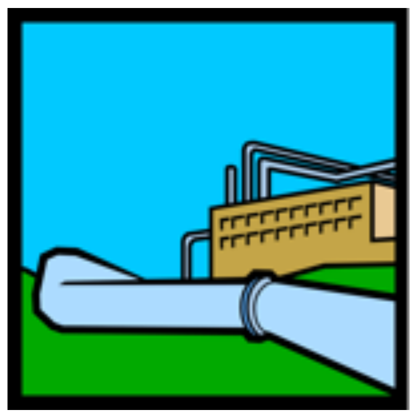
Eco-Industrial Networking:

What is realistic in practice?



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Introduction

I am interested in industrial production systems and their impact on the natural environment. Eco-industrial networking (EIN) and the related concept of eco-industrial parks (EIP) are development concepts that aim to reduce the environmental impact of industrial operations by increasing efficiency, reducing consumption of energy and materials, and reducing waste and pollution. I consider two contrasting examples of industrial systems, and discuss their characteristics, and the local and regional conditions that influenced their development. Industrial symbiosis (IS) is a key component of EIN and EIP approaches. I review some of the literature on IS and use the case studies to shed light on the potential benefits and its limitations. My aim is to provide insights for institutions (such as government) that are considering the pursuit of an EIN- or EIP-based industrial development strategy.

What are EIN, EIP and IS?

Eco-industrial networking (CEIN, 2005) and eco-industrial parks (Cote and Cohen-Rosenthal, 1998) are industrial development strategies that are frequently promoted as a means of reducing the environmental burden of industry in a way that is consistent with economic development and communities. The strategies are inspired by the theory of industrial ecology, which declares that industry should be viewed as a series of interlocking man-made eco-systems interfacing with the natural global eco-system (Tibbs, 1993). It is argued that, by looking at industry from this perspective, and by learning from the symbiotic relationships between organisms in natural ecosystems, new opportunities to recycle materials, conserve energy and optimise the larger production system may be realised. This leads to a phenomenon known as industrial symbiosis (IS), where groups of firms collaborate to exploit synergies that involve exchanges of materials, energy, water or by-products, in order to achieve higher resource productivity and hence competitive advantage (Chertow 2000).

EIN is a practical method of promoting IS in a given setting. According to the Canadian Eco-Industrial Network (CEIN), *Eco-industrial networking involves developing new local and regional business relationships between the private sector, government and educational institutions in order to use new and existing energy, material, water, human and infrastructure resources to improve production efficiency, investment competitiveness, community and ecosystem health (CEIN, 2005).*

Eco-industrial parks (EIP) are geographical clusters of industrial businesses that aim to identify and implement IS opportunities. In addition to facilitating links and developing relationships between stakeholders, EIN activities may involve detailed analysis of material flows and energy use within an EIP, education and training on industrial ecology, best practice sharing and facilitated workshops to identify IS opportunities. There are a number of examples of IS and EIP described in the academic literature (see Chertow 2000) and various organisations and academics promoting EIN[1]. EIN and EIP advocates emphasise the economic benefits of increasing resource productivity (reducing energy and materials inputs, and waste output) and often argue that there are many profitable opportunities to be exploited where the cost savings to firms outweigh the implementation costs or cost of alternatives. Chertow comments that "given these advantages, one might ask why more companies are not engaged in these types of projects" (Chertow 2000, 330). Others add that there is insufficient quantitative evaluation of the benefits delivered (Jacobsen 2006) and recognise real limits to the applicability of IS (Ehrenfeld and Gertler 1997, Esty and Porter 1998).

Why do we need a new approach?

Advocates of industrial ecology argue that if we are to achieve the necessary reduction in our environmental impact (harmful flows to and from the environment), and if we are to do so without

[1] For example, see The Kalundborg Centre for Industrial Symbiosis, Kalundborg, Denmark, http://www.symbiosis.dk; Indigo Development, Oakland, California, USA, http://www.indigodev.com/IE.html; Eco-industrial development Council (EIDC), Halifax, Nova Scotia, Canada, www.eco-industry.org; National Industrial Symbiosis Programme (NISP), Birmingham, UK, http://www.nisp.org.uk; International Society for Industry Ecology (ISIE), Yale School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA, http://www.is4ie.org.

hindering the provision of society's growing needs, we must adopt a more radical approach to our analysis of the problem. A central concept in industrial ecology is a necessary transition from a production system based on linear throughput to one in which material and energy flow in closed loops (Ehrenfeld and Gertler, 1997). To achieve this transition a systems approach[2] is required, where the horizon of analysis extends beyond the individual firm. Only by considering the wider production system as a whole, that is, the network of firms in the economy that process energy and materials and provide end products and services, can we identify the necessary changes to make the system efficient, and compatible with the natural environment.

In the early days of environmental policy making (starting in the 1970s) the issue of the environmental impact of industry tended to be viewed in terms of the actions of individual firms. Government policies targeted specific industries or even individual firms in the form of "command and control" regulations that focused on new technologies or modifications to manufacturing processes that could be introduced to reduce a firm's environmental impact[3]. As well as being costly to police and administer, this type of regulation was criticized for being too restrictive. Direct regulation of individual firms is economically inefficient because it tends to neglect heterogeneity in mitigation costs across firms, industries and sectors of the economy. Secondly, a prescriptive approach provides no incentive to innovate or to go beyond the prescribed level of abatement (Banks and Heaton 1995; Porter and van der Linde 1995; Sparrow 1994).

In the late 1990s, environmental policy-making evolved to embrace economically efficient regulations such as performance standards on vehicle emissions and tradable emission permits. These regulations specify an economy-wide or industry-wide environmental objective, while allowing firms the flexibility to "work out" the most economically efficient means of achieving the objective. In this simple analysis, policy making transitioned from a focus on the means of impact mitigation at the level of the firm to a macro level where the end goal is determined and incentivised. This transition is an

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[2] For more on systems theory see http://en.wikipedia.org/wiki/Systems_theory.

[3] For example the UK implemented Integrated Pollution Control (IPC) in 1990, a regulatory system to control pollution from industry by ensuring the use of 'Best Available Techniques Not Entailing Excessive Cost' (BATNEEC).

improvement, but it raises an important question. To what extent are firms (and consumers) able to respond to opportunities that transcend their immediate boundaries of responsibility? Some may argue that the very nature of a free market economy (in which firms pursue their own interests) prohibits effective collaboration and information sharing and that consequently firms fail to implement improvements that are beyond their field of view. This hypothesis would suggest a need for EIN activities that facilitate collaboration and information sharing and expand the perspective of the individual firm.

Do firms collaborate?

Clearly, inter-firm synergies do exist in the economy. The industrial symbiosis at Kalundborg, Denmark, is a well-known case. IS at Kalundborg evolved gradually over 25 years as the firms sought to make economic use of by-products and to minimize the cost of compliance with environmental regulations (Ehrenfeld and Gertler, 1997). No deliberate institutional mechanism or master plan was required and each symbiosis was negotiated as an independent business deal. As Ehrenfeld and Gertler put it "business leaders have done the right thing for the environment in the pursuit of rational business interests" (Ehrenfeld and Gertler, 1997, 73).

A lack of collaboration in the private sector could perhaps result from concerns about protection of competitive advantage or fears of anti-competitive behaviour (cartels). Esty and Porter (1998) suggest that many opportunities may be simply outside the perspective of corporate decision makers and accounting procedures. However, one can think of many examples of activities that allow firms to share information and collaborate in the pursuit of extra profits; employee networks (formal and informal), interactions with customers and suppliers, jointly funded research, trade shows, and employee mobility to name a few (some would add commercial espionage to this list). Such activities are promoted and facilitated by numerous institutions such as industry associations, chambers of commerce, government agencies, recruitment consultants and also firms in the supply chain such as suppliers, customers and consultants. Indeed, the business practice of supply chain management involves firms (usually led by the producer at the head of the supply chain) orchestrating a participative process whereby members of the supply chain collaborate to share information, reduce costs and reduce risks. During the process, the competitiveness and responsiveness of the whole supply chain is increased. So it is not a question of whether firms are or are not able to collaborate to exploit synergies, it is a question of the extent to which they do. Are firms exploiting all desirable opportunities or is there, some kind of ‘market failure’ or ‘information failure’ that inhibits firms from realising the optimum level of IS? If there is no such failure then we would expect to find genuine reasons (for example additional costs or risks) that explain why firms do not exploit more synergies.

Esty and Porter (1998) find that industrial ecology, when screened through the lens of resource productivity, may lead to innovations that improve efficiency, lower cost and improve the value created by a production process. They suggest three areas where industrial ecology could be applied: 1) within the firm, 2) within the chain of production (suppliers and customers), and 3) beyond the chain of production. Clearly EIN has special relevance in the last two areas. Within the chain of production there may be established communication and collaborative relationships that could facilitate (or substitute for) EIN activity. On the other hand, if there are synergies to be exploited beyond the chain of production, these are less likely to have been identified by existing networks, and so discovery of these could be a valid objective of EIN.

Research Questions

I am interested in the following questions.

1. What factors determine whether a potential IS opportunity is worth exploiting?
2. Is there a significant amount of IS opportunities that are unexploited?
3. If so, are there reasons (e.g. hidden costs) why firms do not exploit IS opportunities?
4. Is there a case for intervention to reduce these costs or facilitate the benefits?
5. If so, what are the appropriate institutional arrangements to support an intervention?

To look for answers to these questions, I reviewed theories presented in the academic literature on IS, and used them to analyse two examples of industrial development.

Example 1. Wilton International

Wilton International is a bulk chemicals manufacturing complex on the north east coast of the UK. The 930 hectare site has special development status for heavy industrial use. It was established after

World War II by Imperial Chemical Industries (ICI), and became a large integrated manufacturing complex by the 1980's, with up to 30 production plants. In the last 10 years ICI has progressively divided up and sold off its facilities to new owners, and the site now hosts many of the world's leading chemical manufacturers such as DuPont, Huntsman, Dow and Union Carbide. Since the mid-1990s, capital investment at Wilton site totalled 770 million Euros ($800 million) and local utility companies made investments of around 1.4 billion Euros ($1.5 billion). The site and its development are currently managed by SembCorp[4], a subsidiary of a Singapore-based company. The company provides utilities (such as steam, electricity, water, natural gas, effluent treatment), infrastructure (pipelines, roads) and a wide range of support services (emergency response, security, logistics, press and community liaison).

A number of local and regional institutions supported development at the site for many years. One North East provides regional assistance for investment, the Tees Valley Development Company (TVDC) represents the five municipal authorities, and Teesside Chemicals Initiative (TCI) is a specialist organisation that serves the needs of the chemicals industry.

Example 2. Maplewood

The small community of Maplewood in the District of North Vancouver, British Columbia, Canada, is a 200-hectare location that is host to a mix of industrial, commercial and residential land users. The 2,500 residents share the location with chemical plants[5] that manufacture sodium chlorate and chlor-alkali products for the pulp and paper industry. Seventy percent of the land in Maplewood is designated for industrial use and, in addition to the chemical plants, there are firms providing waste processing, engineering, light manufacturing, shipbuilding, paper recycling, and construction materials. The site also provides port and rail facilities.

In 2003 Maplewood embarked on a project to combine sustainable community planning with eco-industrial networking. The Maplewood Eco-Industrial Partnership Project was pioneered by a local

[4] SembCorp Utilities UK, http://www.sembutilities.co.uk.

[5] The chemical plants are operated by Canexus and ERCO Worldwide.

EIN consulting group[6] with support from the municipal government (the District of North Vancouver), the local power utilities and Maplewood businesses. Residents, representatives of the local businesses, utility providers and the municipality participated in a *design charrette*[7] to develop ideas and identify practical steps to integrate and enhance all aspects of the community including EIN opportunities. A report was published listing the opportunities identified (see Table 1). However, since then little progress has been made in realising these opportunities[8].

Discussion of examples

The two examples demonstrate contrasting experiences of symbiosis. In the first example, the firms exhibit a high degree of symbiosis on a large scale. In the second, an EIN-based approach is struggling to gain momentum. To understand why this might be, I discuss the theoretical case for IS at each site, the institutional arrangements and the differing approaches to development that each site experienced.

The benefits of IS

Since its inception, the development at Wilton site was based firmly on symbiosis, although it may not have been described using this term. The following quote from a leading industrialist and former chairman of ICI, describes the company's early development of the site:

> *"…our aim was to utilise every last bit of waste and upgrade it by adding value and turning it into something useful. The layout and development of the factory at Wilton bore living testimony to this belief, for each plant was in some way linked to, and*

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[6] Eco-Industrial Solutions, http://www.ecoindustrial.ca.

[7] The design charrette was a three and a half-day process where teams of professionals, community members and industry representatives worked together to synthesize information and ideas into an urban and industrial design vision incorporating eco-industrial, environmental, economic, planning and design components. For more information see http://www.maplewoodproject.org.

[8] Personal communication, Tracy Casavant, Eco-industrial Solutions, September 2005.

supplied by, the others and the end product which had to be disposed of was very small." (John Harvey Jones, 1993)

This approach was not simply a nice idea; it was the only economically feasible option. The manufacture of bulk chemicals involves the transformation of large amounts of raw materials, using energy-intensive processes, to produce commodity chemicals that can be sold in a global market. The amount of product (and by-product) produced by each plant is to a certain degree determined by the chemical reactions utilised in the production process. The costs of raw materials and energy are high and so it is important to obtain as much value from every product and by-product. Furthermore, as most of the products are toxic or have other properties that make transportation and disposal costly (or out of the question), it is essential to find either a market or a way to eliminate or re-process all the by-products of each reaction. Furthermore, continuous and stable production is critical to the efficiency of process plants. These constraints necessitate the identification of manufacturing synergies, with the result that containment, recycling, waste processing and energy efficiency are core competencies in the bulk chemical industry. Ehrenfeld and Gertler (1998) noted the same phenomenon; the case for IS is unconvincing when there are not large, continuous product and process waste streams.

In contrast to Wilton, Maplewood is a small industrial site, with a diverse mix of industries. The two larger chemical plants are classed as heavy industry. The other industrial tenants are categorised as light manufacturing, engineering and service industries. At first glance many of the businesses seem to be potential candidates for IS. Some are involved in materials processing, recycling and consume significant amounts of energy. The two chemical producers are connected by various material exchanges and they are also major energy consumers and potential sources of waste heat, power and perhaps by-product fuels. A number of other businesses are involved in waste recycling and reprocessing; waste oil re-reprocessing, paper recycling, bio-waste re-processing, landfill waste handling and an asphalt production and recycling plant. Other firms could be potential users of waste heat and some are large consumers of transportation fuels for vehicle fleets. Finally, the engineering firms and light manufacturers produce scrap metals and perhaps other waste materials that could have economic re-use benefits. Despite this plethora of material and energy flows and the many interesting opportunities identified during the design charrette (see Table 1), no synergies have to date been acted on by any of the businesses involved.

Table 1. Summary of EIN opportunities identified at Maplewood.

Maplewood EIN Opportunities
_Fuel Cell Power Plant _Coordinated Energy Management Program _Micro Hydro Power Generation _Tidal Power _Alternative Fuels and Lubricants for Vehicles _Reduce Water Consumption and Wastewater Generation _Stormwater Management in Residential, Commerical, and Institutional Development _Harvest Stormwater for Industrial Reuse _New Green Business Opportunities _Traffic-Related Opportunities

I looked at the proposal for a coordinating energy management program, because it was highlighted as the most promising opportunity and one that would be good for generating participation and momentum[9]. The idea behind this proposal is that Maplewood businesses, government agencies and the utilities could leverage expertise and funding to identify and implement energy conservation, efficiency and cascading opportunities by working together and coordinating energy management (District of North Vancouver, 2004). The project report suggested potential savings of more than $500,000 (Cdn.) per year in energy costs within five years. No cost information was provided and the savings estimate was not based on actual opportunities. It was based on a "conservative" estimate that the industrial, commercial and institutional sector could reduce its energy consumption by a factor of 15 percent through "building retrofits, equipment upgrades, increased employee awareness, etc.", none of which involve exploiting synergy between firms.

[9] Personal communication, Tracy Casavant, Eco-industrial Solutions, September 2005.

Table 2. Summary of feedback from key stakeholders

Feedback on Maplewood EIN process
_The EIN process was informative and stimulating _Recognised a number of opportunities _Lack of "hard numbers" on costs and benefits _Other business priorities are more important _Need to demonstrate financial returns before businesses commit _General support for an energy working group _Nothing is going to happen without a champion

I interviewed various stakeholders who were involved in the project to determine what they thought of the results of the EIN project and why the process had come to a standstill. The feedback on the design charrette process was positive, (see Table 2), however a number of problems were identified that partly explain why opportunities were not carried forward. The operations manager of a concrete supplier said there was a lack of "hard numbers" on the costs and benefits[10] and that the rate of return on any capital investment would have to be at least 20 percent, or a five-year payback period. In the literature Chertow (2000) reminds us of the normal business reasons why IS projects might not be attractive. All business ventures face the same hurdles: risk, finance, mobility of capital, and limited resources.

In the research it states that if energy or waste disposal costs are a small percentage of operating costs, these reasons alone will not cause the formation of eco-industrial parks (Chertow, 2000). I asked the operations manager at the concrete supplier about the potential for energy savings at his facility. He told me that electricity and gas purchases accounted for only 6% of the operating budget. He went on to say that energy efficiency was not his highest priority and that he did not have sufficient resources (engineering support) to pursue such opportunities. In fact the Maplewood plant was only one of seven under his responsibility, and his primary task was to prepare for the relocation of a number of these plants. This situation echoes another caution issued by Esty and Porter (1998); that attention to energy

[10] The Maplewood project report also recognised this issue. However, without additional funding detailed feasibility studies were not possible.

and material flows can cause managers to "take their eye off the competitiveness ball" by squandering scarce managerial time. It is a normal condition of business that the limited resources (including management time) are devoted to the highest priorities and the activities with the highest likely payback. Clearly, the opportunities identified in the Maplewood EIN project do not fall into this category.

Costs & risks

The benefits of symbiosis must exceed the costs from the perspective of all firms involved, or else there is no synergy. Esty and Porter (1998) caution that material cycling and an emphasis on closed loop production processes will not always enhance a firm's competitive position, especially when local regulations do not fully internalize the true costs of pollution or disposal. In addition to direct costs incurred to realise a synergy such as those associated with infrastructure, labour or transportation, there are additional risks and hidden transaction costs that firms may face when participating in IS.

Transaction costs may be categorised into regulatory, discovery, contracting and monitoring costs (Ehrenfeld & Gertler, 1997). Regulatory costs are incurred in fulfilling regulatory requirements related to a symbiosis, such as waste transportation controls. Discovery costs are costs incurred in identifying an IS opportunity, such as the costs of obtaining information about other firms and waste materials. Ehrenfeld and Gertler state that discovery costs may be the major impediment to material exchanges. If this is true then an EIN approach could be beneficial if it reduces costs to participants by facilitating the discovery process. Brokerages and markets can also reduce discovery costs, if they exist, by providing information on both demand and supply of waste materials and the prices at which agents are willing to trade. Contracting costs relate to the activities involved in establishing contractual agreements to protect the rights of firms involved in symbiosis. Monitoring costs reflect the additional management and administration costs associated with operating a material exchange.

Risks are also an important consequence of increased dependency on other firms. There may be an increased risk associated with the tie to a single supplier or customer. New material and energy exchanges expose firms to the vagaries of supply continuity and create larger systems of dependency. Provision of standby supplies simply increases costs. The seller also assumes the risk that the buyer may interrupt the flow forcing the seller to pay for disposal of the waste material. Another risk associated with

IS is an increased potential for quality problems. If production systems are more interconnected and complex there is an increased risk that quality problems in one part of the system spread to other parts of the system. Consider the potential implications of food production that is in some, perhaps seemingly harmless way, connected to a production system that contains toxic chemicals or bacteria. No longer is the system intrinsically safe. There is a pathway that presents the possibility that a failure of some sort could lead to contaminated food products.

Unfortunately, the design charrette process at Maplewood did not have the time or resources to explore the costs of exploiting synergies. It could be that the true costs outweigh the benefits when all transaction costs and risks are taken into account. In this case the participating organisations are justified in their reticence to invest further effort in the project. Without any real evidence of large savings to one or more firms, no firm is willing to step forward and initiate a collaborative process to search for savings that may or may not benefit them directly. In the case of Wilton, the corporation was able to bear large transaction costs and manage risks across all plants, because the benefits of the symbiosis were high.

Institutional arrangements

There was a general consensus among the Maplewood interviewees that they would support any process to investigate opportunities, provided it was initiated and managed by someone else. This sentiment was expressed on more than one occasion with the phrase "nothing is going to happen without a champion". Even though one of the utility companies offered to provide fifty percent of the salary of an energy manager who could play a central role in co-ordinating energy efficiency activities, no one was identified for this position. The individuals I spoke to said that the project did not align with their priorities as dictated by their organisation. One could argue that the failure to appoint a champion is due to a lack of institutional capacity. On the other hand, it could be an appropriate outcome given the risks, costs and uncertainty of the benefits. Had the expectations of benefits been higher, it is possible that new forms of collaboration would have occurred between the relevant parties to establish institutional arrangements to support further progress. It is not unusual for private firms to form a consortium or joint venture to exploit a strategic opportunity.

Figure 2. Promotion of synergy opportunities at Wilton International.

Raw Materials
The very heart of Wilton International is petrochemicals, feeding from the Olefines cracker owned by the recently formed HICI. The ethylene, propylene and other products derived from the cracker, together with those from the nearby interconnected aromatics plants, provide a complex of basic chemical building block and intermediates, offering myriad opportunities for value-added downstream processing.

The Major products available are:

- Aniline
- Benzene
- Butadiene
- Ethoxylates
- Ethylene
- Ethylene Oxide and Derivatives
- Propylene Naphtha
- Nitrobenzene
- Nylon Salts
- PET
- PTA
- Polyethylene
- Polypropylene

Utilities
The Wilton International site has a comprehensive range of utilities for companies to benefit from.

The major utilities available are:

- Steam
- Electricity
- Demineralised Water
- Potable water
- Raw Water
- Nitrogen
- Compressed Air
- Natural Gas

Source: Wilton International Welcome Pack, from website http://www.wiltoninternational.co.uk, April 2006.

The early development at Wilton progressed in a very different manner to that at Maplewood. A single large corporation owned the site and controlled the entire development process. ICI owned and operated not only the production facilities and the land, but also the infrastructure on the site, including roads, utilities, a power station and emergency services. Planning, designing and operating such a highly-integrated manufacturing complex required a large central engineering department with thousands of in-house engineers who had full access to the design and operational data of each plant. They were able to reserve vacant plots for future developments and dictate the location of new plants to minimise transportation and infrastructure costs. The expected benefits of the symbiosis that was thus achieved were enough to justify the approach and the costs involved.

After the sale of ICI assets to other operators, the authority for management was transferred to a private enterprise (SempCorp). SembCorp is now responsible for the operation of the site infrastructure and services as well as for the development of vacant land. It is not clear whether SembCorp will be as effective as ICI was in ensuring that new developments achieve a high level of symbiosis with the existing businesses. However, SembCorp are making efforts to exploit synergy opportunities. Figure 2 shows a list of chemicals and services available at the Wilton site that are advertised to prospective industrial tenants in the promotional material on their website. Transfers of energy and products, and provision of services are now managed under strict contractual agreements between SempCorp and its customers. However, even this arrangement is not without its challenges. Negotiating contracts for the supply of services to the customers is proving problematic due to uncertainty in the long-term commitments of the resident firms to the partnership[11]. Rates are dependent on the number of consumers who participate in the service and so a firm's commitment to the deal is dependent on other firms' commitment. During the days of ICI ownership the utilities and services were charged on a "cost plus" basis - the total cost of providing the utility or service was divided amongst the number of users. As plants shut down the cost to the remaining users went up and so a number of customers tried to negotiate long-term contracts. This put the utility provider in a difficult position where its profit margin could easily be eroded.

Without planning intervention there is a very low chance of finding "pairs of coexisting positive environmental, technical and economic factors among more than one or two firms at any one time" (Ehrenfeld and Gertler, 1997). Maplewood does not have the advantage of being masterminded by a central authority in the way that Wilton was. Although the municipal planners play a role in controlling development through zoning, planning permits and bylaws, their influence over the businesses that locate to the site is severely limited in comparison with ICI's role at Wilton. Businesses probably located at Maplewood for specific reasons unrelated to any synergy benefits with other businesses at the site. According to my brief analysis, the industrial businesses at Maplewood located there to be close to their customers in North Vancouver and downtown Vancouver (in the case of the construction industry suppliers and waste recyclers, for example), due to the availability of cheap hydro electricity (in the case of the chemical plants), or because of the port facilities (shipbuilding, construction suppliers). I would characterise Maplewood as an industrial service area for the immediate district and other areas within close transportation distance. If synergies between different operations have been identified I suspect they will be secondary factors. The lack of importance of synergy during Maplewood's development explains why few by-product synergies exist and why few new opportunities were discovered during the design charrette.

[11] Personal communication with business development manager at SembCorp utilities.

In contrast to Wilton, there are various financial disincentives to new businesses considering a move to Maplewood. The land occupancy costs are prohibitive[12] and there is limited space for the site to develop into a larger industrial complex. In any case, such expansion would probably be incompatible with local community objectives. Many of the heavier industries have operated in this location for over 50 years. It may be that heavy industry is in decline on the north shore as existing firms move or close down once they have exploited their existing capital investments.

A final factor in Maplewood's evolution could be a lack of institutional capacity at the regional level. Over the years influential city planners and entrepreneurs have lamented the lack of a cohesive strategy for inward investment and business development across the region (GVEC, 2005). The region is divided into 21 municipalities that are practically autonomous. The scope and authority of the main regional government entity, the Greater Vancouver Regional District (GVRD), is focussed primarily on land management, parks, water services, waste disposal, transportation and other infrastructure-related issues. Even if a strong regional capacity to promote economic development existed, it is debatable whether it would target the heavy industrial sector. A recent private sector initiative to establish a regional development entity, the Greater Vancouver Economic Council (GVEC), carried out a cluster analysis and concluded that the region's strengths lie in international colleges, creative industries (new media, graphic design and creative arts), and in areas related to the regions role as a trade gateway to Asia[13].

Expectations about the scope of IS opportunity should be tempered when there is limited authority to control the development process, when there is limited flexibility to accommodate development, and when there is limited institutional capacity to support the process. Even with these factors in place, the process can take a long time. Synergies at Wilton and Kalundborg took several decades to materialise.

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[12] North Vancouver's occupancy costs (high land prices, tax rates and rental rates) are some of the highest in Vancouver's lower mainland (Harris Hudema Consulting Group and Eric Vance & Associates 1999).

[13] Presentation by Bob Williams to planning students, UBC, 2006.

Role of government

One role of government is to develop a regulatory context that provides the right incentives for reducing externalities, such as environmental impacts caused by industry. As previously discussed, setting economy-wide environmental goals in terms of performance standards (rather than specific technology standards) and using market-based mechanisms such as emission permit trading systems to meet these goals is the most economically efficient method of regulation. Having these incentives in place is an essential pre-requisite of industrial ecology. At the local or regional level, waste management regulations are needed that do not impede re-use or recovery (low transaction costs) and ensure that the true cost of disposal is borne by the producer (the polluter pays principle). Until such a regulatory system is in place EIN has to recognise that the opportunities for IS will be limited.

To plan for the future, industry wants a clear indication of future regulatory developments and reliable economic forecasts. Yet to determine the socially optimum regulatory environment government needs to know what is achievable and the compliance costs to industry. Government is reluctant to tax or otherwise burden private enterprise, for fear of putting domestic industry at a disadvantage competitively. Regional authorities usually want to stimulate growth in local industries by attracting investment. A low-cost business environment is an important factor in attracting investment.

Cluster development

The theory of industrial clusters, pioneered by Harvard Professor Michael Porter in the late 1990's, was a new way of looking at national, regional, and local economies, based on the microeconomics of competition and the role of location in competitive advantage (Porter, 2000). Clusters are defined as geographic concentrations of interconnected companies, specialized suppliers, service providers, and other related firms and institutions. In many ways eco-industrial parks are a type of industrial cluster and therefore the theory of cluster development may provide insights for eco-industrial networking.

Porter criticizes what he calls industrial policy that targets "desirable" industries and intervenes through subsidies or restrictions on outside investment, to favour local companies. He argues that productivity, not exports or natural resource endowments, determines the prosperity of a region or nation. Increased resource productivity is a goal of IS and so EIN could be pursued as part of a cluster development approach to economic development. Instead of focusing on specific industry sectors, Porter suggests that governments should promote “cluster formation and upgrading” and the build-up of public or quasi-public goods that benefit many businesses and allow the economy to move beyond factor cost competition (Porter, 2000). In this context EIN could be the public good provided by government, provided it is not exclusive in its application. Finally, Porter says that clusters form independently of government, when there is a foundation of locational advantages on which to build. One of the key messages from Porter’s cluster development theory is that governments should not attempt to create entirely new industry clusters, but instead should build on established and emerging clusters. EIN approaches should therefore seek out existing evidence of IS and then focus on magnifying it. It is important to recognise that if government institutions fund, support or facilitate EIN activities, they are in effect subsidising the firms involved. Therefore it makes sense to align EIN activities with economic development goals in order to justify them in terms of cluster development. It would be counter-productive to invest in IS that promotes and attracts heavy industry, if the economic development strategy has determined that the region would be better off moving away from heavy industry to an industry that is more compatible and perhaps more competitive in the long term.

Conclusion

It is clear from the development process at Wilton that convincing incentives are essential to stimulate investment in symbioses and that there are costs involved in identifying and managing an integrated manufacturing complex. In this case the incentives were the need to derive economic value from by-products by turning them into marketable commodities (due to the high costs of raw materials and energy), and the high costs of disposal of by-products. The achievement of a high degree of symbiosis required corporate control of development and a site with flexibility to accommodate planned development. Lack of progress with IS at Maplewood can be attributed to a lack of evidence of benefits compared to the costs and risks in investing in EIN activities. Without a regulatory environment that creates an incentive to reduce emissions and waste disposal, the costs outweigh the benefits. Also the region lacks a development authority with capacity to support industry.

The findings suggest a cautious approach to EIN, based on a better understanding of benefits, transaction costs and risks. Learning from cluster development theory may help EIN proponents to identify more appropriate locations where there is already an IS seed in place and where support for EIN activity can be justified on grounds of economic development. Finally, the few examples of successful IS indicate that it is a slow process where opportunities present themselves piecemeal over decades. Unless the economic environment changes, enthusiasm for EIN activities should be tempered and institutional capacity geared to support a slow long-term process of change.

However, if changes in the long-term costs of waste disposal and pollution are anticipated, then there may well be real incentives to invest in EIN now. These costs, as well as the costs of energy, transportation and raw materials, are key factors that determine the optimum level of IS. Particular areas for future research could include the reduction of transaction costs, especially discovery costs, improved methods of evaluating synergy benefits, and the design of effective institutional arrangements for identifying and managing EIN activities.

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