Industrial Ecology

Industrial ecology is an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems. It seeks to balance environmental and economic performance within emerging understanding of local and global ecological constraints. Some of its developers have called it "the science of sustainability".

IE supports coordination of design over the life cycle of products and processes. It enables creation of short-term innovations with awareness of their long-term impacts. It helps design local solutions that contribute to global solutions.

Industrial ecology helps companies become more competitive by improving their environmental performance and strategic planning. IE helps communities develop and maintain a sound industrial base and infrastructure without sacrificing the quality of their environments. And it helps government agencies design policies and regulations that improve environmental protection while building business competitiveness.
Industrial ecology principles and methods can be used by service as well as manufacturing companies. Application of IE will improve the planning and performance of government operations, including local, regional, and national levels of infrastructure.

Indigo Development's Definition

Industrial Ecology is a dynamic systems-based framework that enables management of human activity on a sustainable basis by:

- Minimizing energy and materials usage;
- Ensuring acceptable quality of life for people;
- Minimizing the ecological impact of human activity to levels natural systems can sustain;
- Conserving and restoring ecosystem health and maintaining biodiversity;
- Maintaining the economic viability of systems for industry, trade and commerce.

The Industrial Ecology approach involves (1) application of systems science to industrial systems, (2) defining the system boundary to incorporate the natural world, and (3) seeking to optimize that system. In this context, "Industrial systems “applies not just to private sector manufacturing and service but also to government operations, including provision of infrastructure.

While much of the initial work in IE has focused on manufacturing, a full definition of industrial systems includes service, agricultural, manufacturing, military and other public operations, as well as infrastructure such as landfills, water and sewage systems, and transportation systems.

In an emerging field of study and practice it is natural that understanding of its scope and meaning should be varied. We have completed a content analysis on a large number of these definitions and offer a view of where there appears to be consensus and divergence in defining IE.

A Critique of Industrial Ecology
While Indigo Development has played a key role in developing industrial ecology, we are becoming concerned about the state of this "science of sustainability", including our own practice. So much effort has focused on "picking the low-hanging fruit" that we may be missing the state of the tree. So we are initiating a critical dialogue on IE and sustainable development itself. A first commentary to spark this conversation is here. We will post responses to it.

Green Chemistry

Development of new materials and energy sources to replace non-renewable and polluting substances is itself a part of chemistry and materials science. However, industrial ecology plays a role in evaluating the broader systems implications of proposed solutions like bio-fuels or genetically engineered organisms like industrial enzymes. Can we devote a significantly larger proportion of farm land to crops for ethanol or for new biomaterials and still preserve basic ecological functions and meet growing demand for food? See green chemistry for innovation in this field.

IE and Sustainable Agriculture

An ideal IE project is modeling the system changes required to achieve a transition to sustainable food and fiber production. This involves major issues of sustainability with universal human application, issues that unfortunately are not now high in priority on most public agendas. Meeting the challenges involved in this transition will require interdisciplinary coordination among many technical, economic, social, political, and ecological research disciplines. With hundreds of billions of dollars going into one technical solution, genetic engineering of plants and animals, the stakes are high.

Industrial ecology may be able to help us perceive the whole system required to feed the planet, preserve and restore its farm lands, preserve ecosystems and biodiversity, and still provide water and land for a growing population. Indigo Development is also opening a dialogue on this modest topic and we invite your comments on how IE could address this challenge. Sustainable Agriculture
Defining Industrial Ecology
Reconciling a diversity of definitions

IE is still in a formative stage, with a diversity of definitions and understandings of scope of application. A consensus is emerging around certain key themes, however, there are critical areas of divergence among industrial ecologists. The following discussion is based upon our content analysis of over twenty-five definitions, supported by a similar analysis by researchers at University of Michigan.

Common themes -- an emerging consensus?

The majority of discussions of industrial ecology tend to agree on the following elements.

- Industrial ecology is a systems approach drawing upon methods for analysis and synthesis from systems science.
- This systems approach focuses upon the interaction of industrial systems and the ecological systems (local to global) of which they are a part.
- IE seeks to redesign industrial activities to reduce the ecological impact of human activity to levels natural systems can sustain.
- IE is interdisciplinary, linking the research and planning of many fields, including ecology, engineering, economics, business management, and public administration and law, among others.
- IE studies the flows of materials and energy through the economy, ranging from those of an industrial or public facility to the planet. It seeks strategies to increase the efficiency and reduce the impact of these flows. (This study is often termed "industrial metabolism".)
- Industrial ecology seeks transformation from a linear, wasteful economy to a closed-loop system of production and consumption. In such a system industrial, governmental, and consumer discards would be reused, recycled, and remanufactured at the highest values.
IE enables creation of short-term innovations with awareness of their long-term impacts. Similarly, it enables local decision-making with awareness of broader regional and global impacts.

IE is a means of balancing environmental protection with economic and business viability. This balance must be dynamic, adapting to new knowledge about industry's impacts and nature's responses.

IE is a major component in "the science of sustainability", with the role of designing the transition path for industrial activities, broadly defined. It offers an objective (though complex) foundation for coordinating design of public policy in environmental, technical, and environmental realms.

Industrial Ecology will interact with other fields such as ecological economics and environmental accounting, in creating the foundation for sustainable development.

Areas of divergence

While there is a fair degree of consensus on the elements of industrial ecology just listed, there is also much divergence as to its scope and emphasis. In part this is simply a matter of specialization within the field. But the following differences often go the heart of how different researchers define IE.

- **Timescale:** Some industrial ecologists emphasize incremental change in existing systems. Others speak of far reaching transformation of industry and society.
- **The ecosystem model:** With some, a very popular theme is modeling industrial systems upon the principles and dynamics of ecosystems. However, some ecologists and many engineers question the usefulness of this approach.
- **Materials flows:** Some industrial ecologists focus on the task of increasing the efficiency and reducing the impacts of materials flows in industry and society. In some articles the whole field appears to be little more than this.
- **Scope of application:** Much discussion focuses on change in manufacturing industries, while other practitioners emphasize that IE is relevant to agricultural, service and financial industries, as well
as the design and management of public policy, infrastructure, and facility operations. A few extend IE's domain to the realm of consumer behavior.

- **Key ecological concerns** such as biodiversity, carrying capacity, and restoration are emphasized in the work of university researchers but are seldom mentioned by more technically oriented industrial ecologists. (Allenby & Graedel's definition does emphasize carrying capacity. 1995)

- Some see **institutional change** as a fundamental component of IE. Others discount this, emphasizing the centrality of technical innovation to IE.

- **Materials choices:** The shift from non-renewable, synthetic materials to renewable bio-materials is a central concern for some industrial ecologists. Others focus on improving the environmental performance of petroleum based and other synthetic materials.

Industrial Ecology is both a field of scientific research and a framework for design and decision-making in public and private sectors. These two aspects should be seen as complementary rather than divergent. They need to be closely inter-related to insure a sound basis for developing applications and continuing research on the results of IE-based projects.

back to industrial ecology | Research Tools | Cases | Scenarios | Site Map

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Creating systems solutions for sustainable development through industrial ecology

Industrial Ecology and Systems Thinking

Industrial ecology is a branch of systems science and systems thinking. These terms are over-used and often abused. Here is a brief introduction to what we mean when we use them, and how they relate specifically to industrial ecology.

- A system is a set of elements inter-relating in a structured way.
- The elements are perceived as a whole with a purpose.
- A system's behavior cannot be predicted by analysis of its individual elements.
- The properties of a system emerge from the interaction of its elements and are distinct from their properties as separate pieces.
- The behavior of the system results from the interaction of the elements and between the system and its environment. (System + Environment = A Larger System)
- The definition of the elements and the setting of system boundaries are subjective actions.

The following example illustrates the subjective nature of systems definition. Understanding that we construct a system from a particular point of view is crucial to working with systems thinking and IE.

Applying Industrial Ecology at Three Levels:
A Systems Perspective
In transportation, an industrial ecologist would support short-term enhancements in automobile design through such tools as Design for Environment (DFE). The basic question would be: How can we optimize trade-offs to reduce energy use and pollution in the production process as well as during use of the product?

At another level, an industrial ecologist might ask, how can we transform small vehicle design to capture levels of efficiency and freedom from pollution not possible within the internal combustion model. Rocky Mountain Institute's Hypercar and hybrid electric vehicles are examples.

At a still broader level, an industrial ecologist (possibly in public policy or a competing business) would ask, how can we design integrated transportation systems to move people with highest resource efficiency and lowest possible pollution? How can telecommunications, urban planning, and design of work patterns reduce the number of trips and distance traveled.

See our transportation case for more detail on this example.

A whole systems web site with many links and bibliography: http://newciv.org/worldtrans/whole.html

Complexity theory and practice at Santa Fe Institute http://www.santafe.edu/

back to industrial ecology
Eco-Industrial Parks

Indigo Development introduced the concept of eco-industrial parks (EIP) to staff at the US-EPA in 1993. The Agency then embodied this concept in an Environmental Technology Initiative project, which led to the President's Council on Sustainable Development adopting EIPs as demonstration projects in 1995. By the Fall of 2001 communities in the US, Asia, Europe, South America, and Africa have initiated EIP or other eco-industrial development planning processes.

In our Eco-Industrial Park Handbook for Asian Developing Countries (download it) we have updated the concept and strategies and incorporated cases from Asia. (This work was supported by the Environment Department of the Asian Development Bank.) We now define the EIP concept as:

"An eco-industrial park or estate is a community of manufacturing and service businesses located together on a common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance."
"The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impacts. Components of this approach include green design of park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; and inter-company partnering. An EIP also seeks benefits for neighboring communities to assure that the net impact of its development is positive."

Communities and businesses that create eco-industrial parks will have a foundation for industrial development that is more competitive, more efficient, and cleaner than traditional industrial parks. In addition, new business niches will be opened for recruitment or incubation of new companies.

A grindstone hole along the Tule River in California where members of the Yaudanchi Native American tribe ground acorns into meal.

Benefits: Communities embracing the EIP concept are seeking benefits for all public and private stakeholders.

- Business derives cost savings and new revenues; shared services; reduced regulatory burden; and increased competitiveness.
- The community enjoys a cleaner, healthier environment; business and job development; an attraction for recruitment; and an end to conflict between the economy and the environment.
- Government receives increased tax revenues; reduced enforcement burden; reduced costs of environmental and health damage; and reduced demand on municipal infrastructure.
- For the environment there is reduced demand on finite resources; decreased local and global pollution; increased use of renewable energy and materials; and an overall renewal of natural systems.

Strategies for Designing an Eco-Industrial Park

Several basic strategies are fundamental to developing an EIP or
industrial ecosystem. Individually, each adds value; together they form a whole greater than the sum of its parts.

Integration into Natural Systems

Design the EIP in harmony with the characteristics and constraints of local ecosystems; Minimize contributions to global environmental impacts, i.e. greenhouse gas emissions.

Energy Systems

Maximize energy efficiency through facility design or rehabilitation, co-generation (the capture and use of otherwise wasted heat from the electrical generating process), and energy cascading (the use of residual heat in liquids or steam from a primary process to provide heating or cooling to a later process: steam from a power plant, for example, is used in a district heating system); Achieve higher efficiency through inter-plant energy flows; and Use renewable sources extensively.

Materials Flows and "Waste" Management for the Whole Site

Emphasize pollution prevention, especially with toxics; Ensure maximum re-use and recycling of materials among EIP businesses; Reduce toxic materials risks through integrated site-level waste treatment; and Link the EIP to companies in the surrounding region as consumers and generators of usable byproducts via resource exchanges and recycling networks.

Water

Design water flows to conserve resources and reduce pollution through strategies similar to those described for energy and materials.

Effective EIP Management
In addition to standard park service, recruitment, and maintenance functions, park management does the following:

Maintains the mix of companies needed to best use each others' by-products as companies change;
Supports improvement in environmental performance for individual companies and the park as a whole;
and Operates a site-wide information system that supports inter-company communications, informs members of local environmental conditions, and provides feedback on EIP performance.

Construction/Rehabilitation

New construction or rehabilitation of existing buildings follows best environmental practices in materials selection and building technology. These include recycling or reuse of materials and consideration of lifecycle environmental implications of materials and technologies.

The first pioneers who are developing eco-industrial parks are applying previously tested concepts and practices in an innovative whole system. You can find the separate components of the EIP vision working effectively in industry today. In some cases (energy efficiency in new process, equipment, and plant design, e.g.) there is an obvious contribution to competitive advantage. Many of these "new" approaches are becoming best business practices. Many of these ideas are simply applied common sense:

   Why pay money to create a product you can't sell, call it a waste, and pay someone to dispose of it?

   Why not use the energy of the sun and wind when you locate a building and design its heating and cooling systems?

The real innovation in creating eco-industrial parks is bringing such ideas together in a whole system. Indigo publications provide more detail on the planning of eco-industrial parks. Indigo services include strategic planning, EIP strategic reviews, and workshops for communities and
developers considering eco-industrial parks.

Indigo Development collaborated with Berkeley resource recovery pioneer, Urban Ore, to envision an eco-industrial park anchored by a cluster of resource recovery companies that could utilize streams of discards from home, industry, government, and farm sources. See the resulting paper. The Alameda Country Waste and Recycling Commission is seeking tenants for this EIP.

Home  Back to Sustainable Communities EIP Handbook
We have produced a new and revised edition of our Eco-Industrial Parks Handbook under contract with the Asian Development Bank. The citation is:


We are no longer publishing the original Handbook since the new edition contains major new material. You can download this new version as MS Word 97 files from this page: [ADBHBdownloads.html](ADBHBdownloads.html)

EIP Handbook Overview

The Asian Development Bank asked me to prepare this new edition of our Eco-Industrial Park Handbook specifically for developing countries in Asia. The purpose of this publication is to support the many stakeholders in industrial development who seek a sustainable path for industry in this major region: real estate developers, industrial leaders, economic and environmental policy-makers, financiers, leaders of non-governmental organizations, and leaders of communities that host industrial parks and facilities.

To serve this purpose, the new Handbook includes an overview of each facet of industrial park development. It ranges from the soft
infrastructure of policy, finance economic development, urban planning, and education to the specific architectural, technical, recruitment, and management considerations in industrial park design. It includes many Asian examples as well as ones from elsewhere. In each chapter there are sources of print and electronic information to find more information.

I have made many changes in this EIP Handbook, based on my learning in the last six years from my work with eco-industrial initiatives as well as the experience of my many colleagues in this field. I have revised most chapters extensively and there are several completely new ones (since the 1995 edition for US-EPA). These changes are necessary because this has been a time of rapid change in the state of industrial development and its impacts on nature and society. There are no signs that the pace of change is slowing so you will be able to find updates regularly at this web site.

Real estate developers, industrial plant planning teams, economic development and urban planning personnel, public works managers (especially in solid and liquid waste and energy infrastructure), architects and environmental protection staff can all benefit from using the Handbook. It is also a valuable college text for courses in any of these subjects.

This new edition of the EIP Handbook may focus on the sustainable development needs of developing countries in Asia, however, the basic principles and strategies are applicable anywhere.

Geng Yong, a Chinese industrial ecologist and colleague at Dalian University of Technology, is preparing a Chinese language edition of the Eco-Industrial Park Handbook. Watch for news of its release in the first half of 2002 on the What's New page of this web site.

--Ernest Lowe

Eco-Industrial Park Handbook Table of Contents

Executive Summary

Preface and Acknowledgements

1. Introduction
1.1. Applied Common Sense and Whole Systems Thinking  
1.2. Defining Eco-Industrial Parks  
1.3. EIP Benefits and Risks  
1.4. The EIP: A Menu of Opportunities  
1.5. A Brief History  
1.6. Why Developing an EIP is an Inquiry Process

2. Foundations  
2.1. Cleaner Production and Industrial Ecology  
2.2. Sustainable Architecture, Construction, and Planning  
2.3. New Organizational Relationships

3. EIPs and the Local Community  
3.1. Public Private Partnership  
3.2. Building the Context for an EIP  
3.3. Building Your Local Vision  
3.4. Closer Integration of Industrial Parks and the Community  

A Partnership Between an Eco-Park and the Community for Greenhouse Gas Reductions

4. Planning and Development of Eco-Industrial Parks  
4.1. Ownership Public or Private?  
4.2. Site selection process  
4.3. Predevelopment and feasibility studies  
4.4. EIP Marketing Analysis and Recruitment Strategy  
4.5. Project Organization  
4.6. Environmental Standards in Development

5. Financing Eco-Industrial Parks  
5.1. Introduction  
5.2. Levels of EIP Financing  
5.3. Basic steps in forming Public Private Partnerships (PPP)  
5.4. The Community Capital Investment Initiative  
5.5. Partnership Between the Developer and the Tenants  
5.6. An Investment Fund
5.7. An Action Foundation  
5.8. Positioning Your EIP for Investment  
5.9. Reducing the Risks  
5.10. Funding Dedicated to Sustainable Development  
5.11. Resources for Financing  

6. The Emerging Sustainable Economy and EIP Recruitment Themes  

6.1. Toward a Sustainable Economy  
Increased efficiency and use of renewable energy and material resources  
Ecologically-aware design of communities and the built environment  
Sustaining and renewing natural systems  
Redesign of public and private sector organizations  

6.2. EIP Recruitment Themes  
Agro-Industrial Parks  
Resource Recovery Parks  
Renewable Energy Industrial Parks  
Petrochemical Parks  
Power Plant Parks  

7. Eco-Industrial Policy  

7.1. Introduction  
7.2. Integration of Policy and Policy Organizations  
7.3. Place-Based Policy  
7.4. Resource-Based Policy  
7.5. Incentives  
7.6. Research Partnerships  
7.7. Umbrella Permitting and Programmatic EIA  
7.8. Energy Policy  
7.9. Anti-Corruption Policy  

8. Design Strategies for Eco-Industrial Parks  

8.1. EIP Design Processes and Tools  
8.2. Site Assessment and Planning
8.3. Design of Physical Infrastructure
8.4. Industrial Facility Design
8.5. Building Design
8.6 Sustainable Design in Asia

9. Construction and Implementation

9.1. Construction Process
9.2. Implementation of Economic and Social Programs
9.3. Redesign for Error-correction

10. Management of Eco-Industrial Parks

10.1. There Are Two Management Interests in an EIP
10.2. The Functions of EIP Management
10.3. Key Management Issues
10.4. The Operations Room
10.5. Shared Support Services
10.6 Environmental Management Systems

11. Greening Existing Industrial Parks

11.1. Working with Existing Industrial Parks and Their Tenants
11.2. Guidelines for Self-assessment Audit of Industrial Parks
11.3. Models for Cleaner Production Centers
11.4. Eco-Industrial Networks
11.5. Checklist of Other Handbook Sections Useful for Existing Parks

12. Creating By-Product Exchanges

12.1. Implications for Industrial Park Development
12.2. BPX Across Multiple Sites or in a Region
12.3. The Self-Organizing Model
12.4. The By-Product Utility

13. Appendix

13.1. Project Profiles
13.2 Supplementary Information
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