Eco-Industrial Development
A 21st Century Strategy for Industrial Sustainability
Concepts and Applications

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In order to achieve long-term sustainability, transformation in industrial sectors is essential. This will not be easy, but major reductions in resource intensity and emissions from redesigned production systems can lead to a new level of environmental improvements and sustainable economic growth.
“In an industrial ecosystem, consumption of energy and materials is optimized, waste generation is minimized, and the effluents from one process serve as the raw material for another.”

Frosch and Gallopoulos, Strategies for Manufacturing, Scientific American, 1989
Industrial Ecology is the Discipline Driving the Practice of Eco-Industrial Development

IE concepts can be applied on different scales

<table>
<thead>
<tr>
<th>Within Firm</th>
<th>Across Firms</th>
<th>Regional/Global</th>
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<td>industrial symbiosis</td>
<td>balanced ecological budgets and cycles</td>
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<td>clean production</td>
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Industrial Symbiosis

Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage, involving the physical exchange of materials, energy, water, or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity.

Kalundborg
Financial Benefits

- Capital investment = $75 Million
- Annual return = $15 Million
- Average simple payback = 2-5 years
- Average internal rate of return = 19.5%

Source: Marion Chertow Yale
Kalundborg
Environmental Benefits

Reduction in consumption of primary resources

- oil 45,000 tons/year
- coal 15,000 tons/year
- water 600,000 m³/year

Reduction in waste emissions

- carbon dioxide 175,000 tons/year
- sulfur dioxide 10,200 tons/year

Valorization of "wastes"

- sulfur 4,500 tons/year
- calcium sulfate (gypsum) 90,000 tons/year
- fly ash (for cement etc) 130,000 tons/year

Source: Marion Chertow Yale
Cascading

Occurs when a resource, such as water or energy, is used repeatedly in different applications. In successive uses, the resource is of lower quality, a lower level of refinement, and/or lower value. By definition, a cascade must include at least one use beyond the virgin use of the resource.

Source Marian Chertow Article on Industrial Ecology February 2008
By-Product Synergy

Involves matching of undervalued waste or by-product streams from one facility with users at another facility to create new revenues or savings with potential social and environmental benefits.

The process may involve the physical exchange of materials, energy, water and/or by-products and represents a crucial business opportunity to innovate across industrial processes and organizations by exercising best practices in waste reduction and environmental mitigation.

Source A. Mangan US Business Council for Sustainable Development and E. Olivetti Massachusetts Institute of Technology
Byproduct Exchanges

- North America’s single largest recycling operation
- Recycling calcium sulfite waste of coal power plant
- Gypsum board manufacturer: recycled paper use and zero wastewater
- 100 new jobs and $115 million new capital investment

First Energy & National Gypsum, Pennsylvania
## Eco-Industrial Networking

Can Involve Inter-firm Collaboration on Multiple Levels

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<th>Energy</th>
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<th>Production Processes</th>
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<td>Scrap Reduction and Reuse</td>
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<td>Design for Environment</td>
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<td>Shared EIS</td>
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<td>Joint Regulatory Permitting</td>
<td>Technology Sharing and Integration</td>
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<td>HR Recruiting</td>
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<td>Joint Promotions</td>
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<td>Green Labeling</td>
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<td>Accessing Green Markets</td>
<td>Common Needs</td>
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<td>Recruiting New Value Added Companies</td>
<td>Employee Training</td>
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Eco-Industrial Development
Applies Advanced Environmental Strategies

- Industrial symbiosis and byproduct exchanges
- Eco-parks or clusters
- Clean renewable energy and sustainable materials
- Closed loop water and waste recovery systems
- Clean production and eco-efficiency
- Green chemistry and design for the environment
- Zero waste and emissions
- Greening supply chains
- Eco-enterprises and clean technologies
- Sustainable design methods
Eco-Industrial Development

Can take many forms
- Network of co-located businesses
- Energy, technology, agricultural, other cluster drivers
- Brownfields or greenfields
- One or many facilities, can be a mix of commercial/industrial

Inherently reflects local characteristics
- Resource base and material-energy-water flows
- Regional assets and socio-economic conditions
- Existing industrial and institutional activity
- Community goals for employment, environmental quality and growth
Integrates Ecological Design into Industrial Development

- Requires a proactive approach applied in early stages of industrial development projects.

- Provides a way to integrate industrial ecology concepts and methods to create eco-industrial facilities and parks.

- Can be complex and linked to larger community development efforts in the region supporting the industrial development.
Embraces Industrial Transformation

- Rethinks development paradigms
- Applies industrial ecology models
- Establishes intentional design
US Eco-Industrial Development Examples

**ENERGY-BASED**

- Red Hills Ecoplex
  - Choctaw County, MS

**ENVIRO TECH**

- Chicago Center for Green Tech
  - Chicago, IL

**HYBRIDS**

- Riverside Eco-Park
  - Burlington, VT

**ECO-PARKS**

- Silver Bay, MN

**MATERIALS RECOVERY**

- Hillman Industrial Park
  - Hillman, MI

- Cabazon Resource Park
  - Indio, CA

**ENVIRO TECH**

- Chicago Center for Green Tech
  - Chicago, IL

- Fort Devens
  - Devens, MA

**ECO-PARKS**

- ReVenture Park
  - Charlotte, NC

- Londonderry Eco-Park
  - Londonderry, NH

- Spiritwood Station
  - North Dakota
EID Projects in North America
What is an Eco-Industrial Park?

“A community or network of companies and other organizations, in a physical park, who choose to interact by exchanging and making use of byproducts and energy in a way that provides one or more... benefits over traditional, non-linked operations."

Benefits can include:

- Reduced natural resource inputs
- Reduced pollution - energy use – wastes
- Increases in value of non-product outputs

Extrapolated from Gertler 1995
Londonderry NH Eco-Park

- Power plant & City wastewater treatment plant
- Cooling water for combined-cycle power plant from treated municipal wastewater
- 4 million gallons/day
- Power plant has lower cost water, permitting charges

Water is further purified by plant and evaporated or discharged to river (cleaner than before). Project provided developer simple payback – less than one year.
Since 2001 the State of Minnesota has fostered Eco-Industrial Development initiatives.

The strategy has supported eco-industrial opportunities to:

- Achieve superior environmental performance
- Enhance community sustainability
- Gain a competitive edge in the green economy

The premise is that EID:

- Involves more integrated design of industrial facilities, complexes, and supply chains
- Can create more advanced, competitive, and cleaner industrial operations across production systems rather than just within an individual facility
- Provides the means to capture economic development including clean green enterprises
City of St. Peter, MN
Eco-Industrial Development Feasibility Study 2001

Saint Peter Biochemical Industrial System

Crop Waste
- Synthetic Gas
  - Soy Oil
  - Soy & Other Seed Oils
    - Glycerin (Soaps, Fertilizers, etc.)
      - Biodiesel Refinery
        - Biodiesel
          - 12 MW Peaking Plant

Fertilizer
- Corn Oil
  - Corn
    - Waste Heat
      - CO₂
        - Aquaculture
        - Greenhouses
          - Community Food System

Synthetic Gas
- Synthetic Gas
  - Bio Lubricant Refinery
    - Animal Feed
      - Animal Production
        - Municipal Wastewater Treatment
          - Treated Wastewater

Waste Grain
- Ethanol Refinery
  - Treated Wastewater

Prepared by e4 partners, inc.

- Existing or planned asset
- New Operation - active recruitment
- New Operation - no recruitment to date

www.e4partners.com
Involves Facility Design Transformation
Silver Bay Eco-Industrial Business Park Study 2009

Mission Statement

To network businesses to work with each other and the Silver Bay Community in order to create and diversify living wage employment, by improving resource productivity, eliminating pollution and expanding markets through renewable sustainable energy development.
Silver Bay Renewable Energy Facilities
Engineered Green Infrastructure

A publicly owned utility service for the generation, production and distribution of renewable, sustainable combined heat and power system for the citizens and businesses of Silver Bay.
Integrated Renewable-Based Energy System

Three Forms of Energy Generation in Eco-Park

- Biomass Binary Combined Heat and Power
- Wind / Solar
- Biodiesel though Algal Growth
Environmental and Economic Benefits

- The renewable CHP system will result in a minimal amount of waste and displace approximately 150,000 tpy CO2 emissions.

- It will increase fuel efficiency from about 37 percent, in utility sized coal fired electric power plants, to about 75 percent.

- Complete system emissions at maximum potential to emit will be less than 235 tpy.

- Utilization of 100,000 tpy of wood pellets, displacing a 50/50 mix of propane and fuel oil, yields a total of 127,500 tpy of CO2 displaced.

- Approximately forty (40) construction jobs, fifteen (15) permanent pellet plant operating and 6 logging jobs could be created.
Silver Bay Eco-Park Greenhouse Production

Wind-Algae-Rain-Food Synergistic Systems

- **Wind**
- **Solar**
- **Biodiesel**

**Greenhouse Production System**

- **Rain water & Lake Superior**
- **Fish**
- **Algae**
- **Setsing Basin**

**Inputs**
- **Biodiesel**
- **Energy**
- **Alg**
- **Fish**
- **Food**
- **H₂O**
- **Biodiesel emissions**

**Outputs**
- **Biodiesel Revenue**
- **Fish Meat Revenue**
- **Produce Revenue**
- **Plant Material Algae Cellulose Inputs**

**Processes**
- **Clean water**
- **Nutrient water**
- **Fish compost for soil**
- **Water loss, plant uptake and evaporation**

**Connections**
- **Fish** to **Algae**
- **Algae** to **Fish**
- **Fish** to **Biodiesel**
- **Biodiesel** to **Energy**

**Revenue Streams**
- **Fish Meat**
- **Produce**
- **Plant Material Algae Cellulose Inputs**

**Environmental Benefits**
- **Clean water**
- **Nutrient water**
- **Settling Basin**
Itasca Eco-Park Grand Rapids, MN 2011

- Proposed $5 million redevelopment to transform 223 acre wood products mill site

- Integrated multi-tenant industrial park and incubator for renewable energy and other related businesses

- Opportunity to cluster synergistic businesses to reduce operating costs and maximizes competitive advantages

- 2011 U. S. EDA awarded $1.75 million to advance the project.

- Expected to create 175 jobs and generate $45 million in investment.
Key Lessons

- Eco-Industrial Development takes time and requires a paradigm shift in the way we currently approach industrial development.

- New planning, design, business, and community development models and approaches are necessary.

- Opportunities are emerging and communities are exploring EID via green industrial parks, green manufacturing, and other green economy initiatives.

- There must be a continuum lead by champions followed by early adopters.

- Barriers abound; institutional, existing policies, human resistance to change, lack of resources, and main stream business drivers.

- It takes cross-jurisdictional collaboration to be successful.

- Resources from multiple public and private organizations are necessary.