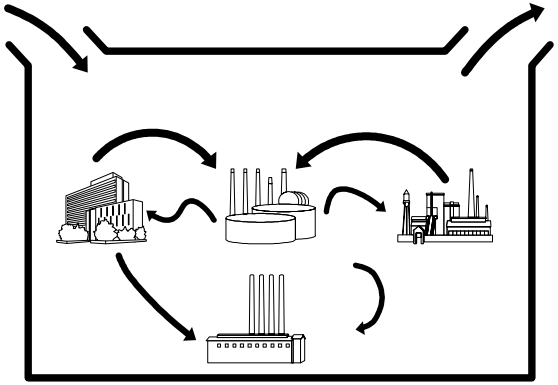
A PRIMER ON INDUSTRIAL ECOSYSTEMS

A STRATEGY FOR SUSTAINABLE INDUSTRIAL DEVELOPMENT



Compiled by

Raymond P. Côté

Industrial Ecology Research and Development Group
School for Resource and Environmental Studies
Faculty of Management
Dalhousie University
Halifax, Nova Scotia

INDUSTRIAL ECOSYSTEMS

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 which is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only.

Lowe, Moran, Holmes, 1996

ECO-INDUSTRIAL DEVELOPMENT PRINCIPLES AND STRATEGIES

There are at least four terms in use in the literature which mean more or less the same thing. These are industrial ecosystem, eco-industrial park, eco-industrial network and eco-industrial development. For purposes of the Canadian Eco-Industrial Network, the term eco-industrial network will be used. Other related terms such as industrial symbiosis and by-product synergy have a more limited perspective although they are important components of an eco-industrial development complex. Eco-industrial networks can range from limited symbiotic relationships involving a few materials and companies to fully mature industrial ecosystems in which infrastructure, buildings and products are designed and used in cyclical and sustaining ways.

The two key descriptors in the term are eco- and networking. In this context, eco- is derived from ecological but it could just as easily have referred to economic. In fact, the first mentions of ecology refer to it as nature's economy. Ecology refers to the structure of the 'household' while economy describes the management of the 'household'. Both structure and management have much to do with relationships and systems. Ecology, of course, is the study of the inter-relationships among species and communities of organisms and the physical environment in which they live. The word network is more generic and refers to chains or connections. Thus, while there may seem to be some redundancy in the terms, network serves to reinforce the underlying concept.

There has been much debate about what is encompassed in the terms industrial ecosystem, eco-industrial park, eco-industrial development and eco-industrial network. These four terms appear to be the most prominent in the current literary landscape at the moment. Eco-industrial park has been used to describe almost any kind of community of businesses which features some ecological characteristics whether located in the confines of a traditional industrial park or not. Industrial ecosystem, somewhat surprisingly, has not gained as much favour in the young industrial ecology literature, even though the term was used in what is widely regarded as the seminal article in the field by Frosch and Gallopoulos in 1989, and ecosystems are the cornerstones in the conventional field of ecology.

Although the field of industrial ecology is a relatively new field of study, there is some consensus developing on the major concepts and strategies. An eco-industrial development is interpreted as a "community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resources issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit which is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only" (Lowe, Moran and Holmes, 1996). The President's Council on Sustainable Development of the United States also recognizes that a) the community of businesses must cooperate with the local community, b) the resources which should be shared include information, infrastructure and the natural habitat and c) the sharing must be equitable.

The principles put forward by Lowe et al focus almost exclusively on technical matters. The human and social dimensions receive no consideration. This area has been addressed by Cote and Cohen-Rosenthal among others. They identify a number of networking possibilities which should be considered in eco-industrial development. In addition to symbiotic relationships involving materials and energy, they point to networking in transportation (car pooling), human resource management (training), information and communications (management information systems), marketing (joint promotions), environment, health and safety (emergency response planning), production (equipment pooling), and quality of life (integrated volunteer programs).

The current state of affairs may be a reflection of the realization that our industrial systems are still at a very early stage of evolution, i.e. hundreds rather than millions of years, and therefore understandably immature. The linear thinking in our industries and the high flow-through of materials and energy are testament to this fact. Chertow (1999) uses a different analogy and refers to the state of eco-industrial parks as similar to that of "Visicalc" in the early computer software. On this basis, then, the terms eco-industrial development and network may be the most appropriate to use in these circumstances. For our purposes in Canada, we have selected eco-industrial network (Canadian Eco-Industrial Network).

In their seminal work, "Fieldbook on the Development of Eco-Industrial Parks" prepared for the U.S.EPA, Lowe, Warren and Moran described the key characteristics of a fully developed eco-industrial park:

- integration into natural systems recognizing the constraints of local ecosystems, especially the capacity to assimilate wastes;
- maximization of energy efficiency through design, cogeneration, inter-plant energy flows and increased use of renewable sources;
- site-wide design of material flows and waste management, ensuring maximum reuse and recycling of materials including water, reducing dissipation of toxic chemicals and linking companies with the community and other businesses in the surrounding area;
- appropriate construction and rehabilitation of buildings and sites, following best environmental practices
- effective management by maintaining the appropriate mix of companies, creating a site-wide information system and encouraging continuous improvement.

In their subsequent book, "Discovering Industrial Ecology - An Executive Briefing and Sourcebook", Lowe, Moran and Holmes identify a number of principles of industrial ecology:

- connect individual firms into industrial ecosystems
- close loops through reuse and recycling
- maximize efficiency of material and energy use
- minimize waste generation
- think of wastes as potential products
- balance inputs and outputs to natural ecosystem capacities
- reduce the environmental burden created by releases
- design the industrial interface with sensitivity to the natural environment
- minimize creating and transporting toxic and hazardous materials
- design industrial use of materials and energy
- redesign processes
- substitute technologies and materials
- do more with less
- align policy with a long term perspective

The study by McCann et al and the Alberta By-Product Synergy project have identified a number of possible ways of closing loops and using by-products. From a planning point of view, there remains much to be done in

reducing the environmental burden of releases and designing the industrial interface with the natural environment of the area. However there are ideas which can be considered. These would include setting aside land for plantations which would serve as carbon dioxide sinks. Such plantations would not be large enough to compensate for the CO2 emissions of the Industrial Heartland but they would play a role not only in mitigating effects but also providing some employment and renewable materials. They could also serve to further protect significant natural areas such as wetlands and watercourses.

In that column in the Journal of Industrial Ecology (Vol.2, No.3, 8-10) Chertow suggests a continuum of industrial symbioses which describe inter-relationships among businesses. These are waste exchanges involving two or more companies; life-cycle management of all materials used by one facility or company; multiple exchanges of resources among several firms in an industrial park; material and energy based relationships among firms within a industrial zone or part of a city or region; a virtual ecosystem in which networking of various types occurs over a larger area.

Lowe et al, Cohen-Rosenthal and Cote all agree that industrial ecosystems must be more than:

- a local waste exchange
- a recycling business cluster
- a district heating or cogeneration project
- a collection of environmental technology companies
- environmentally sensitive landscaping
- environmentally friendly infrastructure
- an industrial park developed around a single environmental theme.

Cote et al have suggested some characteristics of an industrial park operating as an ecosystem. In his view, an industrial area operating as a mature ecosystem would involve:

- the industrial activity would take into account the ecological capacity of the area, paying particular attention to the assimilative capacity of the air, water (surface and ground), and soil to absorb emissions;
- energy production would be based increasingly on renewable resources, and at least increase the efficiency of current energy production and use through cogeneration and district heating;

- buildings would be designed and built to optimize conservation of heat and water, while enabling disassembly for reuse, and recycling at the end-of-life;
- landscaping would use indigenous plants and be designed to support building heating and cooling;
- industries and businesses would be selected based in part on their compatibility for symbiosis;
- management of the development would encourage a web of businesses involving not only producers and consumers but scavengers and decomposers to support cycling of materials;
- redundancy in materials sources would be built into the structure of the system;
- dissipative uses of materials and energy would be discouraged;
- management would establish a common information management system which would facilitate networking.

In a 1997 paper, Ehrenfeld and Gertler reviewed a number of emerging eco-industrial park initiatives and concluded that the key elements of successful eco-industrial networking are:

- adequate financial support for the management infrastructure with a strong public-private partnership;
- a regulatory framework which emphasizes flexibility, continuous improvement, community participation and environmental management systems;
- financing and taxes which have flexibility, encourage the creation of local investment funds, and promote the reduction of waste and enhanced efficiency;
- linking community economic development and community business organizations;
- labour involvement through skills development programs;
- transportation logistics which encourages efficiency, multi-modal approaches, sharing of facilities and public transportation;
- access to land to support co-location;
- sharing of information on operations especially on products and by-products;
- medium to large size industries which can anchor the network;
- private and public sector champions, especially at the local level.

Although there is still some evolution and maturation that must occur in defining and implementing eco-industrial development, it is quite clear that it should involve multiple organisms, not only businesses but other institutions within communities, multiple materials (and energy), and multiple relationships. As a start, a symbiosis may be initiated by collaboration between two facilities involving one material, e.g. hot water, but an eco-industrial development or industrial ecosystem must eventually grow into a network or web.

Sustainable industrial development will require attention not only to ecological and economic aspects but also social dimensions. In this way, perhaps we can be assured that the whole is more than the sum of its parts, a functioning inter-dependent system.

References

Applied Sustainability Ltd. 1999. Alberta By-product Synergy Final Report.

Chertow, M. 1999. The Eco-industrial park model reconsidered. Journal of Industrial Ecology, Vol. 2, No. 3, pp. 8-10.

Côté, Raymond P. and E. Cohen-Rosenthal. 1998. Designing eco-industrial parks: A synthesis of some experiences. Journal of Cleaner Production, Vol. 6, No. 3/4, pp. 181-188.

Côté, Raymond, Robert Ellison, Jill Grant, Jeremy Hall, Peter Klapstra, Michael Martin, Peter Wade. 1994. Designing and Operating Industrial Parks as Ecosystems. Halifax. School for Resource and Environmental Studies, Dalhousie University.

Ehrenfeld, J. and N. Gerther. 1997. Industrial ecology in practice: The industrial ecosystem at Kalundborg. Journal of Industrial Ecology, 1(1): 67-79.

Frosch, Robert A. and Nicholas E. Gallopoulos. 1989. Strategies for manufacturing. In: Managing Planet Earth. A special issue of Scientific American. New York, W.H. Freeman and Company, pp. 97-108.

Lowe, E.A., J.L. Warren and S.R. Moran. 1997. Discovering Industrial Ecology: An Executive Briefing and Sourcebook. Columbus: Battella Press, 190 pp.

McCann and Associates. 1999. A Strategy for Development in Alberta's Industrial Heartland: Eco-Industrial Networking. Edmonton: Industrial Heartland Association.

Industrial Ecology Vocabulary

Examples of terms used in ecology which can be applied to industrial systems.

Adaptation: The adjustments that occur in companies in respect to their environment.

Diversity: The richness of companies, the complexity of the industrial system, and the variation among companies in an industrial park.

Carrying capacity: The maximum population of a given type that a particular industrial park or zone can sustain.

Commensalism: The interaction between businesses in which one company benefits and the other is not affected.

Decomposer: A business that enables recycling by breaking down materials into simpler compounds.

Ecosystem: A more or less discrete unit consisting of people, businesses and physical and chemical components on which they depend.

Food web: The interacting relationship of businesses within an industrial system based on transfer of energy and materials.

Heterotroph: A business which does not process its own compounds or materials but combines them to manufacture products.

Life cycle: A series of stages in the production, use and disposal of materials, products or buildings.

Metabolism: The total of the flows or interactions that occur within a business or within the businesses connected in a supply chain.

Mutualism: Interaction between companies which benefits two or more of them.

Niche: The functional position of a business in its environment.

Polymorphism: The occurrence of two or more forms of a business, product or service.

Synergism: The combination of businesses or factors influencing businesses which results in a greater effect than would occur independently.

Symbiosis: The interaction between companies in which the wastes of one become the raw material for another.

Industrial ecosystems and Eco-industrial networks

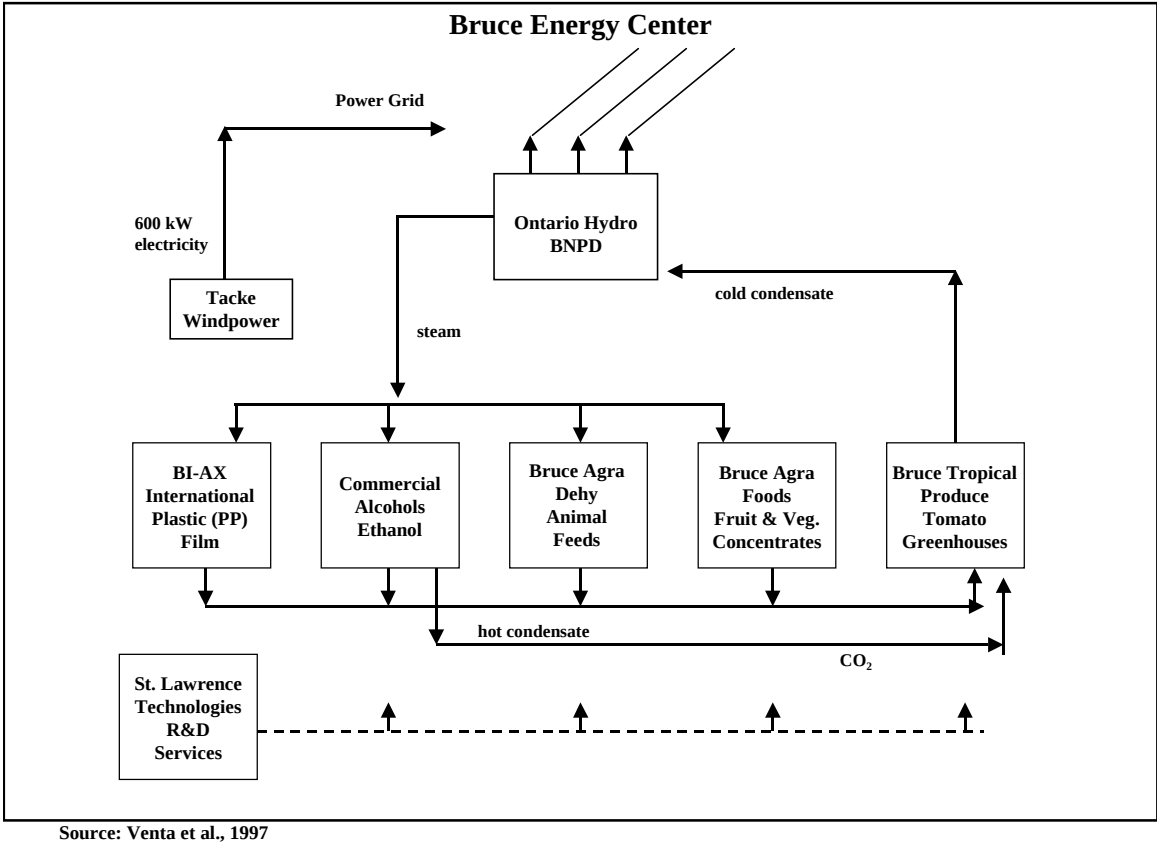
Various types of networks, webs or systems are emerging in theory and practice:

1. Some networks are linked by one material. In the case of the Bruce Energy Center in Ontario, water as steam and condensate is the connecting material. The steam is generated by the power station and cycled through several industries before returning to the power plant.

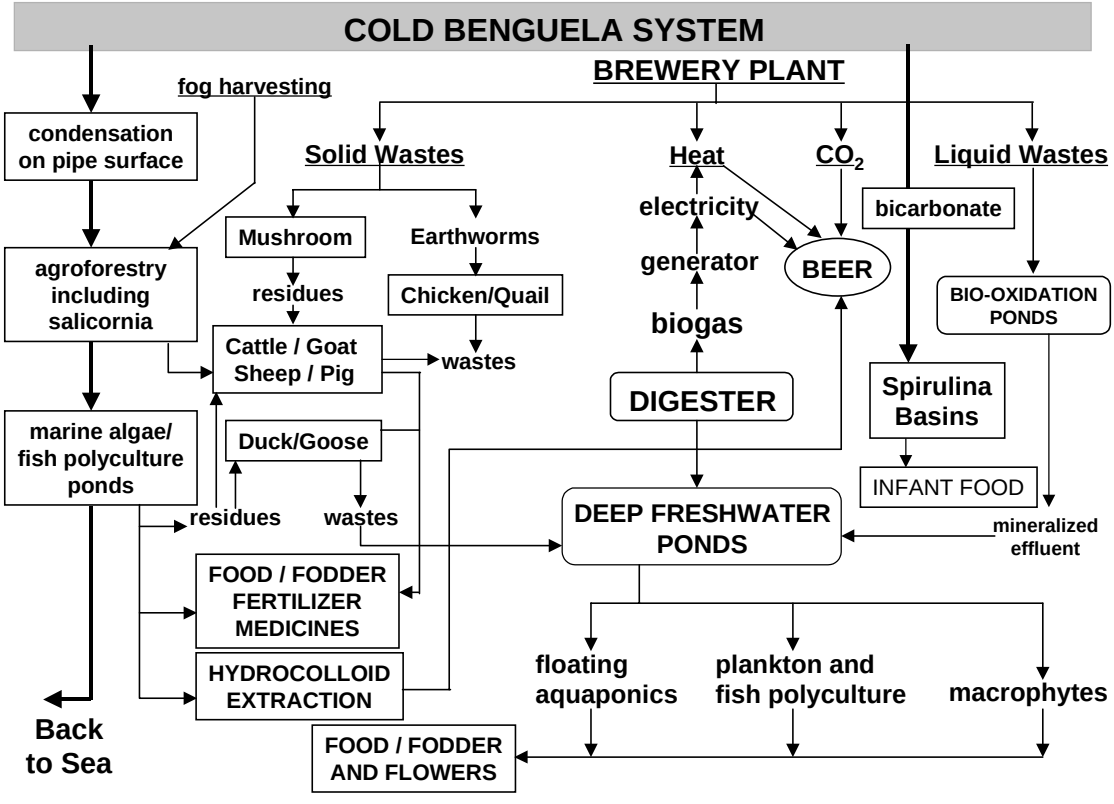
2. In the second case, a central industry, a brewery, is the focal point of the system. The brewery generates a number of by-products which can be used as inputs for other businesses, and in turn, other products are created. Components of this system are in production in Fiji, Namibia and China.

3. The third case is a well-known example of industrial symbiosis in Kalundborg, Denmark. In this case, several industries and a town are linked through a variety of materials. The cost saving and environmental benefits of this symbiosis have been substantial.

4. The final case in the primer involves a waste exchange network in a four county area around Research Triangle Park in North Carolina. In the Triangle J area a large number of by-products and wastes are being exchanged and more have been identified.



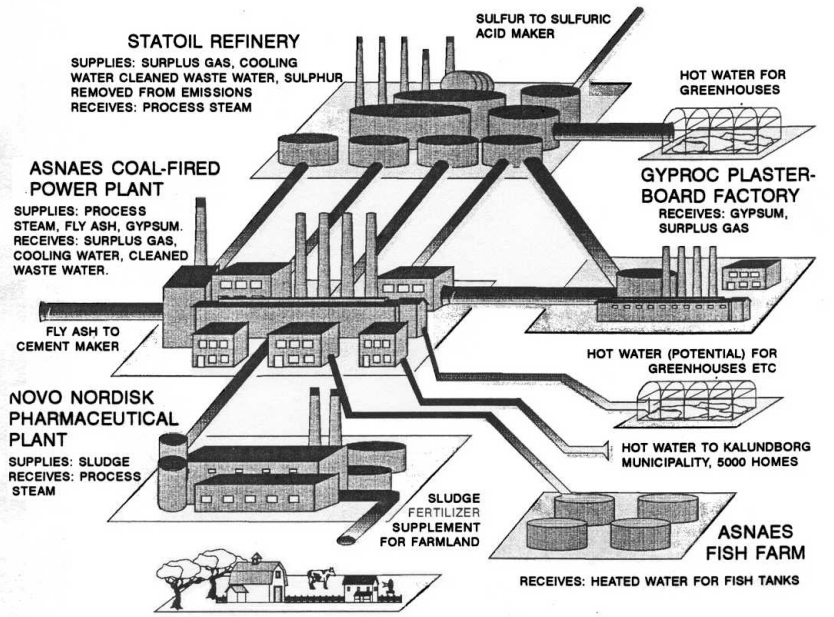
Source: Venta et al., 1997



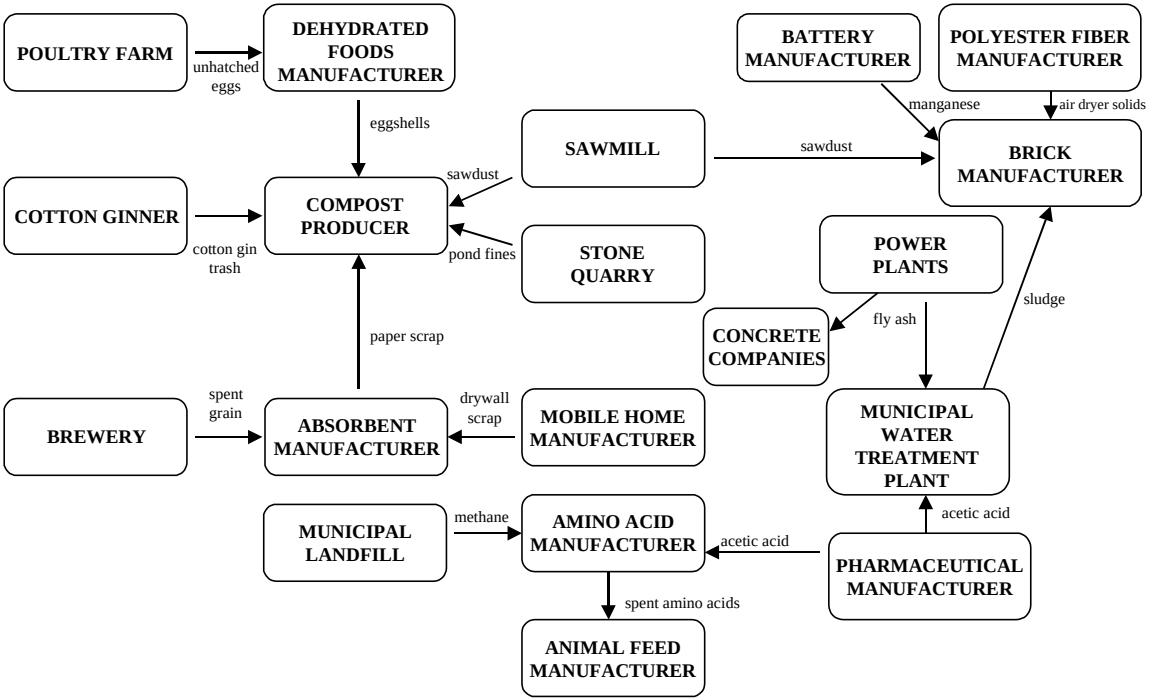
Main Products: beer, mushrooms, earthworms, micro-algae, fish, methane gas, plants

Kalundborg Industrial Symbiosis

DENMARK



Examples of Current Local Partnerships in the Triangle Region



Triangle J Council of Governments 9/2/98

Guidelines for "Win-Win" Projects - Industrial Ecology

The environmental performance of industry can be improved by applying models of the biophysical environment to industrial production. One emerging concept for the development of industrial ecology principles is the Eco-industrial Park (EIP): communities of manufacturing and service businesses that aim to enhance their environmental and economic performance through collaboration in managing environmental issues and resources-including energy, water, and materials. Components of this approach include new or retrofitted design of infrastructure and plants, pollution prevention, and energy efficiency. Strategies for designing successful industrial parks include:

Integration into Natural Systems

- Design the EIP in harmony with the characteristics and constraints of local ecosystems
- Minimize contributions to global environmental impacts, such as greenhouse gas emissions

Energy Systems

- Maximize energy efficiency through facility design or rehabilitation, co-generation, and energy cascading
- Achieve higher efficiency through inter-plant energy flows
- Use renewable sources extensively

Materials Flows and "Waste'Management

- 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
- 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

- Maintain a mix of companies needed to best use each other's by-products
- Support improvement in environmental performance for individual companies and the park as a whole
- Operate a site-wide information system that supports inter-company communications. informs members of local environ-mental conditions, and provides feedback on EIP performance

ConstructionlRehabilitation

- New construction or rehabilitation of existing buildings should follow best environmental practices in materials selection and building technology, recycling or reuse of materials and consideration of lifecycle environmental implications of materials and technologies

Source:

Watson, R.T., Dixon, J.A., Hamburg, S.P., Janetos, A.C. and R.H. Moss. 1998. *Protecting Our Planet Securing Our Future. Linkages Among Global Environmental Issues and Human Needs*. United Nations Environment Programme. U.S. National Aeronautics and Space Administration. The World Bank. November 1998.

Benefits and Opportunities with an Industrial Ecology Approach

Industrial ecology is a systems approach to the analysis of the flows of materials and energy considering the life cycle of products, the design of buildings, infrastructure and industrial parks, and the reuse, recovery and recycling of resources in a manner which is cleaner, and more efficient. The approach recognizes the connectedness of materials, products and infrastructure to ecological functions and services provided by the natural environment.

It is directed at:

- Finding cost savings and new revenues in existing operations;
- Creating new markets for existing goods and services;
- Developing new technologies, processes and products;
- Identifving new organizational, legal and economic innovations;
- Developing infrastructures which encourage exchange, reuse, and recycling;
- Addressing cumulative effects of production and consumption.

For Govemment, the benefits include:

- Enhancing the efficiency of resource use:
- Enhancing the recovery of materials from the consumption system;
- Reducing the cost of industrial infrastructure;
- Supporting the sustainability of communities;
- Identifying new economic development opportunities;
- Encouraging innovation in environmental management and regulation.

Technology Development Opportunities:

- Chemical processes which produce toxic intermediates on demand and in smaller quantities;
- Catalysts which are readily recoverable;
- Bioengineered bacteria capable of decomposing complex materials;
- Low temperature production processes;
- Biopolymers for packaging, adhesives, absorbents, lubricants and other products;

- New recycling and recovery technologies;
- R&D into new materials composed of recycled resources.

Manufacturing Opportunities:
- Material processing equipment;
- Companies altering by-products physically or chemically to meet customer specifications;
- Infrastructure built to efficiently separate and cycle flows of materials, water, heat within and between plants;
- Product remanufacturing

Business Management Opportunities:
- Brokerage firms to handle sales or purchases of by-products;
- Management firms offering comprehensive investment recovery services redeploying, recovering or marketing idle, obsolete, unused equipment or materials;
- Ecosystem restoration firms;
- Organizational design consultants;
- Information management firms;
- Architects and designers of buildings, infrastructure products.

The Industrial Park as an Ecosystem Project Publications

1. Peck and Associates and Raymond P. C^tJ. 1997. Promoting Eco-Industrial Development: Exploring benefits, challenges, drivers and opportunities for progress in Canada. A report to Environment Canada and Industry Canada, Ottawa. (Available from Environment Canada, Ottawa).

2. United Nations Environment Programme. 1997 Environmental Management of Industrial Estates. Technical Report No. 39 prepared for United Nations Environment Programme - Industry and Environment. By R.P. Côté and H. Reid. (Available from SMI Ltd., P.O. Box 119, Stevenage SG1 4TP UK. Fax: 44-1438-748-844 or UNEP, Paris)

3. Côté, R.P., T. Kelly, J. MacDonnell, T. Mermer, R. Murray, T. Smolenaars. 1996. The Industrial Park as an Ecosystem: Sectoral Case Studies, School for Resource and Environmental Studies, Dalhousie University, Halifax, NS. ($20)

4. Côté, R.P., T. Kelly, H. Reid, T. Smolenaars. 1996. The Industrial Park as an Ecosystem: Cross Sectoral Case Studies, School for Resource and Environmental Studies, Dalhousie University, Halifax, NS. ($20)

5. Côté, R.P. and J. Hall (eds.). 1995. The Industrial Ecology Reader, School for Resource and Environmental Studies, Dalhousie University, Halifax, NS. ($25)

6. Côté, Ray, Robert Ellison, Jill Grant, Jeremy Hall, Peter Klynstra, Michael Martin, Peter Wade. 1994. Designing and Operating Industrial Parks as Ecosystems. School for Resource and Environmental Studies, Faculty of Management, Dalhousie University, Halifax, NS. ($25)

Published and Conference Papers:

1. Côté, Raymond P. 2000. Exploring the analogy further. Journal of Industrial Ecology, Vol. 3, No. 2/3, pp. 11-12.

2. Côté, Raymond P. 1999. Industrial ecology and small business: Experiences from Burnside Industrial Park. Presented at a US Environmental Protection Agency workshop, November 16, Washington, DC.

3. Côté, Raymond P. 1998. Industrial ecosystems: Evolving and maturing. Journal of Industrial Ecology, Vol. 2, No. 1, pp. 9-11.

4. Côté, Raymond P. 1998. Thinking like an ecosystem. Journal of Industrial Ecology, Vol. 2, No. 2, pp. 8-10.

5. Côté, Raymond P. 1998. Les écosystèmes industrielles: une stratégie pour le développement durable de Sorel-Tracy. Presented at L'écologie industrielle: une strategie de developpement. Conference internationalle, 15, 16 et 17 Juin, 1998, Sorel, Quebec.

6. Côté, Raymond P. and E. Cohen-Rosenthal. 1998. Designing Eco-Industrial Parks: A synthesis of some experiences. Journal of Cleaner Production, Vol. 6, pp. 181-188.

7. Ashford, N. and R. P. Côté (eds.). Special Issue of Journal of Cleaner Production on Industrial Ecology. Elsevier Publishing. Vol. 5 Nos 1-2, 1997. (Available from Elsevier Press, Oxford).

8. Côté, Raymond P. 1997. Whither Industrial Ecology: The role of the ecological industrial park. Seminar presented at Johnson School of Management, Cornell University. Ithaca, New York.

9. Côté, R.P. 1995. Supporting Pillars for Industrial Ecosystems. Journal of Cleaner Production, Vol. 5, Nos.1-2, pp.67-74.

10. Grant, Jill. Designing Industrial Parks for the Future, Plan Canada, 36 (3), May, 1996. pp. 17 22.

11. Smolenaars, T. Industrial Ecology and the Role of the Cleaner Production Centre. Industry and Environment Review, United Nations Environment Programme - Industry and Environment, Paris. Oct.-Dec., 1996.

12. Côté, R.P. 1996. Industrial Ecosystems: An oxymoron. Ecocycle News Issue No. 4. Summer/Fall. Environment Canada, Ottawa.

13. Côté, Raymond and Thomas Plunkett. 1996. Industrial Ecology:

Efficient and Excellent Production. A book chapter in Achieving Sustainable Development. Environment and Sustainable Development Series, University of British Columbia Press, Vancouver. (Available from UBC Press).

14. Côté, R.P. and J. Hall. 1995. Industrial Parks as Ecosystems. J. Cleaner Production, Vol. 3, No. 1 2, pp. 41 46.

15. Martin, Michael. 1994. Natural Evolution, Artificial Evolution and User Friendly Innovation. Technological Innovation and Global Challenges, Proceedings of the International Association of the Management of Technology (IAMOT) European Conference, United Kingdom, July 1995.

16. Côté, R.P. and J. Hall. 1993. Managing Waste in an Industrial Park Ecosystem. Canadian Waste Management Conference. Saint John, New Brunswick, Oct. 6 8, 1993.

Occassional Papers and Other Related Reports:

1. Hall, J. 1994. Industrial Parks as an Ecosystem, diskette presentation, School for Resource and Environmental Studies, Dalhousie University, Halifax, NS., and Environment Canada, Dartmouth, N.S. ($5)

2. The Burnside Ecosystem: An Education Initiative for Small Business. A collection of articles written for the Burnside news by researchers involved in the project "The Industrial Park as an Ecosystem." 1993 - 1996. School for Resource and Environmental Studies, Dalhousie University, Halifax, NS. ($5)

Theses

1. Casavant, T. 2000. The use of process simulation in industrial ecology.

2. Noronha, J. 1999. The role and influence of scavengers and decomposers in an industrial ecosystem.

3. Pezzack, J. 1998. Company Ecology: A case study of a sales, marketing and distribution company.

4. Reid, H. 1995. Wasted Opportunities: A case study of the waste diversion barriers facing small businesses in Burnside Industrial Park, Dartmouth, NS.

Priced publications can be ordered from SRES Publications, at the address below. Shipping and handling charges will be added to orders sent by mail or courier.

For more information contact:

School for Resource and Environmental Studies
Faculty of Management, Dalhousie University
1312 Robie Street, Halifax, Nova Scotia
Canada B3H 3E2

Tel: (902) 494-3632 Fax: (902) 494-3728
Email: sres@is.dal.ca

WEBSITES
http://www.mgmt.dal.ca/sres
http://www.mgmt.dal.ca/sres/eco-burnside/