Industrial Ecology at the Big Bend

by

Jonah Z. Spiegelman

B.Sc., University of Oregon, 1998

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Master of Arts

in

THE FACULTY OF GRADUATE STUDIES

(Department of Resource Management and Environmental Studies)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

February 2002

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Resource Management & Environmental Studies.

The University of British Columbia
Vancouver, Canada

Date 28/03/02.

DE-6 (2/88)

Abstract

Metropolitan areas around the world face serious choices about the manner in which development should proceed. The widely agreed upon goal of sustainable development has yet to truly reconcile the desire for industrial development with the need for ecological integrity. Industrial ecology (IE) is a framework that aims to mitigate the environmental impacts of industrial development through the integration of industrial processes to maximize resource productivity and minimize pollution emission. Invoking an ecological metaphor, IE describes 'industrial ecosystems' that minimize their flows of material and energy, optimize their design configuration, and exploit the positive behavioral interactions among their constituents. This thesis reviews the industrial ecology literature and takes it further by linking IE with the theory of complex thermodynamic systems in an attempt to deepen the metaphor upon which it rests. If industrial systems are to be modeled after ecological systems, what characteristics of ecosystems should be emulated, and upon what basis does this assertion lie? The answers to these questions constitute my contribution to IE theory, highlight the crucial role of context that remains underemphasized in the literature, and strengthen the overall legitimacy of the framework. This enhanced theory is then applied to an industrial system in Burnaby, BC, at the center of which is a solid waste incinerator. Guided by the IE framework, I gathered data regarding the material and energy flows through the industrial system. This case study demonstrates some characteristics of an eco-industrial system, though the level of integration is generally quite low. The performance of the site is evaluated, and areas of potential improvement are identified. The result is a set of recommendations to facilitate the development of the site into a more fully integrated eco-industrial park that would positively affect the sustainability of the region.

Table of Contents

List of Tables:

Acronyms Used

BCSD	Business Council for Sustainable Development
CED	Community Economic Development
CEIN	Canadian Eco-Industrial Network
EID	Eco-Industrial Development
EIP	Eco-Industrial Park
GBFP	Georgia Basin Futures Project
GVRD	Greater Vancouver Regional District
IE	Industrial Ecology
RCBC	Recycling Council of British Columbia
SPARK	Strategic Planning for Applied Research and Knowledge

Chapter 1: Introduction

Metropolitan centers around the world are faced with serious choices about the manner in which development should proceed. Particularly in areas where significant growth is expected, the strategic planning of development (including the structure of a region's industrial base) locks in a particular urban morphology that has implications far into the future. To date, industrial development has occurred largely without consideration of ecological integrity (and often at its expense). However, without some industrial activity cities must either rely exclusively on imported products or forgo the luxuries of an industrial society. This study examines a partial solution to this dilemma by describing a scenario in which the impacts of industrial development can be mitigated through the application of industrial ecology. Such a scenario allows regions to enhance their economic self-sufficiency without compromising the quality of their environments. In particular, I perceive the potential for firms to fill the industrial equivalents of ecological niches creating integrated industrial ecosystems in which relationships remain dynamic and sensitive to the exigencies of their ecological, social and economic contexts. I apply this theoretical argument to an existing industrial system in Burnaby, BC, to ascertain how well such a theory can be translated into action.

1.1 Setting the Stage

The global climate of industrial development in recent generations has been one of increasingly disposable products generated from energy and resources that have been perceived to be in abundance. In the developed countries, a regulatory atmosphere has emerged in which waste materials are relegated out of the commercial domain and into government hands for 'responsible treatment and disposal'. The managerial emphasis with respect to the economy has been an increasing gross domestic product, which rewards economic throughput without considering the efficacy of production systems to achieve their goals. The result of these trends is a system in which resource throughput is ever accelerating, while concerns about the impending scarcity of natural resources and the accumulation of pollution are growing.

To address these broad issues, sustainable development has been popularized as a goal, but has yet to be defined in a way that is operational on the ground. The familiar schematic diagram of three interlocking circles that represent society, economy and ecology (also known as the 'three-legged stool' model) has largely defied operationalization, despite its conceptual appeal—a deficiency addressed in this study. Industrial ecology is an emerging field that claims to offer a coherent industrial development strategy that leads in the direction of sustainable development. As such, it deserves the scrutiny that this thesis project plans.

1.2 Industrial Ecology

Industrial ecology begins with the assertion that existing industrial systems are unsustainable due in part to the needless isolation of individual industrial processes from each other. The ecological metaphor that informs this body of thought draws a parallel between natural ecological systems and industrial systems in terms of material and energy flows. Just as ecosystems develop food webs and interdependence between species, so too can industries come to feed each other from their inputs and outputs creating industrial ecosystems. On a practical level, the evolutionary development characteristic of ecological systems is carried into industrial ecology by emphasizing continual improvements and innovation in applying the ideas on the ground, and extending industrial linkages to create ever more nearly complete, closed-loop industrial ecosystems. My first research objective is to gain an understanding of industrial ecology as it appears in the literature. The next chapter presents a somewhat uncritical read on industrial ecology, summarizing its main points while touching on issues that I will address later in the thesis.

My main concern is that the metaphor that industrial ecology rests upon is seldom explored very deeply, and may be seen as free riding on the popularity of ecology as an environmentalist paradigm. What characteristics of ecosystems make them sensible models for industrial systems? This, my second research question, is seldom addressed in the literature, and represents the major contribution of this thesis to that literature. The connection between ecological and industrial systems is revealed in chapter 3 through an investigation into the theory of complex thermodynamic systems, which points to commonalities among the dynamics of all far-from-equilibrium systems such as ecosystems, economies and societies. This theoretical framework provides the tangible link that industrial ecology generates through assumption, and (as will be seen) highlights the crucial role of context that the literature sometimes glosses over.

1.3 The Case Study

In order to understand the practical implications of the theory of industrial ecology a particular context must be chosen. The literature too often remains in abstraction, referring to principles while lamenting their lack of implementation. Indeed there are many barriers to industrial ecology—institutional, cultural and cognitive—that have been well articulated in other papers throughout the literature, and thus will not be focused upon herein. Rather, my final research objective is to explore how the theoretical principles articulated in the industrial ecology literature apply in practice at a development site called the 'Big Bend'. Using the principles set out in the literature review, I investigate this industrial system, which already shows some (albeit incomplete) signs of industrial ecology, and conjecture how further implementation might proceed along these lines.

The particular context to be investigated is an interesting one—an industrial system involving a solid waste incinerator owned by the Greater Vancouver Regional District. The primary reason for selecting this site is that it is perhaps the best example of potential industrial ecology available in the region. Given the importance that I attribute to context, the geographic location of the case study is relevant in terms of how conclusions may be interpreted. My interest (motivated in part by funding obligations) in the sustainable development of the Georgia Basin region constrained my selection alternatives to a local case study. However, in general the dearth of fully functioning eco-industrial sites (here and abroad) makes it difficult to empirically study the benefits to be derived from industrial ecology. Further justification for my selecting this case study is offered in chapter 4.

This case is also interesting because it reveals some internal tensions that exist within industrial ecology. To the extent that the aim of industrial ecology is to eliminate waste from production systems, solid waste incineration seems antithetical to its goals. Yet waste-to-energy facilities such as the selected site often fit within the rubric of industrial ecology. This tension will be explored further in chapter 4.

1.4 A Word on Methodology

My thesis is more conceptual than experimental, and as such the methodology is largely thought-based. In terms of field research, I embarked upon an information-gathering exercise through which detailed information about the operations of the incinerator were obtained. My review of the industrial ecology literature defined the relevant areas, and informal interviews and correspondence with members of the incinerator's governance and operations personnel provided me with that data. The detailed information regarding the case study site that appears in chapters 4 and 5 are the result of that field research. The openness and forthcoming attitudes of the interviewees facilitated my research immeasurably, and alleviated the need for a lengthier and more complicated research methodology.

1.5 Thesis in Context

This thesis fits into a larger research program operating through the Sustainable Development Research Institute at the University of British Columbia. The Georgia Basin Futures Project (GBFP) is an interdisciplinary collaborative research project that investigates the possibilities for sustainable futures in southwestern BC through multiple research pathways (see www.basinfutures.net for more on the GBFP). One line of research investigates the possibility of 'dematerializing' regional economies such that economic activity may be decoupled from ecological impact. Industrial ecology is one strategy that may facilitate such 'dematerialization', locating its investigation within the larger research activities of the GBFP. By contributing to the conceptual framework of industrial ecology, the thesis advances the notion of dematerialization into a more fully developed 'policy wedge' (Robinson and Tinker 1997).

In addition to conceptual development, though, this thesis makes a first attempt to operationalize a 'dematerialization' strategy in the Georgia Basin by investigating how industrial ecology could operate on two distinct (though interconnected) levels—that of a particular industrial park and the regional district's solid waste stream in general. As will be explored, the development of an integrated eco-industrial park at the case study site would not only benefit the participants in that endeavor, but could (if thoughtfully established) help mitigate the impacts of the regional district's solid waste stream in an environmentally friendly and economically viable manner.

Achieving sustainability will clearly take more than the implementation of industrial ecology. One conclusion that I reach in later chapters is that 'sustainability' is likely an emergent property of some societal systems, in which individual actors (such as government bodies or private firms) can only play limited roles. The cumulative consequences of those roles have implications for the larger system, and industrial ecology offers insight for only some roles and relationships. Thus while industrial ecology may facilitate a sustainable societal configuration, it cannot unilaterally create one. Indeed to rely solely on IE for sustainable development may turn out counterproductive, as important changes in lifestyle and social priorities would be consequently overlooked. Nonetheless, industrial ecology does offer some sensible contributions to industrial design, and is valuable if only at that level.

Chapter 2: Industrial Ecology: a metaphorical Framework

2.1 Bridging the gap

The appellation 'Industrial Ecology' is an interesting marriage of two notions that are often set opposed to each other in popular environmental debates. On the one hand industry is perceived by many as the culprit and cause of most 'environmental problems'; industrial pollution, mass resource consumption and corporate profiteering are just some negative connotations that accompany the term 'industry.' On the other hand, 'ecology' has become the flagship discipline of the popular environmental movement, whose emphasis has been the reification of the natural world, and the general opposition to human disturbance thereof. Yet despite this apparent inner conflict, proponents would claim the metaphor explicit in the term 'industrial ecology' is tenable on various levels. Using the basic definition of ecology as the study of relationships among biotic and abiotic parts of a system, the inclusion of industrial systems seems appropriate; they are, after all, physically located in ecological communities of some description. The conceptual distinction between natural and anthropogenic systems is itself an artificial construct and contributes to the common tendency to concentrate energies on preserving 'wilderness' while viewing harmful industrial activity as a (necessary) evil separate from the cherished natural environment (Cronon 1995). Dominant cultural mythologies (from Judeo-Christianity to scientific materialism) have effected a conceptual separation of humans from nature. By bridging the gap between industry and ecology, this framework focuses the sustainability debate on solving technical aspects of industrial problems such as toxic pollution and material and energy throughput, rather than pondering the more abstract questions of whether and where problems may exist. The other side of this coin is that most of industrial ecology has very little to say about some of the ethical aspects of the environmental movement such as wilderness preservation or global biodiversity.

2.2 The Biological Metaphor

The biological metaphor deepens as attention is turned toward material and energy flows. Industrial ecology holds that industrial systems should be modeled after (and fit into) ecosystems in order to avoid undue ecological stress. Natural ecosystems, while not static, achieve dynamic equilibria with cyclical flows of material through the various trophic levels, with solar energy as the only external requirement. This is a simplified view of ecological systems, but gives insight into the material flows of industrial systems. At present, industrial systems are perceived as linear and consumptive rather than cyclical and self-sustaining. Each member of today's industrial community operates (more or less) in isolation, consuming raw materials and producing waste, without much consideration of possible synergies with other industries to reduce demand for 'natural capital'. There are very few trophic levels in today's industrial system; generated waste is permanently disposed of in landfills, while virgin materials are extracted from the environment at a cost that reflects the perception of their unlimited availability. To construct an industrial ecosystem, layers of industrial processes are laid out whereby one firm's waste material is another firm's raw resource, minimizing the need for virgin resources. This vision is carried to an idealized extreme of clustered industries within "eco-industrial parks" producing diverse products, with zero emissions as a whole (Chertow 1999).

Industrial ecology's biological metaphor also mandates the internal streamlining of industrial processes to resemble "their counterparts in the biological world" (Frosch and Gallapoulos 1992). In natural ecosystems, each member of a community fits into its niche, playing its part in the metabolism of the system, without exerting excessive pressure on other members. It is important to note that the conditions created in natural systems are the result of evolutionary processes that took many thousands of years to attain. Likewise, industry will have to evolve, forcing some sectors and processes into extinction, while others step up to fill their niche in a more appropriate manner. Unfortunately, this process will need to be much more rapid for industrial processes as environmental pressures grow—the alternative, according to this perspective, being an event of mass extinction.

By invoking the biological metaphor, proponents of industrial ecology suggest that natural ecological systems work well and should serve as the model upon which industrial systems are designed. The basis for this reasoning lies in a progressive evolutionary model in which adaptation successively improves organisms' suitability to local conditions through time. The interplay of the components in a system leads the more suited members of each species to survive and pass on their genes, thus improving the fitness of the composite whole in the next generation. What is missing from this formulation, when extending it to industrial systems, is the driving force of the system.

The biological metaphor takes growth and reproduction for granted, as both are fundamental characteristics of biological systems; but its extension to industry fails to address crucial issues like over-consumption and the excessive scales of economies. Industrial ecology lacks any analogue of homeostasis; there tends to be little attention given to the fundamental constraints that limit the growth of systems. Industrial ecology is often very optimistic that the challenges facing human industry are indeed surmountable and (with a few significant adjustments) a high technology, utopian future may well be achievable without major changes in the consumer culture that has dominated recent generations. For example, "the Factor 10 Club, a group of leading international figures in environment and development, have argued...that a process of dematerialization requiring a ten-fold increase in the average resource productivity is essential in the long term" (De Simmone and Popoff 1997). Management philosophies and design tools like 'eco-efficiency', Design for Environment (DfE), and life-cycle analysis are becoming increasingly popular as means toward this end (ibid; Hawken 1993; Van der Ryn and Cowan 1996). Furthermore, the companies that lead the world in applications of these ideas report impressive savings both in economic and environmental terms (Hawken 1993).

The following sections will explore industrial ecology as it appears in the literature in more detail. For conceptual clarity, I dichotomize the main principles into two categories: external resource webs and internal eco-efficiency. The separation is admittedly artificial since the boundaries of any given system are ultimately arbitrary; as explored in the next chapter, aspects external to any given system may be internalized by expanding its boundaries. However, for the sake of discussion, the categories will remain. Following that, the chapter turns to the social and environmental consequences of the implementation of industrial ecology as expressed in the literature on eco-industrial development. Finally, I will examine some assumptions that underlie the industrial ecology framework.

2.3 External Resource Webs

According to IE theory, the fundamental difference between natural systems and industrial systems is the extent of resource cycling between members of the community (Ayres 1994). Nature has no real analogue of waste; primary producers take solar energy, convert it into chemical energy, delivering that to primary consumers, which in turn deliver it to higher order consumers. Every step of the way, there are scavengers and detrivors that specialize in recycling any resources that escape the system back in at a lower level. Even though a very small proportion of the sun's energy is captured by the system, that which gets photosynthesized is used very efficiently as it passes through the trophic levels. Approximations of this idea have been attempted in industrial parks, but have yet to become the norm; despite the broad appeal of so-called eco-industrial parks (EIPs), actual applications of the principles tend to vary in extent (Chertow 1999). An industrial park in Kalundborg, Denmark is the most widely cited example of this idea (see Ehrenfeld and Gertler 1997), and other examples are being initiated around the world.

Manahan (1999) describes the minimum requirements for an industrial ecosystem as at least one primary producer as a large-scale source of material flow, at least one secondary producer to process byproducts, and a mechanism of co-operation to facilitate a functional relationship. The most basic application is the creation of waste exchanges in existing industrial regions. To some extent, there are already many possibilities for symbioses in industry, and many regions have initiated waste exchange programs to encourage such possibilities. The BC Materials Exchange (BCMEX) is government funded and diverted 3500 tonnes of material in 1998/99 from the waste stream (Neale, Pers. comm., March 12, 2000). The practical challenges of such operations are three-fold. First, there must be an organization that compiles a database that is both comprehensive and accessible to maximize potential exchanges. Second, is the need for public outreach, making industry aware that there are recycled alternatives to virgin resources available and for lower cost. Last is the logistics of the exchange itself; difficulty in the coordination of match-ups across time and space reduces the feasibility of maximizing potential in this area. Furthermore, relying only upon waste exchanges to minimize waste production essentially justifies that production in the first place and ignores the need to forge relationships between the trophic levels of industry.

If industries began to think in terms of by-products, rather than wastes, more lasting and profitable relationships could be developed in the industrial ecosystem. Industrial partnerships could be formed whereby one producer would reprocess scrap to make it valuable to a neighbor, and be supplied reliably, reducing their overall need for resource inputs (Frosch and Gallapoulos 1992). The success of such a venture would be contingent upon demand for (and availability of) such partnerships. While some potential for this to occur certainly exists, the next level of application would consist of start-up companies that specialize in by-product consumption—for example, fish farms or greenhouses built around industries that supply waste heat for operation. According to industrial ecology, the waste stream represents a new resource yet to be tapped; "more energy passes through the windows of buildings in the US than flows through the Alaska Pipeline" (Ruckelhaus 1989). Products and companies that work to prevent such losses may find a broad niche in the market and offer substantial employment opportunities while easing the waste management load and improving the efficiency of the overall system.

The extreme end of the spectrum is a vision of eco-industrial parks with zero material emissions, and complete cycling of by-products and waste materials. Such a vision is limited by the logistics of creating such clusters, as business would have to re-locate into planned industrial parks. Whenever new industrial developments are planned, however, legislated incentives to incorporate some eco-industrial characteristics would likely be feasible. Eco-industrial parks may be attractive to potential participants (start-up companies, or others with existing plans to move, for example) in light of reduced resource and waste disposal costs, not to mention the 'green publicity' that might come along with participating in such a venture. The cost of the alteration of infrastructure, including the relocation of industrial sites, is the largest single barrier to this concept. Without collocation, however, the transportation costs of materials might be prohibitive. Furthermore, many wastes now produced in quantity are often prohibitively difficult to reprocess into usable materials, or are classified as 'hazardous' wastes with disposal prescriptions that disallow innovative solutions. Such wastes that are unconvertible to benign (or marketable) by-products would ideally be eliminated from the system through changes of design processes (Manahan 1999). These changes must occur extensively throughout the industrial community, as each application of this idea is context and process specific. However, the creation of industrial ecosystems that maximize industry synergies could go a long way toward balancing the impacts of industrial activity with the capacity of the ecosystem to absorb industrial disturbances.

2.4 Internal (Eco-) Efficiency

Prior to any functional relationships between members of an industrial ecosystem, each plant or firm must inventory internal processes to identify its material needs and waste-to-by-product possibilities. Moreover, in-house streamlining of processes to reduce the initial generation of waste often proves to be economically sensible as well as ecologically preferable. Many corporations, including 3M and AT&T have initiated such programs and are at the vanguard of innovation. 'Pollution Prevention Pays' is 3M's environmental motto, and saved over half a billion dollars between 1975 and 1993 by actively "designing out pollution from manufacturing products" (Hawken 1993). Those savings represent waste and pollution generation that were prevented through design refinements. Eco-efficiency (the term given to such streamlining) "is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to at least a level in line with the Earth's estimated carrying capacity" (BCSD 1994). This sanguine definition of eco-efficiency omits any practical guidelines for application, but analytic tools are available to the industrial ecologist to bridge the apparent gap between ideas and action. The concept of industrial metabolism is one modeling tool that identifies potential areas of improvement in processes (Ayres 1994). Keeping with the biological metaphor, the analysis of industrial metabolism refers to the characterization of total internal flows of energy and materials within a firm, and could be extended to the industrial ecosystem as a whole. According to Stuart et al (1999), "as companies learn to allocate their wastes quantitatively to the product responsible, they make more informed decisions about product and process design costs and environmental impacts."

Previous pollution abatement measures, while showing some progress, have tended to be end-of-pipe applications such as scrubbers on smokestacks or large waste treatment facilities, the implementation of which can only add to the cost of production. Rather, the concept of eco-efficiency encourages industries to modify the design of processes to prevent the initial production of unrecoverable waste and pollution while converting other wastes into by-products to relieve a neighbor's input needs. 'Design for Environment' (DfE) is a strategy that takes on sustainability in the design phase of production to limit ecological side effects before they occur. For example, products that are designed for disassembly and remanufacture are more easily retained in the productive economy passed their initial lifespan, reducing the volume of virgin resources needed to meet market demand. DfE relates to infrastructure as well as products. Daylighting and passive solar or geothermal heating dramatically reduce the expenditure of energy in buildings; if adopted on a large enough scale pollution associated with energy production would be beneficially affected. Stuart et al (1999) demonstrate that allocating costs to processes (in the case of an electronics assembly plant) can make a substantial difference in terms of energy use and material consumption. Again, a process level study of industrial metabolism could identify sources of inefficiency, while DfE aids in implementing the needed changes in process to maximize resource utilization.

2.5 Enhancing Social and Environmental Equity

Industrial ecology, as it was originally conceived, is a strategy for manufacturing that alleviates the adverse side effects of industrial processes (Frosch and Gallapoulos 1989). The ideas and strategies outlined in the previous two sections come out of that literature. However, over the years since its inception, the idea has developed and expanded to cover far broader implications (Schlarb 2001). The concept of industrial ecology has surpassed technical issues of waste exploitation and pollution prevention, and now includes reference to economic and social benefits that may be derived from industrial ecology. This line of reasoning may be more appropriately referred to as 'eco-industrial development' (EID) given its concentration on the practical implementation of industrial ecology from an economic development perspective. As such, social aspects of sustainability can be incorporated into the justification for industrial ecology as an integrated strategy for sustainable development. This section will outline some benefits that may be derived from EID in terms of social and environmental equity. It is worth noting that many of the positive repercussions of EID outlined here could be attained through any development that emphasized a role for community members. However, linking community participation with industrial ecology strengthens its legitimacy as a sustainable development strategy, and broadens its supporting constituency.

The starting point for making the argument that industrial ecology is good for communities is the assertion that "a healthy [local] economy is one of the foundations of a healthy community" (CEIN 2001). My added emphasis on the localized nature of the economy that EID would build is important in that it reflects my conceptual distinction between open export-oriented economies and local self-supporting economies. In terms of their comparative sustainability, moving from the former to the latter describes the transition from the status quo to a societal system based on industrial ecology. Most of the EID discourse tends to prioritize the strict economic gains, while treating social and environmental gains as collateral benefits. This emphasis may be attributable to the fact that EID is generally marketed toward the business community and economic development officers. The economic focus stands in contrast to the earlier IE literature that prioritized environmental benefits while considering economic and social advantages positive side effects. Either way, of course, the social benefits to be gained through the implementation of industrial ecology tend to be trickle-down consequences, rather than primary goals. An alternative way to perceive the social benefits is that they are emergent properties of functioning eco-industrial systems. In this light, the early economic focus may be warranted, as businesses will be responsible for the initial phases of IE implementation. Once eco-industrial systems begin to be established, the social benefits may be more forthcoming.

EID offers communities the chance to develop the local economic base through "improved business attraction, expansion and retention" (ibid). For reasons mentioned in earlier sections, the development of an eco-industrial area can be attractive to both existing industries and prospective start-up companies that wish to exploit a niche in the developing industrial ecosystem. This creates local jobs for residents, and tax revenues for local government agencies that administer services in communities. An example comes from a depressed neighborhood of Minneapolis, MN in which e4 Partners, Inc worked with community groups to create the Phillips Eco-Enterprise Center (PEEC) as an alternative to the development of a solid waste transfer station. Based on the principles of EID, this development project was designed for resource efficiency in its construction and operation, provides a venue for businesses in the 'environmental sector', and has acted as a catalyst for further urban redevelopment that prioritizes sustainable design principles (Osdoba, 2001).

When eco-industrial development projects are being planned for a given area, advocates and practitioners of the idea encourage the involvement of local interest groups, citizen organizations and local governments in the visioning and planning processes that precede development. This was true for the Minneapolis example above (Osdoba 2001), as well as other EID projects such as in Londonderry, NH, where local businesses and community groups were included on an advisory board that guided the redevelopment of a decommissioned military base into an eco-industrial park (Lowitt 2001). Such inclusion can have an empowering effect for local communities to determine the direction of development in their areas, and can engage local residents to become more active members of their communities. Particularly in communities that are economically distressed the possibility of EID can offer positive alternatives to "the lure of quick income from landfills, hazardous waste dumps and garbage transfer stations" that are often relegated to poorer areas (Schlarb 2001).

Another positive consequence of industrial ecology in terms of enhancing equity relates to the legacy of environmental deterioration that is often associated with conventional industrial sites. To the extent that industrial ecology is effective in reducing waste generation and pollution release, environmental degradation will be mitigated to the benefit of all communities (present and future) that would otherwise be burdened with poor environmental quality.

2.6 Assumptions in Industrial Ecology

The conceptual underpinnings of industrial ecology are distinct from other approaches to sustainable development and serve both as cause for criticism and hope for the idea's potential. The popular base of the larger 'environmental movement' represents a diverse cross section of society. Thus, while the general goal of sustainability may be common to all, the means and mechanisms that one recommends are often subject to dispute. This results in an often-fragmented movement, rife with political infighting and exhausted platitudes (Ellis 1995). One relevant example of such a debate is the question of technology's role in sustainable development. Industrial ecology, a field that originated mainly in engineering and industrial schools of thought, contends that current environmental problems represent a fundamental flaw in the design of modern industrial societies. The technological models that have been employed to further economic (and social) goals have proven themselves to be detrimental to the health of the ecosystems in which they are situated, and must be altered or replaced to ameliorate the damage. Thus, with new 'greener' technologies and improved industrial design, the ecological crisis can be assuaged, while standard of living improves as a result of environmental purity. The creation of a new industrial framework with environmental considerations central to its motivation is, from this perspective, a positive and attainable goal. They claim "the environment *industry can be part of the solution* to achieving this vision [of sustainability] and thus serves a dual purpose by enhancing the economic welfare through profitable business development and also by assisting in the resolution of environmental challenges which threaten our very existence on the planet" (SPARK 1991; emphasis added).

Others who pursue a sustainable future from a different conceptual framework would likely be critical of this line of reasoning, making the argument that relying on technology to solve environmental problems may side-step the critical root of the issue. Lemons & Brown (1995) imply this in suggesting "questions [such as those asked by industrial ecologists] presuppose a definition of a given problem for which only an answer in terms of the technological status quo counts as an answer." This alternate perspective may also view (technological) industrial activity as the cause of environmental degradation, but refutes the notion that technologies are capable of solving their own problems. Mander (1996) contends that the quest for innovative technological solutions has become a driving force in and of itself—one that has proven incapable of addressing real issues; "wave after wave of techno-utopian visions have so immersed us in positive expectation that they have solidified into a paradigm [in which] new technology is virtually synonymous with the advancement of society" (ibid: 346); meanwhile environmental and social problems continue to mount. The environmental technology movement seems, from this perspective, merely to be another type widget that treats the symptoms, rather than addressing the causes of dysfunction.

Perhaps it is not surprising that proponents of industrial ecology seldom address these kinds of questions. Coming primarily from the (often professional) realms of commerce and engineering, proponents of this concept have little to gain from reactionary and uprooting changes in the industrial system. They have a stake in the future of industry and, from all appearances, genuinely feel that the benefits of an industrial society need not be undermined by ecological destruction. Literature on industrial ecology generally omits misanthropic notions that modern human development is fundamentally opposed to environmental sustainability, assuming that the innovative prowess of humanity is capable of tackling the challenge. It tends to speak candidly of the problems, while remaining optimistic about offered solutions. Furthermore, changes that do occur in the industrial framework should be directed by those who intimately know the detailed functioning within—namely, themselves. Who knows better how to improve industry, they might ask, an engineer or a philosopher? If they are correct in believing the former to be more suited to the job, then the prospects for the success of industrial ecology may be encouraging. The intellectual leadership from within industry to pursue the application of the principles of industrial ecology bodes well for its economic viability.

The question remains however, whether the incremental changes in individual company operations will add up to a sufficient reduction in environmentally damaging activities to be called sustainable. This is particularly the case when those companies retain their commitment to continued economic growth and expanding production (Rees, 1995).

2.7 A Call to Deepen the Metaphor

In this chapter I have presented the theory of industrial ecology as it is most commonly discussed in the literature. The essence of the argument is that industrial systems require modification in order to prevent the ecological disruption that is already evident in much of the world. The guiding metaphor is a superficial emulation of natural ecosystems in terms of cyclical flows of matter through multiple trophic levels of industry. Beyond the 'food web' analogy, though, little thought is given to the dynamics exhibited by ecosystems that contribute to their 'sustainability' or make them useful models after which industrial systems should be designed. Indeed, as it is presented in the literature, industrial ecology tends to be quite a shallow metaphor.

The next chapter will attempt to deepen the metaphor that underlies industrial ecology by exploring some of the thermodynamic characteristics of ecological systems. As self-organizing and open thermodynamic systems, natural ecological systems exhibit certain characteristics that explain trophic levels and the advantages of their formation. These characteristics complement the existing industrial ecology framework and strengthen the biological metaphor that underlies it.

Chapter 3: Complex Industrial Systems: connections to a deeper metaphor

The last chapter presented the theoretical framework of industrial ecology as it appears in the literature. The underlying message was that sustainability could be attained with the replication of certain ecological themes in modern industrial systems. Lean industrial metabolism and multi-tiered trophic webs are the two major themes that come out of the literature. But upon what basis does this analogy lie? The justification for invoking this metaphor is seldom explored in the discourse of industrial ecology—it seems to rest on the intuitive sense that the theory makes. Ecosystems are 'natural', so they must be 'sustainable'. Such is the implication of the literature.

The present chapter, however, proceeds beyond (and beneath) that analogy. There must be some deeper reasoning behind industrial ecology that justifies the metaphor more convincingly than 'intuitive sense' can offer. Moreover, given the diversity of natural ecosystems across the globe, simple emulation cannot guarantee that the preferred industrial ecosystem is appropriate to the context within which it must operate. If industrial ecology mandates the design of industrial ecosystems, then designers must be wary of appropriate context; for example, a 'rainforest-type' industrial ecosystem will not likely be suitable to a 'high-desert-type' context. These contextual considerations are notably absent from the IE literature, but seem crucial to the functioning of the system.

In this thesis I make an attempt to contribute to the theory of industrial ecology by investigating the link between natural and industrial systems. In order to do so, the theory of complex thermodynamic systems is introduced and identified as a means of articulating the commonalities between these systems; as well, the theory offers compelling justification for linking industrial and ecological systems in the pursuit for sustainability.

3.1 Thermodynamics and Sustainability

One of the more common conceptualizations of sustainability is that of three interconnected systems—social, economic and ecological—that must be reconciled with each other and brought into harmony (e.g. Robinson and Tinker 1997). To the extent that industry is the interface between society and ecosystems, then, industrial ecology can be said to have identical objectives. Indeed, despite the nebulous and ill-defined nature of sustainability, that is the explicit and ultimate goal of industrial ecology. However, in order to comprehend the dynamics of and interactions between these quite different systems, there needs to be some common language that unites the three. The premise of this chapter is that the laws of thermodynamics provide the common ground necessary to conceptually collate these diverse systems into a manageable framework.

The first law of thermodynamics unites the universe through its assertion that matter and energy are conserved in the universe—neither creatable nor destroyable—but perpetually being transformed between phase states. Everything is composed of matter and/or energy—only their configuration and dynamical properties differentiate between what humans perceive as discrete entities. For the present purposes, the first law accentuates the intimate interconnections between the three prime systems of concern (and everything else, in general).

The second law of thermodynamics refers to the qualitative state of matter-energy, and is typically expressed in terms of entropy—a measure of relative disorder—, which inexorably increases within isolated systems. The dispersal of gases in confined spaces and the diffusion of heat across a given medium are classic examples of spontaneous entropy increases that draw the irreversible 'arrow of time'. However, this formulation of the entropy law applies to thermodynamically closed systems existing at (or close to) thermodynamic equilibrium, which none of the systems of sustainability are. Indeed ecological, economic and social systems tend to spontaneously increase in complexity and structure over time, which seems counterintuitive and appears to make the second law anomalous in these cases.

Clearly, then, if thermodynamics is to help understand the dynamics and interactions of the three prime systems, a new formulation of the second law is needed that relates to open systems operating at a distance from thermodynamic equilibrium. Schneider and Kay (1992) suggest that open thermodynamic systems will invariably resist externally applied gradients that move them farther from thermodynamic equilibrium. When systems encounter conditions of low entropy, they will consistently act to dissipate those gradients in attempting to return to thermodynamic equilibrium, according to this formulation of the second law. This dissipation is abetted by the spontaneous formation of organized structures that more effectively reduce the applied gradients. These emergent structures are what will interest this discussion, but first a clarification of terms is in order.

3.2 Exergy and Gradients

According to the cogent definitions in Ehrlich et al (1977), energy, which can be defined as 'stored work', has both quantitative and qualitative characteristics. Important to this discussion is the qualitative aspect termed 'availability' that describes the proportion of a given quantity of energy that can be converted into 'applied work'—availability reflects the relative usefulness of energy. For Ehrlich et al "the most subtle and overwhelmingly important message of the second law of thermodynamics [is this]: *all physical processes, natural and technological, proceed in such a way that the availability of the energy involved decreases*" (Box 2-3, emphasis theirs). Schneider and Kay (1992) call available energy 'exergy' and unavailable energy 'entropy'. Energy gradients exist when there is a high concentration of available exergy somewhere in a total system. In non-equilibrium conditions, then, dissipative structures form that improve the system's efficiency at converting exergy into entropy, reducing the availability of energy in the system and accelerating gradient degradation.

Exergy gradients are ubiquitous in nature, as are the dissipative structures that emerge to reduce them. Static electrical buildup in the atmosphere represents a gradient, which lightening emerges to dissipate; likewise, the potential energy (due to gravity) of elevated water in a bathtub is dissipated by the vortex that forms over the drain. In the case of the planet, the sun imposes an external gradient in the form of insolation. That energy is ultimately dissipated as latent heat—a qualitative state with far greater entropy. However, as a consequence of photosynthesis (whereby a small fraction of the incoming solar energy is trapped in ecological systems), living organisms and ecosystems have been able to develop highly complex dissipative structures. Various levels of consumer organisms compete to degrade available energy by consuming exergy-rich food and releasing exergy-poor body heat. Schneider and Kay (1992) propose that "more developed dissipative structures will degrade more energy. Thus we would expect more mature ecosystems to degrade the exergy content of the energy they capture more completely than a less developed ecosystem." Biological dissipative structures adapt to local gradients such that they maximize the conversion of exergy into entropy through their biological functioning. Thus as the trophic levels develop and gain complexity, more of the sun's available energy is degraded by the system. This point will become crucial later in the discussion.

3.3 SOHO Systems

One term that has been coined to describe these dissipative structures is 'self-organizing, holarchic, open systems' (SOHO systems), and a small body of literature has emerged that theorize about their dynamics (Kay, Boyle et al. 1999; Kay 2000). These systems are self-organizing with respect to their spontaneous formation in response to exergy gradients. According to Kay (2000) these "dissipative processes emerge whenever sufficient exergy is available to support them." The term 'holarchic' refers to the overlapping and nested hierarchical characteristics of these systems in which interdependence and relationships of mutual causality connect systems and subsystems both vertically and laterally (Kay, Boyle et al. 1999). Finally, SOHO systems are thermodynamically open in that they exist and maintain themselves by processing a sustained exogenous flow of exergy—they are fundamentally and characteristically dissipative structures. According to Kay (2000),

> Once a dissipative process emerges and becomes established it manifests itself as a structure. These structures provide a new context, nested within which new processes can emerge, which in turn beget new structures, nested within which… Thus emerges a SOHO system, a nested constellation of self-organizing dissipative process/structures organized about a particular set of sources of exergy, materials and information, embedded in a physical environment, that give rise to coherent self-perpetuating behaviors.

One key point to be drawn out from this statement is that these structures are organized "about a particular set of exergy, materials and information." These three factors are useful in identifying the nature of any particular structure, and help to comprehend the dynamical requirements of a system. Each will be explored in turn.

3.3.1 Exergy: In order to counteract the inexorable deterioration and dissipation due to entropy (in its classical sense), SOHO systems require access to a steady supply of useful energy (i.e. exergy) that may be harnessed to build and maintain their internal structure. Without this continued source of exergy these systems will collapse. Plants use sunlight to construct themselves from water and carbon dioxide; animals use the energy in the organic chemical bonds initially photosynthesized in plants. Likewise, modern societal systems have exploited fossil fuels to power the formation of industrial and economic subsystems. When planning for the growth (or continuation) of certain systems (i.e. the economy), evaluating the sustainability of our primary exergy source is important. Already, our almost exclusive reliance on fossil fuels has lead to a destabilization of the planet's atmospheric system. As stated above, the planet's primary exergy source is the sun's radiance—even when harnessed indirectly through the hydrological cycle, the formation of biomass and its slow conversion into fossil fuels over millions of years. The latter represents a finite stock of solar exergy, accumulated and concentrated over long periods of time, and is subject to scarcity constraints at an uncertain point in the future. Long-term sustainability in our human systems will require a shift to a more directly solar exergy source, the exploitation of which will neither deplete its availability nor compromise the stability of other supporting systems (i.e. the atmosphere).

3.3.2 Materials: SOHO systems are physical structures existing within a given environment or context. As such, they require a certain amount of material building blocks with which to compose themselves. Water, carbohydrates, amino acids, and trace nutrients are biological examples of this requirement, while ores, minerals, and fibers constitute industrial examples. From a material perspective, the planetary system is closed, and thus is subject to theoretical limits of scarcity as subsystems grow within it (Rees, 1995). Parallel subsystems often compete for materials in a given context, particularly in ecological instances. As human industrial systems grow and consume resources, the competition gets fiercer in some forums, often at the expense of other systems (e.g. other large mammals) that are consequently deprived of their material needs.

3.3.3 Information: In the present sense, information may be "defined as factors embedded internally within the system that constrain and guide the self-organization" (Kay 2000). Think of information as the set of rules or protocols that establish how an exergy source is harnessed to manipulate the materials that constitute a SOHO system. The nature of the information is highly specific to any given system, though factors such as hydrodynamics, gravity, and electro-magnetic attraction-repulsion may be common to many related systems. Genetic coding and replication are clear biological examples of 'information' in the present sense, but act in concert with many other 'higher level' informational attributes. Cultural norms and ideology fit into this category when characterizing larger scale societal systems.

For any given system, some energetic, material, and informational aspects may be identified (though even an incomplete list may be a long one). Thus, commonalities in terms of process and dynamics may be seen across a diverse spectrum of formerly unrelated systems. Kay (2000) goes farther, claiming "natural ecosystems and societal systems cannot be understood without understanding them as SOHO systems."

3.4 Attractors and Thresholds

The last point to be made in characterizing SOHO systems relates to stability and resilience. The quasi-stable equilibrium states that characterize SOHO structures operate within certain limits that are defined by negative and positive feedback. Negative feedback is a term used to describe 'self-correcting' mechanisms that tend toward a certain stable condition, whereas positive feedback processes amplify deviation and tend to destabilize systems. Any given system state has a 'window of vitality', within which negative feedback processes direct its self-organization toward what is termed an 'attractor' that defines the state of the system. Between the minimum and maximum limits, systems tend to be resilient in their propensities to return to their attractor. Resilience is a characteristic that defines how far systems may be pushed away from their attractor without causing destabilization. Beyond a system's limits of resilience, positive feedback takes over, causing a system 'flip' (or bifurcation) to a new domain of stability whose nexus is a different attractor. The parameters along which limits can be reached are (for the most part) uncertain; any number of variables can be significant to the stability of a SOHO structure, and the proximity to threshold limits is not always apparent until bifurcation occurs.

3.5 Operationalizing Complex Thermodynamic Theory

3.5.1 Lessons for Sustainability

The purpose of the present chapter is to explore the system dynamics that characterize complex, thermodynamically open systems existing far from equilibrium. The basis for such an endeavor is that the three 'prime systems of sustainability' all fall into this category, and are thus united in the 'holarchy' of the planet Earth. If the three are to be reconciled, the lessons learned from this formulation should be incorporated into the framework for analyzing them. The theory presented in this chapter is intended to advance the sustainability discourse beyond an abstracted 'three legged stool' into a conceptualization that highlights the interconnectivity and absolute dependence between the social, economic and ecological systems. The larger planetary system that humanity inhabits—of which ecology, society and economy are among myriad parallel or nested subsystems—operates in quasi-equilibrium within certain limits, continually balancing the dynamics of its component parts. Rapid and unprecedented change within at least two subsystems (the productive economy and human population) is stressing the equilibrium structure—testing its resilience. And while the position and proximity of critical thresholds may always be uncertain, there are signs that consequences are already being felt. Global climate change, ozone layer depletion, accelerated species extinction and desertification are all observable episodes that represent divergence from the center of the present attractor (Rees, 1998). Some such deviations have been directly linked to the operation of socio-economic processes, while for others the relationships are more tenuous. However, irrespective of the cause is the stark reality that bifurcation in a high-level system (such as the atmosphere or hydrological cycle) could quite easily compromise the stability of other systems upon which humans depend for survival. The mutual causality characteristic of SOHO systems means that bifurcation at any level has the potential to ripple through other systems unexpectedly.

The inherent uncertainty that comes out of this framework complicates its operationalization for policy interventions. What it does offer, however, is legitimate justification for the Precautionary Principle in its recognition of the unavoidable limits in human knowledge and predictive capability. If humans cannot predict the consequences of their actions, the wisest course may be to proceed with caution and make an effort to avoid obvious large-scale disruption (Rees, 1998). This policy runs nearly opposite to environmental protection policy based on litigation, in which the burden of proof is placed on the injured party. Under this system ecologically disruptive actors are deemed innocent until conclusively proven to be guilty of causing damage, by which time it may be too late to ameliorate the disruption. Overall, perhaps the lesson for sustainability is that humans should acknowledge our participation in—not domination of—systems that are ultimately mutually supporting and interdependent.

3.5.2 Lessons for Industrial Ecology

This thesis centers on industrial ecology, for which SOHO system theory is even more pertinent. To the extent that IE is conceptually based on the mimicry of natural ecosystems, this chapter provides a far more sophisticated read on what it means to 'resemble ecosystems' than appears in much of the industrial ecology literature. Thus, while this chapter offers a fresh look at the metaphors used, it stops short of contradicting them. Indeed, in this chapter I have surpassed metaphor—SOHO system theory draws a direct connection between industry and ecosystems that both reinforces and dispenses with the shallow metaphors upon which much of IE is based. However, the major aspects of industrial ecology outlined in the previous chapter remain largely unchanged as a consequence of the insight from this theory. External resource webs and internal eco-efficiency remain useful sub-headings from which industrial ecosystems may be conceived. As well, the potential social and environmental benefits outlined previously remain valid. As such, I will use these general principles in the following chapters to analyze the case study.

The critical addition to industrial ecology that comes out of this chapter relates to context. As an abstracted theory of industrial design, the IE literature tends to describe the principles of application very generally, then points to specific industrial parks as evidence of its success. However, there are in fact very few functioning examples of industrial ecosystems, and those that do exist were often labeled as such retrospectively. The often-cited system operating at Kalundborg, Denmark is a case in point. This system involves an oil refinery, a coal fired power plant, a cement factory, a pharmaceutical plant, fish farms and a plaster board manufacturer involved in the exchange of various by-products; as well, heat and hot water are supplied to the municipality, sulfur is exported to a chemical maker, and sludge fertilizer supplements go to local farmlands. This highly integrated industrial system is the most widely sited example of an 'eco-industrial park', but emerged spontaneously out of existing personal relationships rather than the wisdom of industrial ecology (Cohen-Rosenthal, pers. comm. June 14, 2001).

Consider the importance of context in the following thought experiment. Industrial ecology makes the claim that following the abstracted principles of by-product synergy and pollution prevention leads to sustainability, and points to Kalundborg as its archetypal example of an industrial ecosystem. Does this then mean that any region wishing to implement industrial ecology as a sustainable development strategy needs the particular industrial mélange existing in Kalundborg? To agree with this supposition would be missing the point of industrial ecology. Indeed it seems that industrial ecology must concentrate upon the relationships between components that already constitute a context, not add components until a preordained content is achieved.

The context for any industrial system is the ecological and societal systems that already operate within a given area. There is no 'clean slate' on which industrial systems may be constructed. Any system that hopes to be successful will have to be cognizant of its place within the holarchy that hosts it. For any given eco-industrial system, what will be the source of exergy and materials; and what information will guide its development? Clearly, in the context of Kalundborg, a certain mix of industries was available to develop into a complex system that effectively exploits available resources. But how translatable is that mix across contexts? And how far can contexts be transmuted to achieve a desired outcome?

The present chapter leads to the assertion that theoretical industrial ecology provides the 'information' requirement that will guide the development of a self-organizing eco-industrial system. It mandates the development of symbiotic relationships among members of industrial ecosystems, but does not (and cannot) specify the detailed nature of those relationships. The sources of exergy and materials will be highly context specific, and the general theory of industrial ecology has no predictive capacity to suggest appropriate actors or sources. When examples are taken out of context, misleading conclusions may be drawn that turn out more harmful than helpful. Instances of this result are ample from the ecological realm in which benign or useful species from one ecosystem turn into intrusive exotic invaders in another. Indeed, eco-industrial solutions must be rooted in place, where the intricate balance of existing systems (ecological, social, or economic) creates the location-specific niches that allow symbiotic relationships to flourish.

The remainder of this thesis will do exactly as suggested above. A context will be chosen, and in that context the theory will be applied. To explore every potential pathway for that system is beyond the scope of the present work. However, a system is identified and an examination will be undertaken from the perspective of industrial ecology. If nothing else, the study will elucidate some issues that industrial ecology will face if it ever is pursued on a large scale.

Chapter 4: The Burnaby Incinerator: an illustrative example from the Big Bend

Having worked up the theoretical foundations for this thesis, the time has come for me to go into specifics. As previously noted, the crucial consideration for applying industrial ecology is context. Only once the context has been identified may the dynamics of the developing industrial ecosystem become apparent. This chapter will introduce the case study—a municipal solid waste incinerator—after dealing with some issues that may not be directly related to industrial ecology, but are nonetheless important to mention. In particular, incineration carries with it some baggage from the waste management discourse that should be ignored.

4.1 An Apparent Paradox

Industrial ecology is the study and development of industrial systems that minimize their flows of material and energy, optimize their design configuration, and exploit the positive behavioral interactions among their constituents. It is a highly normative field that idealizes a particular 'sustainable' configuration and discusses various ways and means for getting there. The underlying message is that there is a problem to be fixed, and *this* is how to do it. Industrial ecology's root metaphor (indeed, its guiding principle) is explicit in the name; if industrial systems were more like ecological systems, the imbalance between the two would be alleviated, and sustainability would be realized.

One of the primary emphases in industrial ecology is the desirability of dramatic increases in energy and material resource productivity. This ideally translates into an elimination of solid waste through a combination of product design innovation and improved recycling processes. Despite confounding thermodynamic constraints, phrases such as 'Zero Waste' and '100% Product' are often used when discussing the objectives and goals of industrial ecology. These terms are more rhetorical than achievable, and merely indicate the preferred direction in which to proceed.

This thesis project explores industrial ecology at the Burnaby Incinerator in the Greater Vancouver Regional District (GVRD). The question arises whether an industrial ecology scenario would include a municipal solid waste incinerator. Arguably an industrial ecosystem would have no need for permanent disposal methods such as incineration, as processes would have been developed that cycle materials back into the productive economy. Energy dissipation such as occurs in incinerators is irreversible and contributes to the overall throughput of the industrial system. Furthermore, to the extent that industrial ecology must adhere to criteria of sustainable development, common concerns about the human health and environmental impacts of incineration need also to be addressed. Indeed, at a very general level of analysis, the implementation of industrial ecology at an incinerator seems paradoxical and contrary to the spirit of the exercise.

A case can be made, however, for the inclusion of incinerators in the broader industrial ecology discourse, and that the Burnaby site is a reasonable one for examination. In general, incinerators should not be ignored by industrial ecology because they exist; an accounting of material and energy flows through society at present may well lead into this type of facility. If industrial ecology hopes to help guide the transition to a sustainable form of human development, then (at least in the short term) incinerators cannot be ignored. Furthermore, to the extent that industrial ecology describes self-organizing systems that exploit opportunities to dissipate thermodynamic gradients, the incinerator represents a viable exergy source about which an eco-industrial niche may develop.

4.2 Issues Around Incineration

It should be noted that the present thesis is not primarily concerned with waste management strategies in a political sense. Industrial ecology is a framework of thought that challenges the very conception of waste; it encourages designers and managers of industrial processes to create systems in which materials are more fully utilized, rather than prematurely discarded as waste. The establishment and development of multiple trophic levels in industrial ecosystems is explicitly aimed at the elimination of waste (both as a concept and an entity) from production-consumption systems; the disposal of waste materials represent a hole in the closed-loop material cycle hoped for in industrial ecology. However, to the extent that it offers an operational pathway from the present to a sustainable future, IE needs to be able to say something about systems that do not fit the idealized industrial ecosystem model. Hence the present thesis explores how IE might deal with an incinerator, which (as already noted) may appear antithetical to the spirit of the model.

Aside from the internal contradictions between IE and incineration, a host of other issues surround incineration with respect to waste management strategies in particular. Indeed incineration is a contentious issue that deserves a tangential discussion here. Different actors in the waste management community have sharply differing opinions of incineration as a means for coping with urban waste streams. The following paragraphs explore the polarization of the debate. These arguments do not come out of the industrial ecology framework, but nor should they be ignored by it.

4.2.1 Landfill-Recycling Dynamics

Proponents of municipal waste incinerators commonly cite the increased longevity of landfills as reason to support these facilities. Due to the approximately 80% reduction in the volume of refuse after incineration, municipalities are conjectured to be able to quintuple the life of existing landfills by building an incinerator.

However, recycling advocates seldom differentiate their condemnation of landfills and incinerators, as both are below recycling on the waste management hierarchy (reduce, reuse, remanufacture, recycle, discard). Incinerators are seen from this perspective as an active disincentive to recycle. The capital expense associated with incinerator construction requires debt servicing for many years. According to Montague (1990), incinerators "must be fueled with garbage for 20 years, making the community's trash unavailable for recycling; about 80% of the waste stream can be recycled OR incinerated but not both."

4.2.2 Pollution Pathways and Temporal Sustainability

The case can be made that today's landfills represent a liability to future generations that inherit the legacy of tainted groundwater and toxic contamination. As part of a programme for sustainability, then, perhaps incinerators, which reduce the need for landfills, have an important role to play. Indeed, incinerators could be seen as contributing to the temporal sustainability of a region by preventing long-term toxification of groundwater from landfill leachate.

On the other hand, incinerators are also point-source pollution generators, and continually burn large amounts of very impure and contaminated fuel. The air emissions contain measurable amounts of major pollutants, and very little can be done to prevent this beyond a certain point. The better the pollution control equipment, the more concentrated are the contaminants in the fly ash scrubbed from the stack. And to the extent that the fly ash gets disposed in the landfill anyhow, questions arise as to the point of the incinerator in the first place.

4.2.3 The Economics of Waste Disposal

There can be no doubt that incineration is an incredibly capital intensive operation. The GVRD incinerator requires $12 million per year in operation and maintenance, and is estimated to have a replacement cost of $120 million. Critics of this process are leery of the magnitude of these costs, and likely wonder if that money would be better spent to promote recycling campaigns.

However, to the extent that environmental problems can be fixed by factoring in 'externalities' that skew markets away from what may be considered an 'optimum condition', incinerators may be seen as preferable to landfills. Because costs are endured immediately, rather than over decades of remediation and clean up, incinerators may be more likely than landfills to encourage source reduction and waste prevention.

4.2.4 Thermodynamic Considerations

One of the main selling points of incinerators is that they can be configured to generate considerable flows of steam, which can be used directly in industrial applications or to actuate turbines that generate electricity. Advocates of these 'waste-to-energy' facilities would add a fifth 'R' to the familiar hierarchy—reduce, reuse, remanufacture, recycle and *recover*. The material waste stream contains a great deal of energy (i.e. energy inherent in the chemical make-up of the material), the exploitation of which makes good sense from the perspective of the first law of thermodynamics.

However, there are different ways to exploit the energy contained in waste materials, incineration being one of many. The second law mandates that any process that transforms energy (from chemical potential to electricity in an incinerator, for example) will lose some portion of that energy through entropic dissipation. With the second law in mind, it makes much more sense to reuse or remanufacture a product without radically transforming its thermodynamic state. Thus, from this perspective, incineration is thermodynamically inefficient when compared to alternatives higher up the hierarchy.

What emerges from this debate is a hierarchy of preference that seems consistent across the spectrum. The classic four 'R's are seldom disputed. Advocates of reduction, reuse, remanufacturing and recycling perceive anything below this level to be highly (read equally) undesirable. Incinerator advocates acknowledge the top of the hierarchy, but slip themselves in neatly as a fifth 'R' and, again, disparage against the landfills that occupy the lowest rung in the hierarchy. Each level props itself up on the faults of the ones below, while landfills remain by far the most common type of waste management facility in Canada.

Probably the most valuable insight that can be drawn from this discussion is that in terms of future directions, the best path forward is unanimous—the higher we get up that hierarchy the better, and even recycling is only half way to the top. Incineration exploits the chemical energy in waste materials through thermal combustion, an irreversible dissipative process. Industrial ecology, as a theoretical ideal, would minimize the dissipative matter-energy transformations that occur in an industrial system, gleaning maximum usage from any flow of exergy through it. Thus, while incinerators should not be explicitly advocated by industrial ecology, they would seem preferable to 'tax and bury' approaches to waste management from this perspective.

4.3 Case Study Site: The GVRD Incinerator at Big Bend

4.3.1 Location:

The GVRD solid waste incinerator is located in south Burnaby between Marine Way and the north arm of the Fraser River in an area called 'Big Bend' (after the shape of the river). The facility is owned by the GVRD, and operated under contract by Montenay, Inc, a large corporation that runs similar facilities around the world.

4.3.2 History:

Upon recommendation by the GVRD Solid Waste sub-committee in 1981, a request for proposals was issued to design and build an energy recovery and solid waste incineration facility in the regional district. Belkin Paper (now called Norampac), property owner and existing operator of a paper plant in the Big Bend site, signified interest in purchasing steam from such a facility in 1984, agreeing to sell an adjacent parcel of land to the GVRD for the construction of what was to become the Burnaby incinerator. In May 1985, the contract to design and build was awarded to GKN Birwelco Ltd, and Montenay Inc. was sub-contracted to manage its operation. In November of that year, the planned plant size was increased to 210,000 tonnes per year (from 140,000 tonnes) and "state of the art" pollution control technology was included in the plans. In 1988, when the testing had been completed and the GVRD had accepted the facility, the incinerator came on line operating at capacity, as it has been in the 13 years since. Upgrades to the pollution control system have included the installation of: in 1993, an Activated Carbon Injection System that controls hydrocarbon and mercury emissions; in 1994, a Recycle Water System that cycles cooling water through the process to eliminate waste water discharge from the plant; in 1996, an Ammonia Injection System in the furnaces to control nitrogen oxide (NOx) emissions, and; in 1998, a Fly-Ash Stabilization System to mitigate metallic leachate from combustion residues. The GVRD has current plans to incorporate a co-generating turbine to generate electricity for export from the steam that is currently not sold to the paper plant.

4.3.3 Context:

The Burnaby incinerator does not exist in isolation. Rather, it is one part of the GVRD integrated solid waste management system, handling a little less than 20% of the solid waste generated in the region. The large remainder of the waste is disposed of in various landfills both in and outside of the regional district. In BC, the regional districts hold responsibility for the management of municipal solid waste under the Waste Management Act, as it was amended in 1990. As such, the allocation of waste materials among the various disposal facilities is flexible to allow strategic interventions in the waste flow pursuant to the waste management plan.

One aspect of the integrated waste management plan (as articulated in 1990) is a 50% reduction in the disposed solid waste through diversion to recycling facilities. Increasing rates of residential and commercial recycling have been seen, but few (if any) regional districts have attained that reduction goal. Recycling advocates claim that up to 80% of municipal solid waste could be recycled, and some American towns have initiated pilot studies that demonstrate this potential (Montague 1990). In the GVRD, increasing diversion rates over the last decade have led to a slight drop in the gross tonnage of disposed material despite a steadily increasing population level. Meanwhile, the per capita generation rates (the sum of disposed and recycled materials) have remained virtually constant at just over 1.3 tonnes per year (RCBC 1999).

Table 1: Annual Material Flows Through the Incinerator
Average values 1991-2000, all units tonnes/year

Inputs	Outputs
Refuse – 248,400	Combustion Gases – 193,662
Lime – 2,600	Bottom Ash – 43,400
Ammonia – 300	Fly Ash – 7,700
Phosphoric acid – 750	Ferrous metals – 7,300
Carbon – 12	

4.3.4 The Process:

While the incinerator should be discussed in the larger context of the GVRD waste flows, the process that occurs at the site is relevant to the debate from an eco-industrial perspective. Thus, this section will describe what occurs on site, including an account of the material and energy flows through the facility.

Trucks that collect solid waste (from residences and transfer stations) arrive at the Big Bend site and key in an authorization code at the weigh scale to gain access to the facility; this records their identification and tonnage information. Upon entrance, the trucks dump their load in a refuse bunker to be stockpiled for combustion. Overhead cranes in the bunker mix the refuse and load it into the furnace feed chutes as required. The crane operator monitors the stockpiled refuse for excessive dampness and other irregularities that may affect the burn when it is loaded into the furnaces. An air circulation system draws the air from the refuse bunker into the combustion chambers to prevent odors from escaping the system.

Once inside the combustion chamber, the refuse moves down a grate, burning above a reference temperature of 800 degrees C. Liquid ammonia is injected into the combustion chamber to control the formation of nitrogen oxides. The solid residue (bottom ash) from the incineration process passes through a magnetic separator, which gleans the ferrous metals from the mix, and the remainder is trucked to the Port Mann landfill. Bottom ash has about 10% of the volume and 20% of the mass of the incoming refuse. The separated ferrous metals are exported to a manufacturer of reinforcing bars.

The gaseous products of the incineration process pass through boilers where they heat tubes filled with water, generating approximately 3.3 tonnes of steam per tonne of refuse burned. Two fifths of that steam is sold to the Norampac paper plant, eliminating their use of natural gas, while the rest is currently condensed. The steam load required by Norampac has diminished slightly over the years as their operations have been downsized, but plans exist to install a co-generating turbine that would generate electricity from the steam that is not sold; that system is scheduled to come online in 2003.

After passing through the boilers, the hot gases enter a pollution control plant that cools the gases and treats them to remove various pollutants. Among the pollution control measures are: lime to neutralize acid gases, phosphoric acid to stabilize heavy metals in the fly ash, activated carbon to control for mercury emissions, and fabric bag filters to trap dust and other particulate matter (the collected material is called 'fly ash'). The exhaust gases pass through a Continuous Emissions Monitoring System (CEMS) that records the levels of various pollutants as they leave the stack (see table 2).

Table 2: Quantification of Pollutant Release
Averaged values 1996-2000

Pollutant	Measured Concentration (mg/m^3)	Calculated Quantity (T/yr)
Sulfur Oxide (SO_2)	53	88.12
Hydrogen Chloride (HCl)	24	39.99
Total Hydrocarbons (THC)	2.3	3.82
Carbon Monoxide (CO)	13	21.64
Nitrogen Oxides (NOx)	308	512.4
Mercury (Hg)	0.022	0.0366
Lead (Pb)	0.006	0.0099
Cadmium (Cd)	0.0022	0.00366
Particulate matter (PM)	2.6	4.327

4.4 Why Burnaby?

Chertow (2000) suggests that there are three 'evolutionary approaches' to implementing industrial ecology. In terms of implementation, a crucial lesson is that cooperation develops over time, and that a step-wise approach often works best. The three evolutionary approaches are: 'green twinning' or the springboard approach, the 'anchor tenant model', and the exploitation of 'small mental gaps'. The Burnaby incinerator fits at least the first two of these approaches, making it a likely candidate for further eco-industrial development. 'Green twinning' is based on the notion that 'success breeds success' and that in cases where symbioses already exist, further expansion of IE applications may be easier. The Burnaby incinerator was originally built as a waste-to-energy facility in conjunction with a neighboring paper mill. In this respect, the site already has the kernel of industrial ecology from which a more developed eco-industrial park may sprout.

The 'anchor tenant model' is predicated on the notion that eco-industrial parks are more often successful when there is a primary participant already dedicated to the enterprise. Having such an anchor tenant or 'rainmaker' supplies stability and risk mitigation for other businesses and participants that may be reluctantly interested. In the present case study, the publicly owned incinerator is just such a 'rainmaker', allowing this pathway to seem promising.

Chertow's (2000) final approach may be less applicable to the present case. The notion of 'small mental gaps' has been recognized as important in terms of achieving sufficient levels of trust among participants in an eco-industrial endeavor. Without trust and understanding, the interdependence that characterizes inter-firm relations in an eco-industrial setting may be seen as overly undesirable. In the present case, it is unclear whether the public ownership of the incinerator would be conducive for such relationships to emerge; while local governments in theory should be trustworthy and accountable for their actions, the cultural differences between businesses and governments may be large. That having been said, the public ownership of the incinerator may indicate stability for the site, lessening the likelihood of it being prematurely decommissioned.

In any case, the fact that the Big Bend site already engages in some industrial symbiosis likely predisposes it to expanding such linkages. Another independent study (Thermoshare 1997) reviewed 40 industrial sites in Canada for their potential to be developed into integrated eco-industrial parks, and identified the Big Bend site as among nine "high priority potential sites". This conclusion was reached based on the "availability of good transportation, planned or existing cogeneration facilities, existing energy intensive industries and potential for recycling" (ibid: 3). I shall follow their lead, and the following chapter investigates the Big Bend site more carefully from an industrial ecology framework.

Chapter 5: Industrial Ecology Explored: theory in context

5.1 Big Bend—through the lens of industrial ecology

My intent is to examine the GVRD incinerator from the framework of industrial ecology, according to the themes and principles developed in chapter 2. Taking this perspective as my starting point forecloses on the opportunity for a comparative analysis of industrial ecology versus other models of industrial design. However, my own reading of the principles and motivation of industrial ecology has exposed its normative character, and thus my analysis is more of a narrative than an experiment. The idea is to generate a narrative guided by industrial ecology that is internally consistent and resonates with the notion of sustainability in the Georgia Basin. To this end, I pursue the ideas and concepts that appear in the literature in more detail, attempting to operationalize some of the general principles into applicable actions that are relevant to the context of the Big Bend site.

In this chapter, I identify four general principles of sustainable development—sustainable resource use, maintaining ecological and human health, enhancing social and environmental equity, and fomenting a culture of sustainability—each of which are elaborated in their sections below. The first three are roughly parallel with the triple imperatives for sustainability—economic, ecological and social, respectively—while the fourth represents the impetus to pursue the overall sustainability agenda. The literature review in chapter 2 provides industrial ecology's translation of the sustainable development principles: external resource webs, internal eco-efficiency, the corollary benefits of eco-industrial development and a commitment to change the industrial model. Table 3 illustrates how the principles of sustainable development are advanced through industrial ecology, and may be broken down into more specific aspects that apply to the Big Bend site under consideration.

Table 3: Basis for Analysis

SD Principle	IE Translation	Bby specific	potential measure	Empirical value
Sustainable Resource Use	external resource webs	*by-product synergy*		
	material recycling	onsite diversion bottom ash re-use	-% of total flow -% of total ash	--3% (fer. metals) --0% except in landfills
	energy cascading	use of steam, electricity, hot water	-GJ -# of linkages	--75000 GJ/month to Norampac
	Water recycling	Water consumption	-liters per day	Zero discharge
Ecological & Human Health	internal eco-efficiency	*Pollution Prevention*		
	technological control	Scrubbers, etc	-Qual. Desc. -compare 5yr trends	--getting better
	Policy instruments	-Emissions Permits -Waste Man. Plans	-Stan'd Vs. Emission -Diversion rates (haz waste prohibitions	--Well under permit levels -bans in place, hard to enforce
Social/Env. Equity	Eco-industrial Development	*Eco-Ind. Park Development*		
	Green Econ. Dev.	Poss. 'scavenger' & 'decomposer' industries	Jobs/firms established	None to date
	Community empowerm'nt	Consultation Processes for dev.	'sense of satisfaction'?	None to date
	Intergeneration al equity	Reduced landfill legacy	Annual tonnage not to landfill	200,000T averted—13% reduction
Cult. of Sust'bility	Commitment to change	GVRD & Montenay Policy	Track record	Iso 14001 cert, freq. upgrades

5.2 Sustainable Resource Use

The principle of using resources in a sustainable manner is derived from the notion that socio-economic systems exist and operate within a finite physical environment in which parallel systems compete for material and energy resources. It is recognition that ever expanding economic and industrial throughput will eventually reach a limit characterized by the destabilization of the supporting ecosystems. As suggested in previous chapters, though, the limits that bound system stability are inherently uncertain and seldom subject to prediction. Indeed, the line between levels of resource use that may be considered sustainable and unsustainable is at best subjective—for some resources the thresholds are fundamentally unknowable. This represents a major barrier in defining material sustainability—at what point does enough become too much? To this question, industrial ecology offers no clear solution. However, what can be drawn from industrial ecology is the principle that for any given resource flow, maximum utility should be obtained by integrating parallel processes in symbiotic resource webs. For the purposes of investigating the Big Bend site, three categories of resources will be considered: materials, energy, and water.

5.2.1 Material Cycling

The material flow through the system under consideration is quite likely different from what most industrial ecology theorists think of when referring to material cycling in industrial ecosystems. With its roots in manufacturing, IE's conceptualized resource flows are probably more pure and predictable than the municipal solid waste (MSW) that represents the primary flow through Big Bend. Indeed, the material resources in unsorted

MSW are diffuse and may be characterized as having a high degree of entropy. Its impurity notwithstanding, however, the 250,000 tonnes of material that pass through the facility per year represent a considerable material flow. Broadening the scope of the system, that amount is a mere 20% of the available flow of that particular material resource. The fact is irrefutable—large metropolitan areas like the GVRD unwittingly produce massive quantities of unsorted municipal solid waste. If lessons may be taken from the natural world (as they may in IE), consider the following analogy. The oxygen gas byproduct of photosynthesis was a highly reactive (and toxic) waste product prior to the evolution of aerobic respiration, but became a vital fuel for the next generation of organisms. Likewise, if a mechanism could be devised whereby MSW could be made useful, unpredictable benefits may be derived from its utilization. In terms of utilizing the material flows through Big Bend, two avenues are possible: before incineration, or after it.

5.2.1.1 Using incinerator ash

At present, the only utilization of material resources in the MSW flow into the Big Bend system is the magnetic separation of ferrous metals from the bottom ash, representing a mere 3% of the material flow. The remaining bottom ash is not put to use except as a covering layer in landfills. The GVRD has long been considering the use of bottom ash as construction aggregate for road building, though nothing has come of it as yet. A number of concerns prevent the deployment of bottom ash in commercial construction applications, including the probable contamination of the material with heavy metals and organochlorides. The high degree of heterogeneity characteristic of municipal solid waste makes it difficult to consistently predict the actual levels of ash contamination. However, a number of treatment possibilities do exist that mitigate against these concerns and some European countries make extensive use of incinerator ash in such applications as aggregate for cement and asphalt, and stabilizing layers underneath roads and pavement. Dhir et al (2000) explore the details of this area extensively.

5.2.1.2 Pre-burn diversion

From a thermodynamic perspective, exploitation of material resources prior to incineration is far more desirable than the use of ash due to the inherent dissipation of embodied energy that incineration represents. Particularly in the present case, where there is a vast excess of MSW available (beyond the incinerator's capacity), pursuing the pre-burn separation and exploitation of material resources makes good sense. At present, the separation and recycling of solid wastes occurs outside the system under consideration, and all materials transported to Big Bend are incinerated. If the system were to develop into a more complex industrial ecosystem, onsite separation and recycling seems like a fruitful avenue to pursue. Infrastructure is already in place that transports materials to the site, and a much greater proportion of that material could be diverted to more efficient processes of utilization than presently occurs. The availability of relatively large quantities of MSW would prevent the incinerator from having to run under capacity even if a significant industry could be forged in culling the waste stream. As well, the Big Bend site has excellent access to transportation routes by road, rail and river, and is centrally located in the GVRD. Another potential advantage of the Big Bend site for such industries would be integration into the district energy system described below.

5.2.2 Energy Cascading

The laws of thermodynamics provide the basis for devising a system of multi-level energy cascading through adjacent industries, matching energy demands with residual quality as it passes between participants. The first law states that energy is never created nor destroyed, so it may be 'traced' through an industrial system. Meanwhile the second law mandates that the energy in a given system will lose its availability to entropy as it cascades between states. The critical lesson is that it is possible to extract the 'availability' of energy at each stage or level for different applications up to a point. Despite the conservation of energy, exergy steadily decreases to nothing as 'available energy' is degraded progressively at each level in the system. The goal of industrial ecology should be to maximize the use of exergy as it dissipates toward equilibrium.

5.2.2.1 Direct Steam Applications

The Big Bend case is an interesting one from an energy perspective, as the material and energy sources are the same. The system obtains its primary power by extracting the energy contained in the combusted material. To the extent that the material would otherwise go to a landfill, this may be considered 'free' power. At present, refuse is burned in self-sustaining furnaces that require natural gas burners only during start-up and shutdown procedures, or during 'upset' conditions. Every tonne of refuse burned generates approximately 3.3 tonnes of high-pressure steam, for a total of 825,000 tonnes of steam annually. When leaving the boilers, the steam is 248 ° C, and 3040 Kpa. Steam of this pressure and temperature may be useful in various industrial applications. In 2000, approximately 42% of this steam was sold to the Norampac paper plant, eliminating their use of natural gas. For now the remainder of the steam is condensed, wasting the energy. The availability of this residual steam could attract other industries that currently generate steam independently for their processes. The GVRD sells its steam for 85% the cost of generating an equivalent amount of steam in natural gas boilers.

5.2.2.2 Electrical Co-generation

The symbiotic relationship between the incinerator and the paper plant represents a fruitful application of industrial ecology at Big Bend, but there is clearly room for improvement. The most obvious area is the 58% of the high-quality steam that is currently wasted. The GVRD has plans to install a co-generating turbine that would generate electricity from the remainder of the steam. The maximum power output of this system will be 22.5 MW at plant capacity, which is more than an order of magnitude higher than the annual electrical load of the facility. This surplus electrical power would be available for export to other local industries, or could be sold back to the power grid. This electrical generation system is expected to come online in 2003.

5.2.2.3 District Heating

Beyond steam and electricity, however, energy could be cascaded further to supply low-level energy demands locally through the provision of heat and hot water to nearby industrial and residential areas. According to a report published by Natural Resources Canada and Environment Canada (Arkay and Blais 1999), so-called "district energy systems use central energy plants to meet space heating, domestic hot water, and cooling needs" for a variety of energy users from a single source using integrated energy distribution and transfers systems. The incinerator at Big Bend could supply such services to the local area from the energy that is presently wasted through condensation. The timing of this idea is particularly fortuitous given the fact that the areas surrounding the incinerator are presently being developed for light industrial and warehouse uses. Representatives at Montenay are currently initiating preliminary talks with the developer of that land to install such a system, but have yet to finalize the deal. If realized this system would allow the Big Bend industrial area to develop and mature without adding to the demand of the Lower Mainland's power requirement. If that development were also to be oriented toward re-use and recycling industries, then it would fit symbiotically into to larger 'waste stream ecosystem' in the region.

5.2.3 Water Recycling

Water is a precious and, despite the annual rainfall in the GVRD, potentially scarce resource. Industries almost always require water to fulfill some process objective, and the incinerator site is no different. Water is presently used in this system not only in the boilers and steam circuit, but in the pollution control plant as well. In the latter case, the effluent gases are cooled and scrubbed with water, resulting in the potential for seriously polluted wastewater discharge; various strong acids, heavy metals and organic pollutants all may reside in the pollution control plant's wastewater. The location of the plant near the bank of the Fraser River escalates the potential implications of such emissions.

However, in 1994 a water recycling system was installed that eliminated the discharge of pollutants in aqueous form by internalizing the water circuits. Onsite treatment now closes the water loop such that the only water to leave the plant comes from staff sinks and toilets.

5.3 Ecological and Human Health

The extent to which the natural environment can absorb and process pollution is limited, and beyond a certain point pollution release becomes toxic to both humans and their ecological environs. The recognition of these natural limits triggered the environmental movement decades ago, and continues to be a central principle of sustainable development today. Unfortunately, as with sustainable resource use, the transition from acceptable to toxic levels of pollution is not always clear. Governments regulate polluters through the issuance of permits or the specification of guidelines, but often the specified levels are chosen arbitrarily, or are based upon factors other than health effects. At other times pollution regulation specifies a particular technology that is deemed to be sufficient, but this tactic works against continual improvement over time.

Industrial ecology's position is that industries should act overtly to minimize pollution release as a fundamental objective of their processes. Proponents assert that efficiency gains may be achieved by culling the waste stream for useful components; any components that are unusable or overly hazardous should be designed out of the system at the front end. Applied to the incinerator, this may mean burning only benign materials such that the effluent gases are clean, and the ash may be used in other applications. Broadening the system, the implication is that manufacturers would not use hazardous materials in production or would take responsibility for recovering the toxics they do produce. This would make the solid waste that remains benign enough to dispose in whatever way that seems appropriate.

With respect to incinerators, airborne pollution is a key concern. Due to the fundamental conservation of matter, any harmful substances that exist in the refuse will be denatured in the combustion chamber, condensed in the ashes, or emitted into the atmosphere. Thus, there are three distinct strategies for preventing pollution from escaping the incinerator: maintaining a minimum combustion temperature, effective pollution-control systems and managing the inputs such that they are free of pollution precursors.

With respect to the combustion temperature, the furnaces are engineered to operate above a minimum reference temperature of 800 degrees C. Table 4 shows the number of hours that the incinerator failed to meet this target, during which time incomplete combustion likely led to increased emissions. The cause for such 'upset conditions' is usually excessive moisture or inconsistencies in the content of the refuse. Engineers at the incinerator continually monitor both the feedstock and chamber temperature, minimizing the duration of such upset conditions. The data in table 4 suggest an improving trend in this regard.

Table 4: Hours Minimum Reference Temperature Not Achieved

Year	Unit 1		Unit 2		Unit 3		Plant Average (%)
	Hours	% of Total Hours	Hours	% of Total Hours	Hours	% of Total Hours	
1991	97	1.22	135	1.70	49	0.62	1.18
1992	56	0.74	82	1.02	35	0.43	0.73
1993	31	0.39	62	0.76	6	0.07	0.40
1994	65	0.79	128	1.55	65	0.79	1.04
1995	126	1.52	164	2.0	76	0.92	1.48
1996	28	0.34	32	0.39	10	0.12	0.28
1997	10	0.12	22	0.27	8	0.10	0.16
1998	8	0.09	14	0.17	11	0.13	0.13
1999	9	0.11	14	0.17	15	0.18	0.15
2000	2	0.02	3	0.04	3	0.04	0.03

Source: unpublished GVRD data.

5.3.1 Technological Controls

The GVRD incinerator has an extensive pollution control system that is considered 'state of the art'. Some of the major pollutants are targeted with specific control measures. Examples include ammonia injection into the furnaces to control the formation of nitrogen oxides, the addition of lime in the pollution control plant to neutralize acid gases, activated carbon to trap mercury emissions, and phosphoric acid to stabilize other heavy metals. The efficacy of the pollution control measures presents itself in the monitoring data below.

Table 5: Permit Limit and Averaged Pollutant Emissions

Pollutant	Permit limit mg/m³	Measured Concentration mg/m³ 1991-1995 (% of limit)	Measured Concentration mg/m³ 1996-2000 (% of limit)
Sulfur Oxide (SO_2)	200	86 (43%)	53 (27%)
Hydrogen Chloride (HCl)	55	19 (35%)	24 (44%)
Total Hydrocarbons (THC)	40	0.5 (1.3%)	2.3 (5.7%)
Carbon Monoxide (CO)	55	9 (16%)	13 (24%)
Nitrogen Oxides (NOx)	350	367* (n/a)	308 (88%)
Mercury (Hg)	0.2	0.054 (27%)	0.022 (11%)
Lead (Pb)	0.05	N/a	0.006 (12%)
Cadmium (Cd)	0.1	N/a	0.0022 (2.2%)
Particulate matter (PM)	20	5.2 (26%)	2.6 (13%)

* Permit level not in place for earlier time period
Source: Unpublished GVRD Data

In terms of monitoring, there is manual stack testing by an independent monitor, as well as continuous emissions monitoring systems (CEMS) installed on the stacks. Table 5 shows the permit limit for various pollutants and their measured concentrations over the last ten years. The emissions concentrations are averaged into two five-year periods to suggest trends in pollution control. The data are not perfect in that control technologies were added and adjusted over the ten-year period, as were the techniques used to measure emissions. However, two aspects of the table are worth pointing out.

Firstly, with the exception of HCl, CO and THC, the concentration of all classes of pollutants dropped over the ten-year period. It was suggested by representatives of the incinerator that the measured increases in the three pollutants were caused by improvements in monitoring capacity, rather than an actual increase in emissions. This raises the question of how much further the monitoring program could be improved; that is, to what extent are the measured values still misreporting actual emissions. Nonetheless, at face value the trends are encouraging.

The second significant point is that in most cases, the measured emission levels are well under the permit level. As shown in Table 5, with the exception of nitrogen oxides, all are less than half of the permitted level, and most are less than a quarter. The implications of this are either that the incinerator is very effective at controlling air pollution release, or the permit levels are in dire need of revision. Which of these alternatives are closer to the truth is hard to estimate, but both likely have some validity. Further investigation into the derivation of permit levels would shed some light on this question.

5.3.2 Managing Inputs

From the perspective of industrial ecology, this second strategy for mitigating human and ecological health impacts of an incinerator is preferable to end-of-pipe technological controls. Scrubbers and other pollution control technologies have diminishing marginal utility such that beyond a certain point, any further effectiveness becomes prohibitively costly. Indeed, any back end mitigation strategy stresses the existing system by adding individual costs to the operator, the benefits of which will be diffuse. Such strategies are subject to 'Tragedy of the Commons'-type problems that may act as disincentives for those that pursue them.

Conversely, if pollution issues can be preempted prior to incineration a better outcome is conceivable. That which does not enter, cannot come out. The overall waste management system, of which the Big Bend incinerator is a part, currently has mechanisms in place that aim to prevent the incineration of materials that would lead to hazardous pollution emissions. For example, many household hazardous wastes such as paints, chemicals, and car batteries are prohibited from the municipal solid waste stream. This effort works in conjunction with recycling programs and manufacturer product stewardship programs (whereby producers of hazardous materials are charged with the responsibility of safely recycling or disposing of their products). The issue that complicates this management plan is that, as separation and diversion occur extensively in residences, implementation and enforcement become problematic; every car battery that finds its way into the incinerator has a measurable impact on emissions of lead and sulfur dioxide.

This notion of managing inputs may be taken a step farther with the application of the deep industrial ecology that is the focus of this thesis. Drawing from the SOHO theory presented in chapter 3, if parallel systems are established that are self-organizing around the materials that cause problems in the incinerator (e.g. electronics, computer monitors, batteries, etc), then their complementarities will provide the incentive to pursue individual goals for the common good. Thus, an industrial ecosystem may develop if firms were established whose focus were scavenging and decomposing the flow of materials in the existing waste stream. The incinerator could broaden the niche by providing access to cheap exergy (via steam, electricity, heat and/or hot water) through its integrated district energy system. Each firm would need to be profitable in its own right to provide the incentive to keep the system operating, but the combination of abundant material resources and available energy make the scheme seem promising.

5.4 Implications for Social and Environmental Equity

As discussed in chapter 2, the benefits that may be derived from industrial ecology, relating to the enhancement of social equity are largely trickle-down benefits, secondary or tertiary to the primary action. Even the environmental benefits of industrial ecology remain incremental and piecemeal until broad implementation occurs. The relationships in these kinds of systems are rarely linear; only given significant action will many of the spin-off social implications be felt. The macro-economic benefits of a growing industrial base, more jobs, and increased tax revenues result from the establishment of new industrial trophic levels, and will not accompany the implementation of a low level of industrial ecology. The societal benefits of EID are emergent properties of established industrial ecosystems. Given also that the symbiotic partnerships are what spur the environmental benefits, similar threshold effects may be expected for both social and ecological gains.

The Big Bend site has not really progressed into this depth of industrial ecology implementation, so perhaps it should not be too surprising that few of the possible benefits in this category are observable here. However, this section will outline the extent to which the GVRD incinerator has made progress in this area. Many of the ideas that will be presented will have been alluded to in the previous sections. The remainder of this chapter, then, will highlight the possibilities as they trickle down.

5.4.1 Green Economic Development

Through its history, the Big Bend site has produced few jobs that may be credited to industrial ecology. Aside from the initial construction crew, the operations staff at Montenay amount to 40 full time employees. All are skilled jobs in either management or engineering that at least one employee felt lucky to hold. From a community economic development (CED) perspective, the case is sub-optimal in that the company in charge (Montenay Inc., a subsidiary of the Onyx Group, a subsidiary of….) is a large multinational corporation, whose only responsibilities to the people of Greater Vancouver lie in company policy and its contractual agreement with the GVRD.

The possibilities for 'sustainable economic development' have not begun to be explored at the Big Bend site. Indeed there has been no explicit aim to do so by any party, and it should be made clear that the governance of the existing system is not informed by industrial ecology at all. Nonetheless, it is well within the realm of reason to conjecture a viable system that would allow for extensive CED projects that pursue sustainability through industrial ecology. Exploring the fine details of the system may be beyond the scope of the present work. Some specific suggestions will be made in the next chapter, but in general, when dealing with complex self organizing systems, the process of discovering what works may involve living it. The task is to evaluate the context, identify available exergy and materials in the system, and inform their manipulation by the principles of industrial ecology. Each niche or pathway becomes a business opportunity when viewed as establishing complex dynamical systems. From groups of informed individuals emerge highly successful collective entities—organizations, corporations, political parties, etc—that are able to self-organize and sustain themselves in the larger dynamical system. When conceived in this way, sustainable development and industrial ecology become fertile ground of opportunity, rather than constraints on the status quo.

5.4.2 Community Empowerment

As with 'green' economic development, the community empowerment benefits that may be derived from industrial ecology have not emerged from the low level application extant at the Big Bend development site. Empowerment comes through the involvement and participation of local communities, whose ideas and ambitions are encouraged to flourish in an eco-industrial setting. The case study has yet to reach the critical threshold that would open the door to such opportunities. The developments that have occurred on site have not been deemed to require even cursory public consultation. Indeed the initial construction of the incinerator a decade and a half ago proceeded in the face of vocal public resistance. More recently, those responsible for managing and governing the facility have considered it a demonstration of the incinerator's benignity that most residents of the GVRD are unaware of the incinerator's existence.

It is important to recall, though, that the incinerator and the Big Bend site do not pretend to be guided by industrial ecology. Thus, perhaps they should not be faulted for not pursuing an industrial ecosystem, despite the potential benefits that elude them as a result. In order for the social benefits to emerge, the system and conceptual framework have to be embraced from within the existing structure. Management of the development site would have to commit to the process, and actively facilitate the inclusion of the community in order realize any empowerment benefits that may result.

5.4.3 Intergenerational Equity

Intergenerational equity is a guiding principle of sustainable development, even in its broadest and more general form. The Bruntland Commission's (1987) famous definition—'development that meets today's needs without compromising the ability of future generations to meet their own needs'—deals almost exclusively with this issue. On a societal scale, this objective is far reaching and challenges some fundamental assumptions of the modern socio-economic system. The practice of discounting future gains and losses is the best example of how the present economic system runs counter to sustainable development, and systematically disadvantages future generations (Rees and Wackernagel, 1999). However, the need to avoid leaving a legacy of ecological deterioration and socio-economic depression is paramount to the goals of sustainable development and industrial ecology.

Many of the particular aspects and strategies of industrial ecology discussed at length already contribute to intergenerational equity. Using resources at a sustainable rate and minimizing the pollution and waste load that must be assimilated by the natural environment are broad categories of action whose underlying motivation is preserving ecological integrity for future generations. Every subsystem in the complex industrial ecosystem has a specific role in this goal—a role defined by the particular process played out by that entity. It is the collective totality of the system that has the emergent property that may be termed 'sustainable' or 'unsustainable'—each actor can only play its part in the overall effort.

The GVRD, as governor of the region's waste flow, has a very important role to play, to be sure. The disposal facilities owned by the GVRD, including the incinerator, have large potential for environmental disruption and must be managed with due diligence to prevent ecological disaster. To date (and admittedly without detailed empirical studies) the incinerator appears to meet its cursory obligation of sound operation and responsible management. However, landfills remain the primary destination for solid waste in the region, building a legacy of seriously polluted sites for future generations. For its part, the incinerator does reduce the amount of material destined for landfills by reducing 250,000 tonnes of refuse to 50,000 tonnes of ash every year. However, that amounts to only a 13% reduction when the total solid waste flow is considered. And given the immediate air pollution impacts of incinerators, quintupling the capacity of the incinerator would certainly be considered a step in the wrong direction. Dramatically improving the rate of material recovery and recycling in the regional economy is what industrial ecology suggests, as it contributes to both resource productivity and pollution avoidance. My analysis suggests that the incinerator (at its present size) may be able to facilitate the establishment of an eco-industrial system whose goal is to exploit and process the solid waste stream as a primary resource.

5.5 A Culture of Sustainability

In order for the promise of industrial ecology to come to fruition, a cultural shift will be required. Many sustainable development theorists ultimately arrive at that conclusion (e.g. Rees 1998; Daly, 1996). The dilemma boils down to the norms, values and beliefs that inform the everyday actions of individual citizens, private sector organizations and governance structures. Industrial ecology seeks to minimize adverse impacts of industrial processes by changing the conceptual framework from which industrial systems are viewed; rather than industries being treated as isolated entities engaging in linear production mechanisms, they are viewed as members of a community with the capacity to fill a particular niche that helps sustain the community at large. Using complex ecological systems as models of efficiency and sustainability, industry can identify problem areas and modify processes as necessary to reduce environmental impact. Such goals must be sought for within the industrial community where the detailed knowledge of process design is most highly concentrated, but responsibility does not end at the industry margins. "These concepts must be instilled into the practices of government and industry, into our social ethos, and they must be recognized by the communications media" (Frosch and Gallapoulos 1992). Government has the mandate to set rules within which ecological, social and economic imperatives are aligned, while individual consumers must acknowledge and exercise their roles as decision makers in the market place and polling booths.

For their part, the governance structure of the GVRD incinerator has made some progress. The facility was the first of its kind in Canada (and the second in North America) to have received ISO 14001 certification for its environmental management system. Over the course of its history, the incinerator has an impressive record of upgrades to its pollution control system. Now, with the pursuit of electrical co-generation and the possibility of an integrated district energy system, the general direction of development seems in line with the goals of industrial ecology. Perhaps if the management came out and openly declared (and seriously acted upon) a commitment to an eco-industrial development pathway, more of the benefits that are predicted in the literature would be realized.

Chapter 6: Perspective and Possibilities: a debriefing and concluding remarks

6.1 Perspective

In this thesis, I have endeavored to explore industrial ecology and understand it as a strategy for sustainable development. The motivation for this undertaking comes from the objectives of a larger collaborative research project called the Georgia Basin Futures Project that identifies the need to 'dematerialize' regional economies as one step toward sustainability. The notion of dematerialization can be understood as one strategy decoupling economic activity from ecological impact, and fits well with the ideals of industrial ecology. The growing literature dealing with this area identifies many possibilities to increase the productivity of resources through design innovation and enhanced recycling schemes. Slowly, these ideas are being taken up in the private sector as corporations and entrepreneurs report on the successes they have experienced at the vanguard of this movement. The leading edge of industrial ecology enjoys the "free lunch" benefits of technological upgrades that offer one-time efficiency gains (Ayres 1993) without radically transforming industrial processes. To carry industrial ecology forward will require more comprehensive implementation with respect to building partnerships and linkages in the regional industrial system.

The initial literature review that formed the basis for my understanding of industrial ecology left me with a lingering suspicion that the optimism expressed in the literature was somehow overstated. As promising as the ideas sounded, something about the whole theory seemed a little suspect; it made too much sense, in a way, and the confounding point was that industrial systems were not in fact set up this way. The broad principles of industrial ecology—dichotomized herein as external resource webs and internal eco-efficiency—seem undeniable, and the few examples that appeared in the literature (e.g. Kalundborg) work quite well. After digging a little deeper, though, it became apparent that industrial ecology is less straightforward than its proponents claim. Despite the simplicity of the analogy as a conceptual framework, operationalizing IE's ecological metaphor becomes incredibly complex when placed in the context of a given region involved in the quest for sustainability.

Every region has a unique industrial mix that reflects its historical and geographical context, reducing the extent to which empirical trends and case studies may be generalized in the propagation of industrial ecology. In particular, for a region such as the Georgia Basin, in which industry plays a relatively minor (and diminishing) role in the overall economy, industrial ecology appeared initially to be of little help in imagining a sustainable society.

Such doubts, however, failed to break my interest in industrial ecology as a concept, and further study revealed the hidden potential that it contained. Through an investigation of ecological economics and complex systems theory, a more robust ecological metaphor began to emerge that allowed me to dispense with the worn-out examples that industrial ecology clings to in the literature. This route of investigation into the dynamics of complex thermodynamic systems highlighted the ways in which ecosystems are a function of the contexts in which they exist. Rather than being characterized by their constituent parts (i.e. which species eat which, and under what trees), this perspective centers on the dynamic relationships between those parts with an emphasis on the material and energy flows among them. This emphasis makes particular sense for industrial ecology since material and energy flows between actors are exactly what the original metaphor related to—only when I attempted to translate lessons across contexts were matters confused. I realized that to foment industrial ecology in the Georgia Basin does not requires massive industrial development; the industrial diversity of Kalundborg need not be emulated here any more than we should emulate Denmark's ecological diversity in the pursuit of sustainability (which is absurd). The key is to recognize the opportunities and limitations inherent in a given place, as each ecosystem will have unique niches to fill from within.

From this insight, an internal tension of the present study may be resolved. In preliminary discussions of the topic with colleagues doubt was expressed about the lessons to be learned from the conclusions of my thesis. In particular, a 'sustainable' scenario envisioned for the Big Bend might give credence to incineration as a waste management strategy, which would ultimately work against industrial ecology if used to justify incinerator construction elsewhere. But this would represent a case in which context was ignored, and by this point I hope it is clear that my intention is otherwise. The fact is that an incinerator already exists in Greater Vancouver's industrial ecosystem. Industrial ecology, as I have construed it, can be useful as a framework that facilitates our development toward a more integrated and effective system based upon what we have now and what we want in the future.

6.2 Possibilities

This final section is devoted to my recommendations for pursuing industrial ecology at the Big Bend. My vision for the site is an integrated eco-industrial park populated with businesses that obtain their material requirements onsite from an increasingly separated solid waste stream, powered through the district energy system emerging from the incinerator. Thanks to the integrated waste management system operated by the GVRD, the solid waste stream can be increasingly redirected through the Big Bend site as private sector firms are established in the eco-park, incrementally reducing the excess amounts that currently head to landfill. Recycling and product remanufacturing operations are obvious matches for the site, and a centralized composting facility should be established. The incinerator would continue to burn materials for which recycling or reuse alternatives remain uneconomic. Additionally, firms such as greenhouse agriculture and breweries could fit in to exploit the steam and low-level heat availabilities on-site. Even if the region were to be able to effectively redirect waste materials in sufficient quantities that the incinerator became under utilized (and landfills unneeded), the district energy system could be supplemented with natural gas or various alternative fuels to keep the resident industries operating. The following recommendations are fairly specific actions that could be taken to initiate the establishment of an eco-industrial park at the Big Bend development site. Together, they offer some direction for the development of the site, as considered for this study.

Specific Recommendations:

- Establish electrical cogeneration capability at the incinerator to fully utilize generated steam.
- Link the incinerator to the surrounding industrial area through a district energy system to broaden niches in the new industrial ecosystem.
- Expand Product Stewardship Programs to keep more toxic materials out of the waste stream.
- Continue with incremental pollution control improvements.
- Secure an arrangement with Big Bend stakeholders that commits to eco-industrial park (EIP) development.
- Create an advisory board from stakeholders that would oversee the recruitment and development of the new EIP.
- Issue an open call for tenants for local entrepreneurs to engage in the EIP, emphasizing scavengers and processors of refuse (see Appendix 1 for an example of such a call).
- Establish a central composting facility onsite (could be privatized) that diverts organic waste from permanent disposal to more useful applications.
- Bar intensive greenhouse agriculture from Agricultural Land Reserve, offering space in the Big Bend EIP as an alternative.
- Contract a firm that treats and processes bottom ash for commercial applications.
- Explore the potential for Norampac to receive post-consumer paper products separated onsite.

References:

Arkay, K. and C. Blais (1999). The District Energy Option in Canada. Ottawa, NRCan & Environment Canada.

Ayres, R. (1993). On Economic Disequilibrium and Free Lunch. Fontainbleau, France, INSEAD.

Ayres, R. (1994). Industrial Metabolism. The Greening of Industrial Ecosystems. B. R. Allenby, D. Washington, National Academy Press.

BCSD (1994). Internalizing Environmental Costs to Promote Eco-Efficiency, BCSD.

CEIN, C. E.-I. N. (2001). An Introduction to Eco-Industrial Networking and the Canadian Eco-Industrial Network. Toronto, CEIN.

Chertow, M. (1999). "The Eco-Industrial Park Model Reconsidered." Journal of Industrial Ecology **2**(3): 8-10.

Chertow, M. (2000). "Industrial Symbiosis: Literature and Taxonomy." Annual Review of Energy and Environment **25**(1): 313-337.

Cronon, W. (1995). The Trouble with Wilderness; or Getting Back to the Wrong Nature. Uncommon Ground. W. Cronon. New York, WW Norton.

Daly, H. (1996). Beyond Growth. Boston, Beacon Press.

De Simmone, L. and F. Popoff (1997). Eco-Efficiency. Boston, MIT Press.

Dhir, R. D., T & Paine, K (2000). Sustainable Construction: Use of Incinerator Ash, London.

Ellis, J. (1995). On the Search for a Root Cause: Essentialist Tendencies in Environmentalist Discourse. Uncommon Ground. W. Cronon. New York, WW Norton.

Erlich, P. and e. al (1977). Ecoscience: Population, Resources, Environment. San Fransisco, W.H Freeman & Co.

Frosch, R. and N. Gallapoulos (1989). "Strategies for Manufacturing." Scientiic American **261**(3).

Frosch, R. and N. Gallapoulos (1992). Towards an Industrial Ecology. The Treatment and Handling of Wastes. London, Chapman & Hall.

Hawken, P. (1993). The Ecology of Commerce. New York, Harper Collins.

Kay, J. (2000). On Complexity Theory, Exergy, and Industrial Ecology: Some Implications for Construction Ecology. Construction Ecology and Metabolism: the Material Cycles. C. Kibert and J. Sendzimir.

Kay, J., M. Boyle, et al. (1999). "An Ecosystem Approach for Sustainability." Futures(fall; preprint version).

Lemons, J. and D. Brown (1995). The Role of Science in Sustainable Development and Environmantal Protection Decision Making. Dordrecht, NE, Klever Academic.

Lowitt, P. (2001). Eco-Industrial Development: lessons from the trenches. Key Strategies for 21st Century Economic Development, Toronto.

Manahan, S. (1999). Industrial Ecology: Environmental Chemistry and Hazardous Waste.

Mander, J. (1996). Technologies of Globalization. The Case Against the Global Economy and For a Turn Toward the Local. J. Mander. San Fransisco, Sierra Club.

Montague, P. (1990). "As if the future mattered..." Rachael's Hazardous Waste News **167.**

Osdoba, T. (2001). You Did What? Key Strategies for 21st Century Economic Development, Toronto.

RCBC (1999). Municipal Solid Waste Tracking System. Vancouver, Ministry of Environment, Lands and Parks.

Rees, W. (1995). "Achieving Sustainability: Reform or Transformation?" Journal of Planning Literature 9(4): 343-367.

Rees, W. (1998). "How Should a Parasite Value Its Host?" Ecological Economics 25: 49-52.

Rees, W. and M. Wackernagel. (1999). "Monetary Analysis: turning a blind eye on sustainability." Ecological Economics 29: 47-52.

Robinson, J. and J. Tinker (1997). Reconciling Ecological Economic and Social Imperatives: A New Conceptual Framework. Surviving Globalism. T. Schrecker. London, Macmillan.

Ruckelhaus, W. (1989). "Toward a Sustainable World." Scientific American **261**(3).

Schlarb, M. (2001). Eco-Industrial Development: A Strategy for Building Sustainable Communities. Ithaca, NY, Prepared for US Economic Development Administration.

Schneider, E. and J. Kay (1992). "Life as a Manifestation of The Second Law of Thermodynamics." Advances in Mathemaics and Computers in Medicine **Pre-print version.**

SPARK (1991). Creating the Future: a Strategic Plan for the Environment Industry of BC. Victoria, Science Council of BC.

Stuart, J., L. Turbini, et al. (1999). "Activity Based Environmental Inventory Allocation." Journal of Industrial Ecology **2**(3): 95-108.

Thermoshare (1997). Integrated Eco-Industrial Parks: with cogeneration, energy cascading and recycling. Ottawa, Thermoshare, Inc.

Van der Ryn, S. and S. Cowan (1996). Ecological Design. Washington, Island Press.

Appendix 1: Example Call For EIP Tenants

This is an actual call for tenants distributed on an email listserve for a park in the San Fransisco Bay area. I have reproduced it here (with permission) as an example of what could be done for the GVRD eco-park that I propose for the Big Bend.

"SECOND CALL FOR TENANTS
ALAMEDA COUNTY ECO-INDUSTRIAL PARK
SEPTEMBER 20, 2001

The purpose of this Call for Tenants is to identify companies who may be interested in leasing or owning a building in a new and unique industrial development in the eastern San Francisco Bay Area.

The Alameda County Waste Management Authority and Recycling Board (Authority), working in conjunction with a Master Developer and the City of San Leandro, is seeking tenants for an Eco-Industrial Park. Please read on for more specific information.

SITE CHARACTERISTICS
The proposed location for this unique Park is a 21.27-acre site zoned for General Industrial uses. The Property is located on Davis Street in the City of San Leandro, California along Highway 880. The site has excellent access to transportation corridors, including the Port of Oakland, the Oakland International Airport, and rail access to the Property.

PROSPECTIVE TENANT CHARACTERISTICS
The Authority has a limited amount of time to identify appropriate tenants for this unique project. We are interested in communicating with companies with the following characteristics:

- Engaged in environmentally sound manufacturing/product development, preferably utilizing recovered materials
- Capable of moving or expanding the business while maintaining financial viability
- Currently operating under a sound business plan
- Interested in leasing or owning own building (build-to-suit opportunity available; no outdoor processing)
- Able to pay lease rates of approximately .60 - .65/square foot per month
- Capable of entering into an agreement to participate with the Master Developer by the end of the year 2001
- Willing to participate in a collaborative project of national significance which is expected to attract positive recognition and media attention.

WHAT IS AN ECO-INDUSTRIAL PARK?
The Eco-Industrial Park proposed for this Property is an industrial park housing a group of businesses who work together to enhance their environmental and economic performance. Eco-Industrial Park tenants will be the manufacturers and value-added processors who use recycled materials, such as paper, glass, and wood generated and

purchased locally to produce new products. Other manufacturers of environmentally preferable products will also be considered if they offer opportunities for byproduct synergies with other tenants.

The Eco-Industrial Park is an important component of the Authority's efforts to reduce the amount of material landfilled in Alameda County. It is also an important focus of the City of San Leandro's and the Alameda County Economic Development Alliance for Business (EDAB)'s business attraction and expansion efforts.
Co-locating businesses that add value to materials currently going to landfills by re-manufacturing these materials into new products is vital to the Authority's market development efforts. Given the cost and lack of availability of land in the Bay Area and of doing business in an urbanized area, the chance to site a project close to supplies of recovered materials offers unique benefits in the form of reduced transportation costs and other business expenses, such as insurance, job training, and equipment.

UNIQUE ADVANTAGES OF THIS PROJECT

- Proximity to varied and vibrant markets and sources of feedstock, including one of the nation's largest transfer station/material recovery/reuse facilities, the Davis Street Recycling Park. This facility recovers wood, metal, cardboard, paper, glass, plastic containers, yard waste, food waste, and electronics. Concrete, soil, and other recyclables are sorted from construction and demolition waste. A reuse business for salvaged building materials and a tire recycling business also operate at the facility.
- Up to $3 million in infrastructure improvement funding available to support the development.
- Access to Authority Revolving Loan Fund for resource recovery-related businesses, Redevelopment Area participation, and other specialized funding available to assist tenant businesses that locate in the Park.
- Intensive media attention and public recognition expected for positive environmental and economic performance."