Executive Summary

Despite a growing interest in and awareness of applications of industrial ecology (IE), such as eco-industrial parks (EIPs), little information is available about the potential economic and environmental benefits of EIPs, the process for successful EIP development, the important regulatory issues surrounding EIPs, or the technologies needed to support them.

This report contains the results of a body of research intended to investigate and support the development of EIPs—communities of companies modeled after industrial ecosystems. EIPs can exist within defined boundaries and broader industrial ecosystems in a region. These communities consciously collaborate to enhance their economic performance through improved environmental performance. Their design is based, in part, on an understanding of the dynamics of natural systems and includes features such as conversion of wastes into valuable inputs, cogeneration of energy, shared environmental infrastructure, and the minimization of material throughput.

E.1 INTRODUCTION

The purpose of this project is to expand on the information available about EIPs. As noted above, little information is available regarding EIPs. Thus, this project aims to

- ➤ demonstrate the potential economic and environmental benefits of an EIP through a case study in Brownsville, TX/Matamoros, Mexico;
- ➤ articulate a process for successful EIP development;

- examine the regulatory issues surrounding successful EIPs; and
- identify technologies that are important to the success of the EIP concept.

The project offers insights and tools for those parties developing broader industrial ecosystems or redeveloping existing industrial parks.

E.1.1 Background

An EIP is a community of manufacturing and service businesses seeking enhanced environmental and economic performance by collaborating in the management of environmental and resource issues. 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.

Some developers and communities have used the term EIP in a relatively loose fashion. We encourage applying this term to developments that are more than

- a single byproduct exchange pattern or network of exchanges;
- a recycling business cluster (e.g., resource recovery, recycling companies);
- a collection of environmental technology companies;
- a collection of companies making “green” products;
- an industrial park designed around a single environmental theme (i.e., a solar energy-driven park);
- a park with environmentally friendly infrastructure or construction; and
- a mixed use development (i.e., industrial, commercial, and residential).

An EIP may include any of these features. But the critical element in defining an EIP is the interactions among its member businesses and between them and their natural environment.

EIPs may provide benefits to the companies that participate, to the to the local community, and to the wider community. EIPs also pose some formidable challenges and significant risks.

E.1.2 Previous Research

Prior to commencing this study, the EIP was virtually unexplored. We were unsure whether and under what conditions the EIP concept could be applied with economic and environmental success. We had little information about the specialized technologies required to support EIPs; we did not know what the most appropriate role of government might be. Finally, since few EIPs had been developed purposefully, few people could describe an appropriate process for designing and developing EIPs.

E.1.3 Study Objectives and Research Approach

This project addressed four primary research questions:

R1: How do we determine the potential economic and environmental benefits that may be realized by applying the concepts of IE to current and planned U.S. and Mexican commercial and industrial developments, and what might these benefits be for a prototype EIP in Brownsville/Matamoros?

R2: What is the range of government's appropriate role (federal, state, and local) in facilitating the development and management of EIPs, and how might this role vary in alternative EIP venues?

R3: How do we identify the environmental technologies needed to fully apply IE principles and concepts, and which specific technologies will be needed for the prototype EIP in Brownsville/Matamoros?

R4: How applicable are the results of the Brownsville/Matamoros case study to other venues, particularly other border-area industrial parks?

> The companion to this document, *Fieldbook for the Development of Eco-Industrial Parks*, expands on the issues identified in this document by discussing each issue, providing potential solutions to problems, and illustrating how solutions have been implemented in other EIPs. It also guides the reader to other sources of information about each issue.

Our approach to answering these questions was to develop a case study of a potential EIP in Brownsville, TX, and Matamoros, Mexico and to write a "fieldbook" for planning, developing, and managing EIPs. We use the case study to uncover and illustrate important EIP issues related to each of the four research questions. The *Fieldbook* addresses the issues raised by the case study. It identifies the problems, discusses potential solutions, provides examples of how actual EIPs have handled each issue, and provides sources of information and other resources for addressing these issues. In doing so, it synthesizes all of the elements involved in developing and operating an EIP. The *Fieldbook* addresses each of the elements of the definition provided in Section 1.1.1.

We took a five-step approach to our EIP case study:

1. Develop methodology.
2. Build a prototype.
3. Define scenarios.
4. Collect data.
5. Calculate results.

Following the simulation of the economic and environmental impacts of the EIP, we take a closer look at research questions 2 and 3 by examining the regulatory issues involved in the case study and the technologies that are important to the EIP scenarios. We also examine the specific assumptions behind our analysis to assess the transportability of our results. Finally, we identify the challenges to EIP development that surfaced during our investigation.

E.2 EIP IMPACTS ON FIRMS AND COMMUNITIES

One of the most pertinent issues related to EIPs and other applications of IE is the size of the potential economic and environmental benefits. Although we can identify isolated and immature examples of the application of IE in an industrial park setting, very little has been written about the magnitude of benefits to expect from participation in an EIP, and a systematic framework for measuring these benefits does not exist.

We also need to understand the circumstances under which the potential benefits might be greatest. The magnitude of the benefits of forming an EIP is likely to vary greatly depending on the specific circumstances. Success of an EIP might depend on the industries involved, the location of the EIP, the economic profile of the region, the openness of local developers to a new development strategy, the local political and regulatory environment, and the willingness of the business community to work together.

E.2.1 EIP Stakeholders

EIPs might affect the companies that participate in them, the managers of EIPs, the members of the communities that host them, and the wider community.

EIP members are the building blocks of the EIP's economic and environmental systems. Each EIP member exchanges inputs (labor, capital, and materials) with other EIP members, members of the community, and suppliers and customers from outside the community. EIP members seek to maximize their profitability.

The EIP management unit adds value to the production and service functions of EIP members by performing the roles that in some way support improvements in the EIP's efficiency.

The EIP's community is the local social, environmental, and economic system in which the EIP resides. The local community, which includes community government, households, and community businesses that are not members of the EIP, is the area in which the EIP has the greatest economic, environmental, and sociological impact.

E.2.2 Sources of EIP Benefits and Risks

Each of the stakeholders identified above can potentially benefit from the EIP as an alternative form of business organization. However, the EIP also poses risks.

Membership in an EIP can potentially bring economic benefits to companies by improving their efficiency, reducing their infrastructure requirements, providing access to better information about their customers and suppliers, and reducing their costs for regulatory compliance. However, the EIP may also require that each member form relationships with other EIP members that might bring greater risk than traditional customer/supplier relationships. Furthermore, because the EIP is an emerging form of organization, members face regulatory and technological uncertainties that pose additional risk.

Perhaps the most significant challenge to EIP development is designing it with the flexibility required for longevity.

EIPs have the potential to bring economic and environmental benefits to the communities in which they locate. The EIP can provide a basis for industrial recruitment, diversify the industrial base, encourage the development of new industries, and improve the competitiveness of existing companies. The EIP can also reduce the environmental burden of existing industrial activities and mitigate the environmental impact of new firms. However, communities face a number of challenges in developing and supporting an EIP. Finding a source of development funding, determining what organization should manage the EIP, attracting a viable combination of companies, and gaining the cooperation of regulatory agencies all pose significant challenges to making EIPs viable and successful. Perhaps the most significant challenge to EIP development is designing it with the flexibility required for longevity.

E.2.3 Quantifying Impacts

The economic benefits to EIP members can be measured in terms of several indicators of profitability and investment return:

- change in annual profit
- change in the cost of production per unit
- change in productivity
- return on investment (ROI)
- payback period

Economic benefits to communities can be measured in terms of the EIP's contribution to

- value added by manufacture;
- total number of production workers;
- total production worker wages;
- average wage;
- tax revenues; and
- public expenditures for sewerage and sanitation, as a percentage of value added or tax revenues.

These statistics can be compared for the EIP and for other types of development.

The EIP cannot be considered successful unless it fully complies with all applicable environmental regulations. Beyond compliance, the environmental impact of the EIP can be determined by examining the resource use and emissions of groups of companies in a with-EIP versus without-EIP scenario. A weighting scheme could be used, if necessary, to place all discharges on a risk-based metric and to convert quantities of resource use to a single metric of resource efficiency. Other weighting schemes can be developed that account for a community's special environmental concerns. Other environmental factors, such as the EIP's impact on community aesthetics and wildlife habitat, can also be considered.

Our approach to simulating the economic and environmental impacts of the EIP is to compare the without-EIP scenario (baseline) to each of the with-EIP scenarios. We examine the impact of each scenario on the profitability, resource use, and solid waste of the EIP companies as a group.

E.3 A PROTOTYPE EIP FOR BROWNSVILLE, TX/MATAMOROS, MEXICO

The prototype EIP for Brownsville/Matamoros comprises a group of EIP member relationships that we think are feasible for the area, given the community's resources, the existing economic structure, and the available technology. We focus on the Brownsville/Matamoros area to take advantage of the richness of the issues that might be explored there, including border issues, environmental challenges to economic development, the importance of the support of a local champion, and the influence of incoming industry.

E.3.1 Building the Prototype EIP

To develop the prototype EIP and the EIP scenarios, we used information we collected from many companies operating in the area, as well as one company that operates in another location, but which we believe would fit well with the economic and environmental conditions of the proposed EIP.

Choosing a Site

Some of the relationships among these companies and their potential economic and environmental impacts depend on details specific to a site. After considering several potential sites, we chose to assume that the prototype EIP is centered at the Port of Brownsville (Port).[1] The Port provides excellent infrastructure and access to industry, and several of the anchor members of the prototype EIP are currently located at the Port.

[1]A brief description of the Port of Brownsville is provided in Appendix B.

Choosing the Members of the Prototype EIP

To choose members for our prototype EIP, we looked for companies that presented opportunities for symbiotic linkages with other companies in the area and were willing to participate in the exercise. The *Fieldbook for the Development of Eco-Industrial Parks* describes a procedure for analyzing potential byproduct exchanges among EIP members.

With the help of the Brownsville Economic Development Council we identified a subset of the businesses in Brownsville and Matamoros as potential candidates for the prototype EIP. We screened these companies and identified companies that were willing to participate and provided opportunities for symbiotic links with other companies. Then we visited the companies to collect information about the inputs and outputs of each company, the potential for using recycled material where virgin material is currently used, and the potential for marketing byproducts that the company currently processes as waste. We summarized these site visits and prepared a chart detailing the inputs and outputs of each company. From this chart, we identified several opportunities for symbiotic byproduct exchange. The prototype EIP contains 12 members.

EIP Port Members

1. Refinery—The refinery produces three products: naphtha, diesel, and residual oil.
2. Stone company—The stone company brings limestone into the Port and distributes it to companies in the area. At baseline, it sells stone to the asphalt company.
3. Asphalt company—The asphalt company uses limestone from the stone company and residual oil from the refinery to produce asphalt for use on roads in the area.[2]
4. Tank farms—Clusters of tanks belonging to a variety of companies offload a variety of fluids brought into the Port by ship and store them until they are delivered to their destinations by tanker trucks.

Remote Partners

5. Discrete parts manufacturer—This company produces plastic and metal parts using screw machines, automated roll feed punch presses, and injection molding.
6. Textile plant—This company assembles garments.
7. Auto parts manufacturer—This company uses plastic injection molding, metal stamping, and powdered metal forming to make small parts for assembly at a maquiladora facility.

[2]Currently, the asphalt plant actually imports its oil from outside the community. When the refinery is operating, it will use residual oil from the refinery. We assume this at baseline.

8. Plastic recycler—This recycler accepts 12 types of plastic, grinds it, and sells the grind overseas. The company also manufactures plastic pellets from scrap.
9. Seafood processor and cold storage warehouse—This company processes seafood and acts as a cold storage warehouse.
10. Chemical plant—This plant manufactures anhydrous hydrogen fluoride. The major byproduct is $CaSO_4$ (gypsum).
11. Manufacturer of magnetic ballasts—This company produces electronic and magnetic ballasts.
12. Gypsum wallboard company—This EIP member, located in Houston, is the only member not located in the Brownsville/Matamoros area.

E.3.2 EIP Scenarios

Although many other potential analysis scenarios are probably possible, we investigated five EIP scenarios (see Figure E-1) described below because they appeared to have the greatest potential for economic and environmental benefits.

Figure E-1. Five Scenarios for the Prototype EIP Analysis
The five EIP scenarios build on each other as new symbiotic relationships are added in each step.

Scenario 1 *Baseline*	Baseline EIP members and production activities.
Scenario 2 *Pollution Prevention*	Members implement noncooperative pollution prevention activities.
Scenario 3 *Pollution Prevention plus Industrial Symbiosis*	EIP members develop symbiotic relationships with other EIP members and remote partners.
Scenario 4 *New EIP Members*	New symbiotic relationships develop as a result of new EIP members.
Scenario 5 *Collocation and Joint Services*	Remote partners locate within the EIP. EIP provides environmental services.

Scenario 1: Baseline Production and Trade Activities

Figure E-2 provides a graphical representation of the baseline scenario.[3] At baseline, very few symbiotic relationships exist between these companies:

- The refinery sells its residual oil to the asphalt company.
- The company sells limestone to the asphalt company.

Scenario 2: Pollution Prevention

This scenario describes some pollution prevention (P2) and recycling opportunities that can provide economic and environmental benefits to the companies acting independently of other EIP members. We qualitatively analyze the following opportunities, which are relevant comparisons for later scenarios:

- The discrete parts manufacturer introduces an aqueous cleaning system and an oil–water separation system.
- The textiles company recycles cutting room clippings.
- The automobile parts manufacturer purchases a ringer system for absorbent socks and rags.
- The seafood processor uses brownwater for noncritical cleaning processes.

Scenario 3: Industrial Symbiosis

The first development stage of the EIP is fairly limited (Figure E-3).

- The discrete parts manufacturer sells scrap plastic, which is currently landfilled, to the recycler. He also purchases plastic pellets, which he currently purchases from a more distant source, from the plastic recycler. The benefits arise from conducting both transactions with a local broker.
- The textile company sells plastic, which is currently landfilled, to the plastic recycler.
- The auto parts manufacturer begins selling scrap plastic to the local recycler, rather than the current recycler he uses in Chicago.
- The ballast manufacturer sells scrap asphalt to the asphalt company for mixing with its virgin materials.

[3]Each of these descriptions is based on the operations of companies in the Brownsville/Matamoros area. However, we have also made assumptions about operation data where the actual data were not available.

Figure E-2. Scenario 1: Baseline Activities
These companies form the baseline scenario for the Brownsville/Matamoros EIP.

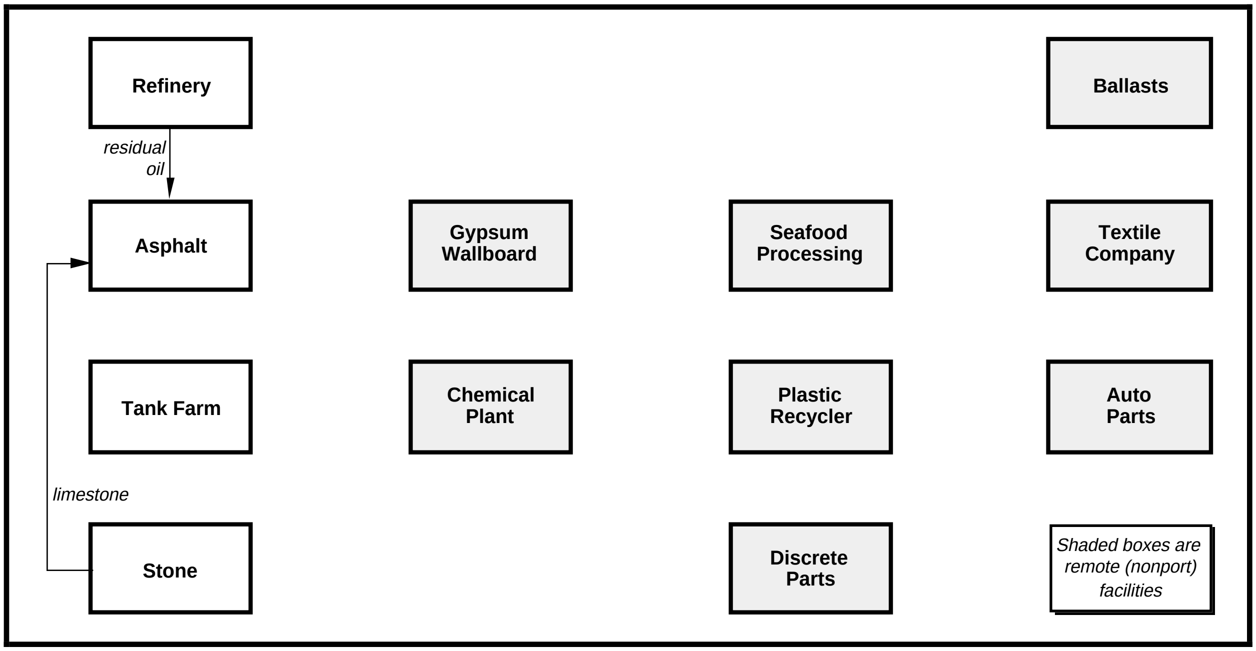
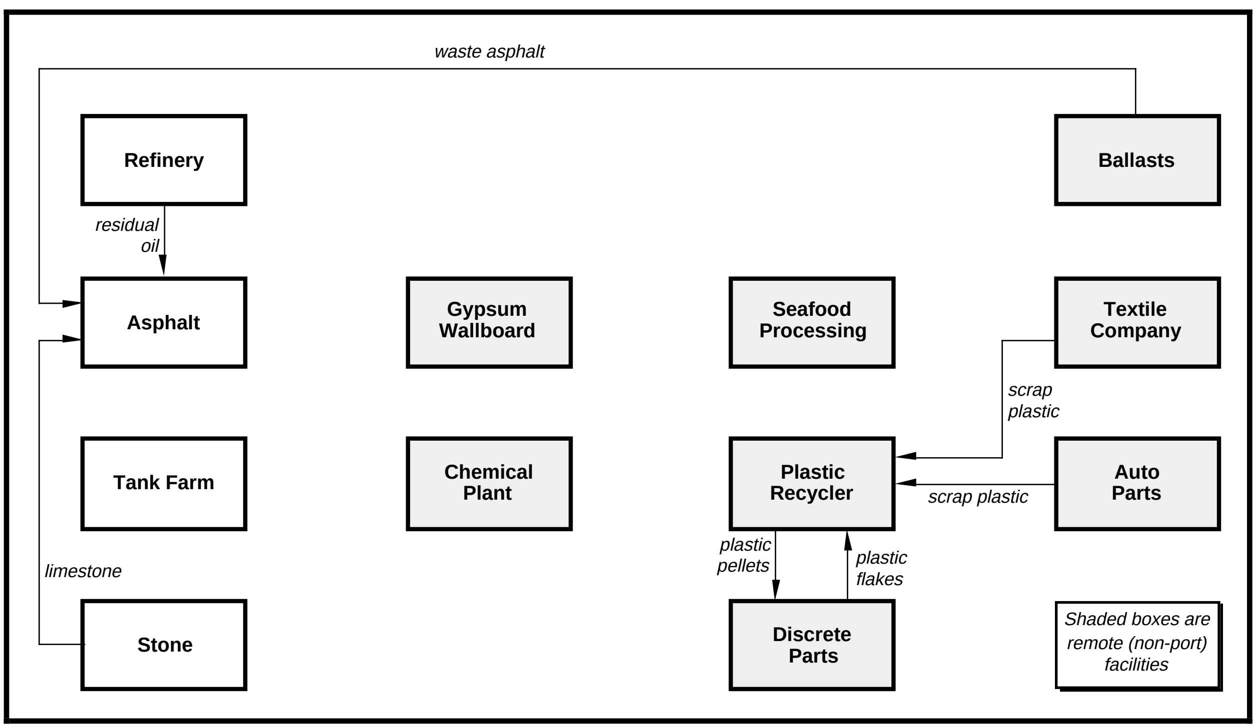


Figure E-3. Scenario 3: Industrial Symbiosis
The exchange of scrap plastic and waste asphalt among noncollocated companies characterizes this scenario.



Scenario 4: New EIP Members

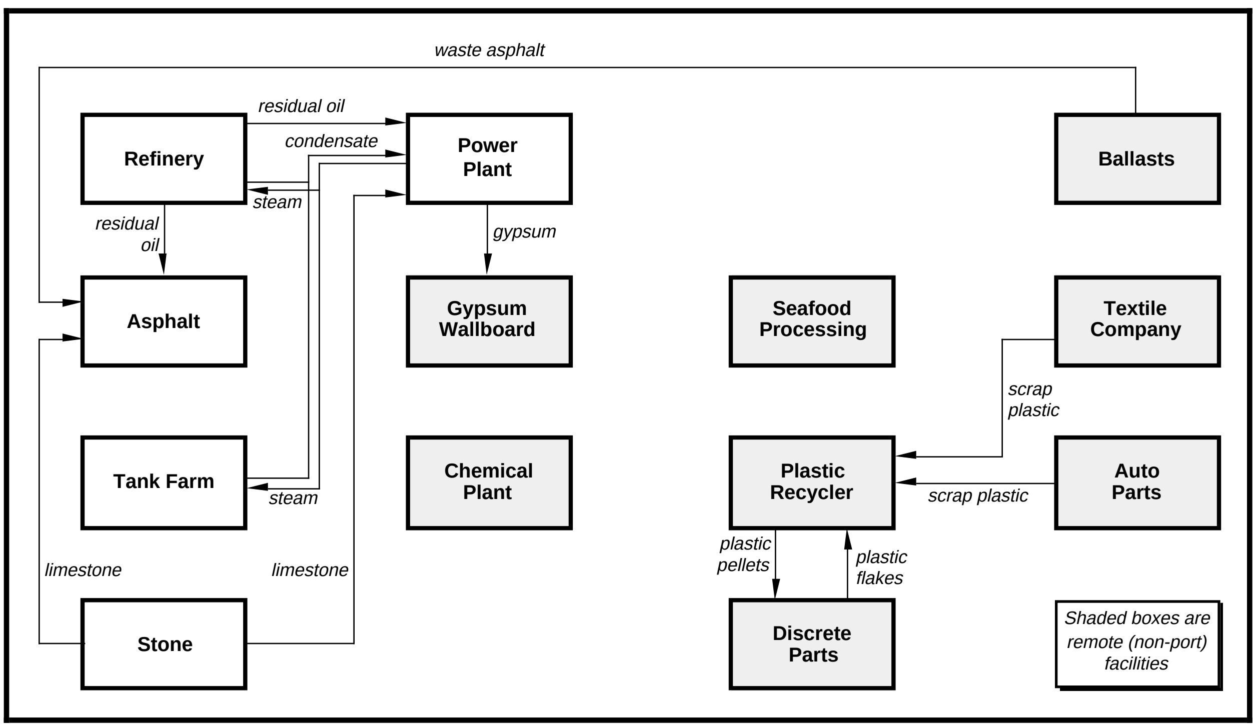
In this stage, we examine the environmental and economic benefits of creating new businesses within the EIP (Figure E-4). The new members include the following:

- a power plant burning *Orimulsion*™, a heavy bitumen emulsified with water equipped with a steam pipeline to distribute process steam to other EIP members and
- a remotely located gypsum wallboard company.

These projects will require investment but will result in the following set of symbiotic relationships:

- The power plant delivers waste steam, through the pipeline, to the refinery and the tank farm. Once the energy in the steam is spent, the condensate is returned to the power plant and recycled to make more steam.
- The stone company delivers stone to the power plant for use in the scrubbers in the power plant's air pollution control system.
- The wallboard company receives waste gypsum from the power plant.

Figure E-4. Scenario 4: New EIP Members
A power plant and a remote gypsum wallboard company are added to the EIP.



Scenario 5: Pollution Prevention, Industrial Symbiosis, and Collocation; Joint EIP Services

In this stage, we assume that the remote partners are collocated with the remainder of the EIP members. We *do not* analyze their decision to move into the park from their current location; we only show the additional benefits that could be derived from collocation. We also analyze the provision of several joint services, which we assume the Port can provide once the EIP has enough members to make these activities economically feasible. These joint services include a solvent recycler, an oil recycling operation, and a water pre-treatment plant. These changes produce the following opportunities:

- Each of the exchanges described in Scenario 3 takes place with lower transportation costs.
- The water pretreatment plant provides clean water to the power plant.
- The solvent and waste oil recyclers are used by several EIP members.

Figure E-5 also shows the seafood processor providing brownwater to the textile company. In our prototype, this brownwater is used to provide a rooftop sprinkling system to cool the textile company. Although we do not quantify the benefits of this relationship in Chapter 4, we include it in Figure E-5 because it demonstrates one important method for conserving water—water cascading, which we discuss in Chapter 6.

E.4 RESULTS OF THE EIP PROTOTYPE SIMULATION

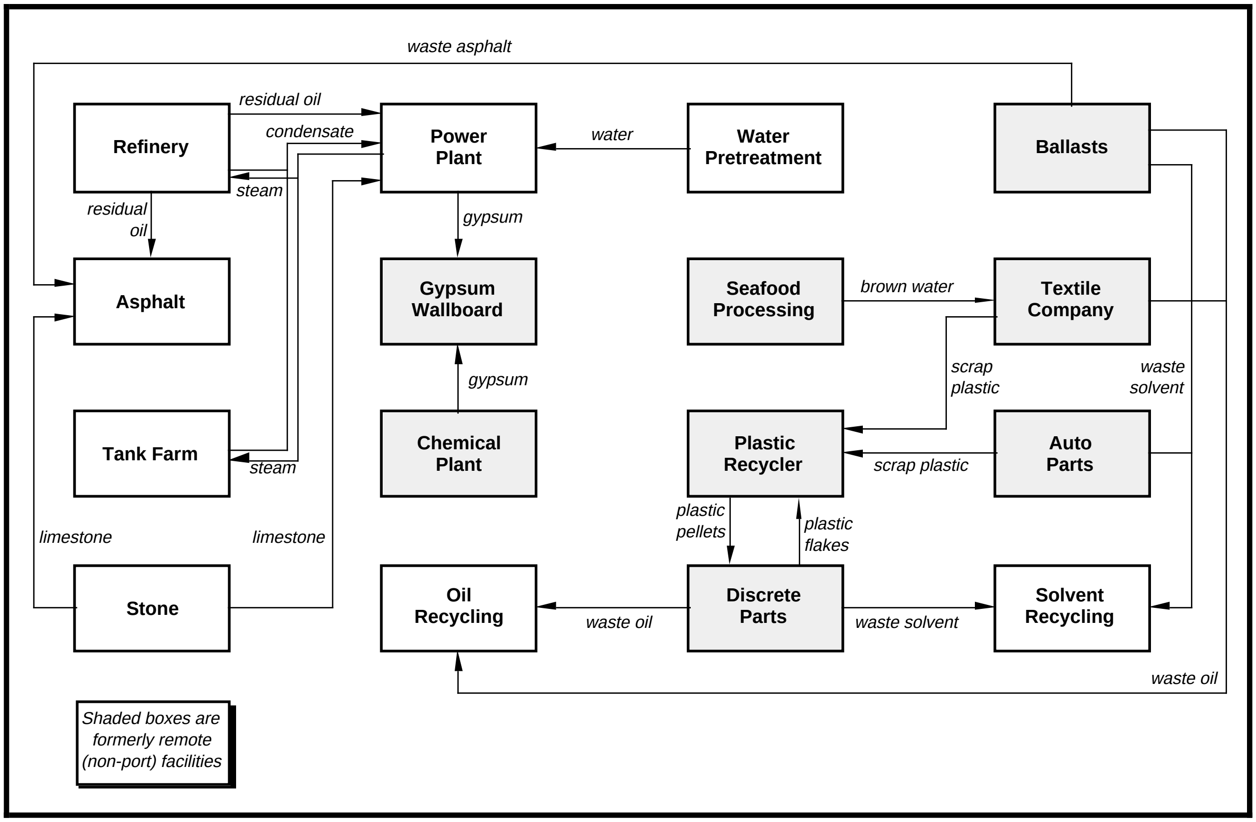
In this section, we review the results of our economic and environmental analysis of each EIP scenario.

E.4.1 Analysis Approach

The analysis procedures and spreadsheet model used to simulate changes in economic and environmental performance can provide three basic types of information for each EIP scenario:

- net changes in their materials flows
- changes in their net annual revenues
- their incremental annualized fixed costs

Figure E-5. Collocation and EIP Services
All previously remote facilities are assumed to be located at the Port and solvent and oil recycling facilities serve the EIP.



From this information, we calculated changes in annual profit, ROI, and payback periods. These measures refer exclusively to the profitability of the EIP relationships we describe, rather than to the overall profitability of an EIP member, which would require complete knowledge of each company's baseline operations and finances. Net changes in materials flows represent the expected environmental impact of each EIP scenario.

Data Sources

The facilities described in this case study are model plants that are based on information obtained from representatives of the companies operating similar plants in the Brownsville/Matamoros area. We call this analysis a simulation, rather than an estimate, because, although we used actual engineering and economic data wherever possible, we encountered difficulty obtaining the level of detail and accuracy necessary for credible estimates of the impact of the simulated symbioses.

In our case study, we refer to the net benefit, rather than the annual change in profit, of a symbiosis. This is the combined annual change in revenue for all EIP companies minus the combined annualized investment and O&M costs required to facilitate the symbiosis. Although this is basically the same as profit for all companies combined, we do not know how these benefits will be distributed among the EIP members; thus we refrain from calling these benefits profits.

Net Benefit, Payback Period, and ROI

The net benefit of an EIP relationship is the change in annual net revenue minus the annualized investment required to move from baseline to each EIP scenario. Because we cannot realistically predict how these changes in net revenue would be distributed among the companies, we compare the combined annual change in revenue for all EIP companies to the combined annualized investment and operation and maintenance (O&M) costs required to facilitate each new level of symbiosis. We call this the net benefit of the symbiosis, because it is not really appropriate to speak of profit when discussing the joint benefits of the EIP.

We calculated an ROI for each relationship. ROI is

$$\sum_{i=0}^{n} \frac{\Delta\pi_{t+1}}{(1+r)^{i}} = 0$$

where $\Delta\pi_{t+i}$ is the net benefit (benefit minus cost) of the investment; t is the amount of time over which the investment provides benefits (or costs), and solving for r provides the ROI. We calculated the payback period for each scenario as the total investment divided by annual net revenue.

E.4.2 Simulation of Economic and Environmental Benefits

Table E-1 summarizes the results of the quantitative analysis of the EIP, comparing a number of economic and environmental indicators from the baseline.

The benefits of an EIP expand as companies take on greater investment, greater risk, and a greater level of cooperation among each other.

Our case study demonstrates that the benefits of an EIP expand as companies take on greater investment, greater risk, and a greater level of cooperation. In Scenario 2, we described some efficiencies that companies capture on their own by engaging in waste reduction activities. In many cases, they gain concrete economic and environmental benefits with little investment and little risk. These opportunities require no cooperation or dependence on other companies.

In Scenario 3, we demonstrated that the opportunities to improve economic and environmental performance expand when companies are informed about how they might work together to improve the “industrial ecosystem” in their community. For this scenario, the economic benefits were small, but the risk and investment required

Table E-1. Summary of Simulation of EIP Benefits Over Baseline
The economic and environmental benefits of the EIP grow as the symbiosis expands to include more partners and as those partners locate closer to each other.

Indicator	Scenario 3	Scenario 4	Scenario 5
Net annual economic benefit	$107,384	$4,658,786	$8,180,869
ROI	359%[a]	38%	59%
Payback period (years)	0.28	2.64	1.69
Reduction in landfill waste			
Plastic (lbs)	131,227	131,227	131,227
Asphalt (lbs)	730,831	730,831	730,831
Gypsum (tons)		121,545	121,545
Change in resource use			
Orimulsion (bbls)		163,142	163,142
Residual oil (bbls)		-273,750	-273,750
Water (gals)		15,768,000	15,768,000

[a]This reflects only changes in net revenue from asphalt, since the plastics exchange required no investment.

were also small, since the relationships between the companies involved operations that were peripheral to their main production activities.

In Scenario 4, we found that a single new member of an industrial ecosystem can have an important impact on the opportunities available to the EIP. We also saw the dramatic increase in potential EIP benefits derived from increasing dependence of the EIP members on each other. These increased benefits were accompanied by increases in investment and risk.

In Scenario 5, we demonstrated that collocation of EIP members can increase the opportunities and benefits of an industrial symbiosis. Although many profitable opportunities for symbiosis do not require collocation, these benefits can expand if EIP members locate in a single physical location, under a single management structure that includes shared infrastructure, regulatory structure, and joint services. This implies, of course, an even greater level of dependence of companies on each other and on the EIP management.

E.4.3 Lessons and Limitations of the Case Study Analysis

Our case study was based on a number of assumptions and much conjecture. However, it served to demonstrate some important points about the elements required for a successful EIP:

1. The first and most essential input to the EIP is information about members' operations.
2. The success of the EIP requires that members are open to depending on each other.
3. To achieve the greatest economic benefits, the EIP will require substantial investment in infrastructure.
4. The economic and environmental benefits to the EIP and the community are greater if the potential symbiosis opportunities are recognized during the planning stages of a park or plant. Retrofitting existing plants, while possible, decreases the economic benefits.

Our analysis was limited in several ways. First, within the scenarios we examined, we did not consider the influence of the changes in operations on several important factors that may affect the EIP's economic and environmental impact:

- the risk to companies of investing in symbiotic relationships with suppliers and customers
- the risk to companies that they may be liable for the environmental impacts of other EIP members' operations
- the implications of the operations changes depicted by the scenarios for the regulatory costs faced by each EIP member

The second way in which our analysis was limited was that we did not examine whether the EIP member would rather locate at the EIP than at alternative locations. That is, we assumed that everything else about the baseline scenarios and the with-EIP scenarios was the same except for the byproduct exchanges. This would certainly not be true if a company was trying to decide whether becoming a member of an EIP would be more profitable than some alternatives.

The third way in which our analysis was limited was the exclusion of aspects of the EIP aside from the symbiotic relationships between companies, shared infrastructure, and shared EIP services. EIPs may differ from traditional industrial parks in other ways that affect the magnitude of the environmental and economic benefits.

Finally, we did not consider the costs of managing the EIP.

E.5 REGULATORY ISSUES AND APPROACHES FOR ENCOURAGING EIP DEVELOPMENT

The second research question we addressed with this project was, "What is the range of government's appropriate role in facilitating the development and management of EIPs, and how might this role vary in alternative EIP venues?" We address this question in Chapter 5 by describing how environmental regulations affect EIPs.

E.5.1 Regulatory Issues Surrounding EIP Development

Environmental regulations often create disincentives for industry to develop and implement P2 programs or to exchange potentially useful byproduct materials for other applications. Several regulatory issues are particularly germane to companies trying to participate in an EIP.

- **Definition of waste:** The lack of distinction between solid and hazardous wastes and secondary materials in the language of Resource Conservation and Recovery Act (RCRA) leaves little room for generators to reuse, recycle, or reclaim the waste to recover any beneficial constituent or use any property of the waste.
- **Definition of source:** The term "source" can apply to an entire industrial facility or to each point at which emissions are released. However, it is most appropriate to view the EIP as a single source for some pollutants, because the sum of discharges from each company may be greater than the net discharges of the EIP. Furthermore, the current definition of source poses a significant administrative burden on many industrial facilities.
- **Liability:** Two liability concerns are
  - ✓ the use of potentially hazardous secondary materials in other applications subject to liability under RCRA's "derived from" rule and
  - ✓ the liability of separate companies when regulated with other members of industrial parks or regions under single regulatory umbrellas.
- **Single-medium permitting:** A multimedia approach to regulation will be necessary to encourage EIP members to take a systemic view at reducing their wastes, rather than to shifting waste from one form (and medium) to another, without significantly reducing the totals.
- **Brownfield versus greenfield issues:** To prevent EIP development from encroaching on green spaces, a company needs incentives such as those included in EPA's (1995) *Brownfields Action Agenda* will contribute to clarifying.
- **U.S–Mexico border issues:** Regulation of EIPs along the border will be complicated by different sets (U.S., Mexico, and bilateral) of environmental regulations. Some progress has been made toward establishing binational "border-area" permits that cover facilities located in border areas with both

U.S.' and Mexico's environmental protection laws under a single piece of legislation.

E.5.2 Prototype EIP Regulatory Case Study

The Brownsville/Matamoros prototype EIP scenarios provide a backdrop for analyzing regulatory issues surrounding each scenario and possible regulatory approaches for encouraging EIP development. Because we did not consider changes in regulatory requirements in our case study analysis, we felt it was important to provide some idea of the regulatory considerations and costs that might face the companies in the prototype EIP. We provide highlights of this analysis for each scenario.

- **Scenario 1:** The petroleum refinery and possibly the asphalt company must apply for a new source review permit, permit variance, or flexible permit to comply with 40CRF262 (standards for generators of hazardous waste) and 40CFR279 (used oil management standards).
- **Scenario 2:** The discrete parts manufacturer and the automobile parts manufacturer must obtain a new source review permit, permit variance, or flexible permit.
- **Scenario 3:** The auto parts manufacturer, because it is a maquiladora firm, may be required to report to its governing body that the scrap is being shipped to another U.S. site. The ballast manufacturer may need to modify its RCRA permit to comply with 40CFR262 (standards for generators of hazardous waste) and 40CFR268 (land disposal regulations).
- **Scenario 4:** The power plant may need a new source review permit for generating steam.
- **Scenario 5:** All companies using the solvent recycler or the oil recycler would be required to submit an application for variance or flexibility to 40CFR262 (standards for generators of hazardous wastes), 40CFR264-265 (tanks and containers), and/or 40CFR279 (used oil management standards). The recycler would be required to obtain new source permits for all major federal and state statutes.

The re-permitting process or application for a permit variance would cost the manufacturer from $450 to $75,000, depending on the type of permit sought and details of the proposed modification.

E.5.3 Regulatory Strategies for Supporting EIP Development

The challenge over the coming years will be to balance the tradeoffs between regulatory strategies that meet aggressive environmental goals and those that allow and encourage innovative approaches, such as EIP development, to meet those goals. Generic regulatory strategies for encouraging P2 and IE in the context of EIP development include the following:

- ➤ modifying existing regulations
- ➤ streamlining existing permitting and reporting processes
- ➤ moving from technology-based to performance-based regulations
- ➤ promoting facilitywide permitting
- ➤ promoting multimedia permitting
- ➤ market-based approaches
- ➤ voluntary agreements
- ➤ manufacturer "take-back" regulations
- ➤ technology transfer
- ➤ opportunities for technology development and commercialization
- ➤ IE technology development grants

E.5.4 Current Regulatory Initiatives Encouraging EIP Development

Recognition of the benefits of P2 and IE already is driving some regulatory initiatives to promote not only source reduction but also the reuse and recycling of waste and secondary materials. These current regulatory initiatives include the following:

- ➤ EPA's P2 Policy Statement, which eliminated some of the confusion surrounding the terms P2, waste reduction, waste minimization, and recycling and established a hierarchy of waste management by placing P2 (source reduction and environmentally sound recycling) above waste treatment, control, and disposal
- ➤ EPA's Solid Waste Task Force, which is revising the rules governing hazardous waste recycling in an effort to give industry more flexibility for recycling
- ➤ EPA's Permits Improvement Team, which is working in the following areas:
  - ✓ alternatives to individual permits
  - ✓ administrative streamlining
  - ✓ enhanced public participation
  - ✓ P2 incentives

    - ✓ training
    - ✓ performance measures
- ➤ Brownfields Economic Redevelopment Initiative, which is establishing pilot sites; clarifying liability and cleanup issues; building partnerships with states, clients and community representatives; and fostering job development and training
- ➤ Technology Transfer Initiatives to advance environmental technology development and transfer

E.5.5 Regulatory Policy Recommendations

One of government's roles in supporting EIP development is to increase the flexibility of the regulatory structure so that it functions to encourage greater innovation. Changing the regulatory structure to more flexible, more resilient, systemic solutions will require environmental regulations that are less focused on single-medium and single-source controls. This type of flexibility will allow EIPs to respond to environmental issues of greatest concern in their communities.

Optimal regulatory solutions for future EIP developments will require the following:

- ➤ clearly defining regulatory problems associated with EIPs to reduce the uncertainty of potential EIP members
- ➤ allowing industry maximum flexibility consistent with solving environmental problems
- ➤ encouraging open communication and cooperation among key stakeholders
- ➤ encouraging a systems approach to regulation

E.6 TECHNOLOGIES SUPPORTING EIPS

The appropriate technologies can improve the sustainability of the EIP. Although we cannot identify specific technologies that are important to all EIPs, we can provide a framework for identifying them. Clearly, the technologies contributing to the success of each EIP are specific to the EIP's particular industrial activities, the characteristics of the industrial symbiosis, the geophysical characteristics of the location, the available resources, and many other factors.

E.6.1 Technological Challenges for EIPs

Technology's role in the EIP is to help communities, EIP members, regulators, designers, and managers solve potential problems and meet challenges. Technologies can help an EIP meet challenges in the following ways:

- **Improving the EIP's economic efficiency.** Technology can improve the economic efficiency of EIPs by helping members reduce transaction costs and take advantage of economies of scale and scope.
- **Improving the technical and cultural feasibility of symbiotic relationships.** Technologies can lead to symbioses compatible with existing production systems and the skills of existing workers and managers.
- **Reducing risk and improving flexibility for the symbiosis.** Technologies that improve process flexibility will reduce the risk that a member of the industrial symbiosis cannot purchase or supply a material in the required quantities or of the required quality.
- **Reducing the environmental burden of the production and consumption of EIP goods and service.** Many, but not all, of the technologies that take advantage of economic efficiencies will also provide environmental benefits to the EIP.
- **Reducing the costs of regulatory compliance.** Any technology that reduces the cost of reducing air emissions, water discharges, hazardous wastes, and solid waste will reduce the cost of complying with the associated regulations. Other technologies are more specific to meeting the demands of the regulatory process.

E.6.2 Technologies Meeting EIP Challenges

Because each EIP will have a unique set of companies and symbiotic relationships, identifying a list of technologies that might be important to its sustainability is difficult. However, certain categories of technologies help capture the efficiencies available to an EIP and meet the technical, cultural, and environmental criteria discussed above:

- transportation technologies
- recovery, recycling, reuse, and substitution technologies
- environmental monitoring technologies
- information technologies
- energy and energy-efficient technologies
- water treatment and cascading technologies

E.6.3 Technological Challenges in the Brownsville/Matamoros Case Study

Some technologies of interest to the Brownsville/ Matamoros EIP are

- *plastics separation,*
- *solvent recycling and recovery,*
- *recovery of byproducts,*
- *cogeneration, and*
- *water treatment and cascading.*

The Brownsville/Matamoros case study examined applications of some of the technology types listed in Section E.6.2. Our report provides details about the following technologies:

- **Recovery, Recycling, Reuse, and Substitution:** The case study explored the feasibility of several types of plastics separation in Scenario 3, reuse of synthetic gypsum that is a byproduct of power plants and chemical manufacturers in Scenario 4, and solvent recycling and recovery in Scenario 5.
- **Energy Technologies—Cogeneration:** Scenario 4 of our EIP case study included a simulation of a cogeneration relationship between a power plant and other members of the EIP.
- **Water Treatment and Cascading:** Scenario 5 of the EIP case study included a discussion of an exchange of brownwater between the seafood processing plant, which produced it as a byproduct of seafood processing, and the textile company, which could use it to cools its roof. We also investigated the feasibility of applying several types of water treatment and cascading schemes in the prototype EIP in Brownsville/Matamoros. Joint treatment of segregated waste streams allows companies to achieve economies of scale not possible if they operated independent wastewater treatment plants.

E.7 SUMMARY AND CONCLUSIONS

In this section, we address the final research question, "How applicable are the results of the Brownsville/Matamoros case study to other venues, particularly other border-area industrial parks?" First, we note the assumptions and conditions that were specific to our case study and scenarios and explain how our results might be more or less applicable in other circumstances. Second, we summarize the challenges to EIP development that we identified while building the EIP prototype, developing the simulations, calculating the case study results, exploring regulatory roles, and investigating the potential impact of technology.

The transportability of the results of the EIP case study depends on the ability of communities, EIP members, regulators, EIP designers and engineers, and EIP managers to meet these challenges. The EIP *Fieldbook* (Lowe et al., 1996) further investigates these challenges, provides potential solutions, and examples of cases in which the solutions have been successful.

E.7.1 Transferring Results to Other EIPs

Our case study and the analysis of regulatory and technological changes needed to support an EIP were driven to a certain extent by the specific conditions found in Brownsville/Matamoros. Not all potential EIPs will have these same elements.

Our scenarios were motivated largely by a cogeneration situation. In Brownsville, we found a situation in which the community's power needs suggested a new power plant with cogeneration. However, cogeneration is not profitable in all cases and therefore may not be appropriate for all EIPs.

However, usually an anchor tenant provides rich opportunities for converting byproducts into useful intermediate goods. In Brownsville/Matamoros, the anchor tenants are an oil refinery and a power plant. In other cases, it could be a chemical plant, a large food processor, or some other company that produces byproducts that have a low ratio of value to weight. This low ratio implies that, to be valuable, these byproducts must be processed nearby to decrease transportation costs.

Other issues that are likely to affect the success of an EIP are the following:

- resource scarcity
- community industrial structure
- industry dynamics
- environmental considerations

Our simulation of the potential economic and environmental effects of an EIP has demonstrated that success is possible under the right conditions. Ultimately, the success of an EIP depends on the specific local context for EIP development. However, communities can apply an analysis framework similar to the one we developed in this report to assess their chances for success. Communities also must consider whether they can meet the considerable challenges to EIP development.

E.7.2 EIP Challenges

Developing a successful EIP presents challenges to each of the EIP stakeholders.

Challenges to community organizations and local government include the following:

- ➤ building local support
- ➤ setting EIP performance objectives
- ➤ sharing ownership, development, and costs
- ➤ developing EIP financing strategies
- ➤ recruiting industry
- ➤ reducing administrative red tape

Potential EIP members face the following challenges:

- ➤ estimating EIP benefits and costs
- ➤ determining the right mix of partners
- ➤ finding appropriate technologies
- ➤ reducing regulatory uncertainty and liability
- ➤ marketing EIP membership to customers

Local, state, and federal regulatory agencies are challenged to

- ➤ streamline zoning, permitting, and other development regulations;
- ➤ add flexibility to environmental regulations;
- ➤ develop appropriate technology, promote technology transfer, and provide technical training; and
- ➤ encourage the exchange of information among EIPs.

Those who develop, design, and build EIPs are challenged to improve the success of the EIP by

- ➤ choosing a site that will maximize the economic and environmental benefits of an EIP,
- ➤ designing park infrastructure that incorporates the needs of the EIP members for specialized services,
- ➤ designing industrial facilities that build in the flexibility that allows the EIP to grow and evolve,
- ➤ designing buildings that maximize the efficiency of energy and materials, and
- ➤ using construction practices that are consistent with the EIP vision.

The challenges to EIP managers include the following:

- ➤ managing the design and development process
- ➤ maintaining relationships between companies
- ➤ managing EIP property and shared support services
- ➤ ensuring the future viability of the EIP

Disclaimer

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