KIET Occasional Paper No. 74

A Potential Paradigm for Sustainable Regional Development: Eco-Industrial Park

Kihwan Kim

September 2009

KIET Korea Institute for Industrial Economics & Trade

Kihwan Kim, Senior Research Fellow

Korea Institute for Industrial Economics and Trade (KIET)
66 Hoegiro, Dongdaemun-Gu, Seoul, 130-742, Korea
TEL : (82)(2)3299-3114
FAX : (82)(2) 963-8540
http : //www.kiet.re.kr
ISBN 978-89-5992-245-1 93320

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I. Introduction

A new way of thinking about economic development is taking shape in communities around the world. This thinking comes from a common sense observation that the places we work waste and dump too much waste into and onto the land. The rapid population increase and expansion of resource-consumption are contributing to a worldwide environmental, social and economic crisis. Environmental damage is serious, from climate change causing life threatening natural disasters to species extinction and the destruction of natural eco-systems.

The notion that economic and industrial development should be sustainable is a widespread view among economic and regional development practitioners. The sustainable development movement is a comprehensive approach to overcome social, environmental, and economic problems and to ensure a better quality of life for everyone. Regions aiming to attract industries and business are seeking ways to balance economic, social and environmental objects.

Industry and its impact on economic and social development and the environment have been at the center of the debate on sustainable development. Many experimental urban or rural eco-industrial park development projects have been encouraged. However, there are very few signs of actual change. Most new industrial park developments repeat the

patterns of those before them. They facilitate the use of cars, provide essential services of water, sewage treatment, gas and electricity rather than attempt to manage or to achieve local autonomy in basic facilities and services.

At the local and regional scales, there is often a strong emphasis on developing sustainable development strategies as a key part of local and regional economic strategies. Recent years have seen the beginnings of a policy initiative that has attempted to integrate economic, social and environmental aims through eco-industrial development. Eco-industrial development adds value to businesses and regions by optimizing the use of energy, materials, and resources. Eco-industrial development suggests that maximizing resource efficiency involves assessing and optimizing underused regional assets. Assets include human resources, natural habitats, cultural resources, and existing institutions.

One possible way of achieving eco-industrial development would be through eco-industrial parks. An eco-industrial park is an area of manufacturing and service businesses located together on a common property. Tenant businesses seek to enhance environmental, economic, and social performance through collaborative management of environmental and resource issues.

The goal in this paper is to sketch out the themes of eco-industrial development, mainly focusing on eco-industrial parks. The concept of sustainable development is introduced and several aspects of eco-industrial parks, such as characteristics, benefits and risks, development examples, are followed. Also, design plans for eco-industrial parks and a series of policy recommendations for eco-industrial development are outlined.

Ⅱ. Concept Of Sustainable Development

Literally, sustainable development refers to maintaining development over time. Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations to come.

The term was used by the Brundtland Commission and has become the most often-quoted definition of sustainable development, which is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This is based on intergenerational equity, and is used in much of the mainstream economic literature.

It is important to recognize three coreelements of the Brundtland Commission's definition as George Perkins Marsh pointed out. First, sustainable development assumes that, for good or ill, humankind will both affect and be affected by the environment as we seek to develop our lives, our families, and our communities and ensure their well-being. Second, we will ultimately fail in our goals for family and community if we do not find ways to make our interactions with the environment meaningful. Third, sustainable development cannot be achieved by focusing only on the environment and the economy. There should be a balance between environmental protection, social development, and economic devel-

opment.

There are many different definitions of sustainable development in circulation. Several definitions and interpretations are introduced in Table 1.

It is important to understand that sustainable development is not an approach focused solely on the environment. It is true

Table 1 Definitions of Sustainable Development

Definitions of sustainable development
'In principle, such an optimal (sustainable growth) policy would seek to maintain an "acceptable" rate of growth in per-capita real incomes without depleting the national capital asset stock or the natural environment asset stock.'
'The net productivity of biomass (positive mass balance per unit area per unit time) maintained over decades to centuries.'
'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs'
Interpretations of sustainable development
'A creatively ambiguous phrase... an intuitively attractive but slippery concept.'
'Like motherhood, and God, it is difficult not to approve of it. At the same time, the idea of sustainable development is fraught with contradictions.'
'It is indistinguishable from the total development of society.'
'Its very ambiguity enables it to transcend the tensions inherent in its meaning.'

Source : An Introduction to Sustainable Development, 2nd Ed. Jennifer A. Elliott, Routledge, 1999.

that sustainable development begin with the recognition that a sustainable future should be based upon protection of the environment. However, it is also the case that environmental science alone can never be the answer to a sustainable future, although it is a critically important element in facilitating sustainable development decision making.

Sustainable development is not tied to a physical planning model. Sustainable development reaches beyond particular projects and beyond the contours of a given physical space. Some planners sometimes have in mind a somewhat narrower application of the concept than sustainable development has in the international commitments.

Sustainable development also comprehends the critical role of economics and markets, but it rejects any simplistic notion that wecan grow our way to sustainability or that the market alone will satisfy the central commitments of sustainable development.

The World Business Council for Sustainable Development points out the concept of eco-efficiency as one of the means of achieving sustainability. It identifies seven elements of eco-efficiency:

- Reduce the material intensity of goods and services.
- Reduce the energy intensity of goods and services.
- Reduce toxic dispersion.
- Enhance material “recyclability”.
- Maximize sustainable use of renewable resources.
- Extend product durability.
- Increase the service intensity of goods and services.

However, there is some confusion about the use of terms sustainability and sustainable development. Goodland(1995) distinguishes environmental sustainability, economic sustainability, social sustainability and sustainable development. Environmental sustainability is defined as maintenance of life-support system. Economic sustainability is the economic tantamount of environmental sustainability, being defined as maintenance of economic capital. Social sustainability is defined as the maintenance of social capital. Sustainable development should integrate the three types of sustainability and use these methods to any type of development sustainable.

□ Eco-industrial Development

Another similar concept, eco-industrial development, is worth reviewing. Eco-industrial development is a subset of sustainable development. Sustainable development tends to focus on broad models of biodiversity, global warming, forest and oceans. Solutions look at overall fiscal policy, tax laws, tradable permits and so on.

The eco-industrial concept encompasses a range of approaches, including pollution prevention, byproduct exchange, green design, life-cycle analysis, joint training programs, and public participation. At its root is an emphasis on fostering networks among businesses and communities to optimize resource use and reduce economic and environmental costs. Some have emphasized pollution prevention, technological innovation, and other approachesto improving efficiency within single product lines. Eco-industrial development originates in

the emerging field of industrial ecology. In a general sense, eco-industrial development is industrial ecology in practice. Eco-industrial development seeks to increase business competitiveness, reduce waste and pollution, create jobs and improve working conditions.

□ Industrial Ecology

Industrial ecology is an approach to managing human activity on a sustainable basis by seeking the essential integration of human systems into natural systems. It intends to minimize energy and materials usage, and to lower the ecological impact of human activity to levels natural systems can sustain. Its objectives are preserving the ecological viability of natural systems, ensuring acceptable quality of life for people, and maintaining the economic viability of systems for industry, trade and commerce.

Industrial ecology attempts to understand the potential for environmental improvement in industry using an analogy of industrial systems to natural ecological systems. Rather than just focusing on narrow concepts such as cleaner production and less waste, industrial ecology offers an holistic conceptual framework for systematic industrial change needed to eliminate environmental damage. The effects at the level of the individual firm or process are considered important, but need to be connected to the wider industrial ecosystem.

Processes and industries are considered as closely related entities rather than isolated and unrelated components. This provides a basis to connect different waste-producing proce-

sses, plants, or industries into an operating network that minimizes the total amount of industrial wastes. The focus changes from minimizing waste from a particular process or facility (i.e. pollution prevention), to minimizing waste produced by the larger system as a whole (Brand and de Bruijin, 1999).

Industrial ecology represents a development concepts evolving from cleaner production and eco-efficiency, which are concerned with reducing material inputs and wastes at the firm level. Therefore, industrial ecology requires major technological innovations, not just incremental increase in efficiency and minor modifications of existing production processes.

In an industrial ecosystem, effluents and wastes from one process are used as the input materials for other processes or recycled for further production. Not only participating firms benefit financially, but there social gains in the form of reduced environmental impacts and improved jobs and working conditions. In a perfect industrial ecosystem, there would be complete or near complete internal recycling of materials, and zero discharges. In reality, this is probably unattainable, but nevertheless a goal worth pursuing. However, there has been a growing interest in the local and regional application of industrial ecology concepts in the form of eco-industrial development.

The direction presented by industrial ecology is the way to strive at in environmental policy andindustrial environmental management. A number of economic, environmental and social advantages can be gained from such an approach:

- Waste products from one industry provide the inputs for another, reducing input costs;
- Reduced waste streams mean lower waste disposal costs;
- Waste now has an economic value, increasing profits;
- A larger and more varied economic base is created;
- Reduced emissions mean less need to separate industrial and residential land use and reduced movement between the two.

Ⅲ. What is an Eco-industrial Park?

1. Defining Eco-industrial Parks

While interest in policies for sustainable development continues, actual implementation has been less than expected. However, in recent years, policy initiatives that integrate economic, social and environmental considerations have been pursued in various forms of eco-industrial development. Following the concepts of industrial ecology, such eco-industrial initiatives attempt to increase firm's competitiveness, while reducing waste and pollution and creating jobs. In their most advanced forms, eco-industrial parks have been developed where participant firms use each other's waste and by-products as inputs and engage in energy exchanges.

Eco-industrial parks are based on industrial ecology concepts. They aim to increase business performance while reducing pollution and waste(Cohen-Rosenthal, 1996). Despite the interest in eco-industrial parks, the definition regarding what constitutes an eco-industrial park is rather ambiguous. Lowe and Warren(1996) define an eco-industrial park as follows:

"a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials. By working together, the community of businesses seeks a collective

benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance."

The US President's Council on Sustainable Development also defined an eco-industrial park as a "holisticcommunity of businesses that cooperate with each other and with the local community to efficiently share resources(information, materials, energy, infrastructure and natural habitat), leading to economic gains, improvements in environmental quality and equitable enhancement of human resources for business and the local community."

However, many developers and practitioners use the term in a much looser sense. Almost any development that possesses environmental features is considered an eco-industrial park. Research Triangle Institute identifies seven different types of eco-park development which are shown in the following table(Table2).

Table 2 Types of Eco-Park Development

· A single by-product exchange pattern or network of exchange
· A recycling business cluster (e.g. resource recovery, recycling companies)
· A collection of environmental technology companies
· A collection of companies making 'green' products
· A industrial park designed around a single environmental theme (e.g. a solar energy-driven park)
· A park with environmentally friendly infrastructure or construction
· A mixed use development (i.e. industrial, commercial and residential)

Source : Research Triangle Institute (2001).

2. Characteristics of Eco-industrial Park

The eco-industrial park concept is based upon several fields of research and practice that have emerged in the last decade, including industrial ecology, cleaner production, and sustainable urban planning, architecture, and construction. These fields contribute to the broader movement to demonstrate the principles of sustainable development in policy and concrete projects. New patterns of inter-company relationships and organization design offer additional support for the eco-industrial park concept.

(1) Cleaner Production and Industrial Ecology

The main purpose of industrial ecology is to find the proper balance between environmental, economic, and social aspects of a system. Cleaner production can be considered as an area of research and practice that shares the common goals and similar objectives with industrial ecology. The basic dimensions of these two disciplines are reviewed within the boundary of the eco-industrial park.

□ Cleaner Production

Cleaner production is a preventive environmental strategy applied to processes, products, and services to improve overall efficiency and reduce risks to the environment as well as humans. It seeks ways not only to conserve raw materials and energy, but also to cut down the quantity and toxicity of all emissions and wastes in production processes. Reducing the negative impacts along the life cycle of a product is

another objective that cleaner production seeks.

Several policy instruments such as regulation, voluntary programs, and education can be implemented to emphasize the environmental aspects of industry. Regulations regarding environmental standards that a firm must meet to operate and penalties that a firm faces when they fail to do so are recommended. Voluntary programs which emphasize sharing and dissemination of information and market-based instruments such as taxes, tariffs, subsidies, which encourage environmentally beneficial decisions, are also useful. Transparency through which public awareness of the dangers of pollutants should create public pressure on firms to reduce their discharges. Information and education, such as public health education that help understand the risks to human health from pollutants are also included.

□ Applications of Industrial Ecology in Eco-industrial Parks

A broad understanding of industrial ecology as the science of sustainable development underlies recommendations for eco-industrial park development. Eco-industrial parks are envisioned as sources of many benefits to local communities and have become one of the most common applications of industrial ecology.

The systematic framework of industrial ecology can help eco-industrial parks to solve problems in their development and management. Tenant recruitment, hazardous materials management, and greenhouse gas reduction are these examples.

Developers with a holistic foundation of industrial ecology

will find recruitment suitable in a business sense. They will be able to diversify their recruitment activities rather than targeting the same large companies. They will also target emerging industries that will help them to become more self-sufficient in energy and materials through technologies for renewable energies and increased energy efficiency.

Hazardous materials management is another example of how industrial ecology can tackle difficult issues of environmental management. Industrial ecology systems suggest the need of designing policies and regulations for hazardous materials management. They encourage setting short term initiatives and innovations in a long term context. Thus, planners at eco-park would act to impact policy at local and national levels to set goals for a cleaner economy and elimination of the high risk materials. Also they would seek policies that encourage adoption by industry of green chemistry products, effective treatment and recycling technologies.

Another illustration of industrial ecology at work is a greenhouse gas reduction program. Eco-industrial parks have an important application of industrial ecology since they have easy access to intervention with industry and communities. Their concentration of industries and channels for communication, learning, and action enable more rapid change than simply approaching companies individually. This is especially important in a global issue like climate change.

(2) Sustainable Design and Construction

Another major basis for eco-industrial parks is the environmentally friendly design and construction of its facilities.

Designers in thesefields are keen on applying principles parallel to industrial ecology. The construction and operation of buildings and infrastructure have impacts on local ecosystems and communities as well as global effects such as climate change. Fortunately many energy efficient design can reduce the costs of operating buildings and industrial facilities and lessen the environmental impacts.

Planners have given high priority to the sustainable design in residential and commercial buildings and new approaches to urban design. Engineering firms usually play the central role in design of industrial facilities. They often encourage clients to realize the cost savings possible in eliminating wastes.

Eco-industrial park development can provide an opportunity for the newly emerging field of sustainable industrial facility design. Eco-industrial park will provide a test bed for integrating architectural ideas with green approaches in infrastructure, plant, and production process. The design of eco-industrial parks calls for integration into the community which implies broader urban planning. Sustainable urban planning seeks to integrate land use, transportation, waste treatment, and infrastructure into a plan optimizing community use of energy and materials. A sustainable community plan also addresses issues of social and economic aspects. Since many industrial park developments now include employee housing at or near the site, sustainable urban planning practices enable developers to better integrate this pattern of land use.

Certain principles of sustainable design and construction can be summarized as follows:

- Minimize resource consumption.
- Select materials and design for durability.
- Maximize resource reuse.
- Use renewable or recyclable resources.
- Protect the natural environment.
- Create a healthy, non-toxic environment.
- Integrate building and infrastructure design into the natural and human environments.

3. Benefits and Risks of Eco-industrial Park Development

(1) Benefits of Eco-industrial Park Development

□ Economic efficiency and profitability

The appeal of eco-industrial parks for tenant businesses and industrial development is increased profitability and cost savings through economies of scale and added value to outputs. With eco-industrial development, companies can find opportunities to improve energy and material use efficiency through waste exchange, recycling, innovative technology, and production processes. Regulatory penalties for harmful practices may also be eliminated or reduced.

Companies located in an eco-industrial park can share the expenses for infrastructure and services, such as business services, waste management, purchasing, training and recruitment, transportation, and other common costs of doing business. Savings on production, disposal, and regulatory costs can

make companies more viable.

While the focus of eco-industrial development has been on manufacturing, it can benefit the retail and other sectors as well. Eco-industrial approaches offer regions an opportunity to attract newbusinesses and jobs to previously undervalued areas. As businesses and their workforces locate in a neighborhood, markets for retail services are strengthened. Services in the financial, communications, and administrative sectors may find new markets as local industries grow.

For the companies involved, an eco-industrial park offers the opportunity to decrease production costs through increased materials and energy efficiency, water recycling, and elimination of practices that incur regulatory penalties. Increased efficiency may also enable park members to produce more competitive products.

In addition, some common business services may be shared by firms in the park. These may include shared waste management, trading, purchasing, emergency management teams, environmental information systems, and other support service. Such industrial cost sharing could help park members achieve greater economic efficiency through their collaboration.

Small and medium size firms often have a problem in gaining access to information, consultation and know-how. The integrative approach of eco-industrial park development can support such enterprises in overcoming these barriers and gain access to investments they may require to improve performance.

These benefits for participating companies are likely to in-

crease the value of property. The services generate new revenues for park management authorities. Overall, eco-industrial parks may gain a competitive advantage, an especially important benefit in a time when there is a overcapacity in the industrial real estate market.

□ Better environment and improved environmental supervision

Eco-industrial parks will reduce many sources of pollution and waste, as well as decrease demand for natural resources. Site tenants can reduce their environmental burden through more innovative approaches to cleaner production. These include pollution prevention, energy efficiency, water management, resource recovery, and other environmental management methods and technologies. Decisions about eco-industrial park location, infrastructure, and recruitment targets will be reached in the context of the constraints of local carrying capacity and ecological characteristics of potential sites.

Eco-industrial development also seeks to promote environmental supervision at the firm, industrial park, and regional levels. The ultimate environmental goals of eco-industrial strategies are to reduce the use of raw materials, decrease pollution, increaseenergy efficiency, reduce water use, and decrease the volume of waste products requiring disposal in landfills. This approach encourages companies to adopt innovative processes and technologies that reduce waste of energy, water, and materials. Businesseslinked in eco-industrial networks form materials exchange relationships to

decrease the amount of waste going to landfills. Eco-industrial development encourages tenants and management to collaborate with the community to identify and support community-wide resource exchanges through the recycling, reuse, and manufacturing opportunities.

Each eco-park should serve as a working model for park developers to improve profitability while meeting high environment and social standards.

□ Job retention and growth

Eco-industrial development supports job growth and retention in several ways. When companies reduce the cost of materials, waste disposal, and fines for failing to comply with environmental regulations, they can invest their savings in retaining employees and hiring and training of new ones. Savings resulting from economies of scale particularly benefit small- and medium-sized businesses. Emphasis on green design improves indoor workplace quality, and therefore, worker health and productivity. These result in higher employment for regions, better opportunities and working conditions for employees, and a better-skilled and more productive workforce for employers.

The enhanced economic performance of participating businesses will make eco-industrial parks a power economic development tool for communities. Such parks are likely to attract leading-edge corporations and open niches for new or expanded local ventures. Both will create new jobs in much cleaner industrial facilities. Companies in the region will gain

new clients for services and buyers for products from other firms in the park.

Development of eco-industrial parks will create programs for extending their economic and environmental benefits across the community's industrial sector. This promises cleaner air, land, water, major reductions in waste, and a generally more attractive environment.

□ Regional development

Proponents of eco-industrial approaches point to a host of economic, environmental, and social benefits for regions. The objective of these approaches is to add value to a region's economy, strengthening its industrial, social, and supporting institutions in a way that attracts new businesses. Eco-industrial development emphasizes the need to encourage stakeholders in identifying community assets, problems, and alternatives, and in planning and implementing economic development program. The eco-industrial development strategies for maximizing resource efficiency, economic growth, and regional sustainability offer a set of mechanisms for redeveloping disadvantaged sites without repeating the contamination of past industrial activities.

In fostering stronger partnerships among citizens, businesses, government agencies, and non-profit organizations, an eco-industrial park can enhance its host neighborhood. By revitalizing existing businesses, redeveloping underdeveloped sites, and attracting new businesses, eco-industrial projects can provide local residents with greater opportunities to work

in their own neighborhood.

As eco-industrial projects are in the early stages of development, there are real and perceived uncertainties and risks associated with implementations. Although there may be potential benefits from eco-industrial park policy initiatives, their development is not problem-free. Indeed, there are a number of potential barriers to the development of an industrial ecology approach.

□ Risks of interdependence

Developing an eco-industrial park is a complex task which requires integration across many fields of design and decision-making. Success depends on a level of collaboration among public agencies, design professions, project contractors, and companies locating in the park. Eco-industrial development's emphasis on collaboration, interaction, and interdependence raises a number of concerns. The transaction costs of working with the community and other businesses, particularly competitors, may be high in terms of time, labor, transportation, communication, and monitoring.

Beyond those costs, businesses may be wary of entering into byproduct exchange relationships where the quantity and quality of supply is not guaranteed. Uncertainty over shifts in production and the ability of secondary markets to cope with the excess or shortfalls of materials adds sufficient risks. Developing alternate sources of materials may also be more difficult or costly in the eco-industrial case. In particular, companies using each other's residual products as inputs

also face the risk of losing a critical supply or market if a plant closes down. To some extent, this can be managed as with any supplier or customer relationship, keeping alternatives in mind and writing contracts that insure reliability of supply.

In addition, certain companies are not used to working in community and may fear the interdependence this creates. Collaboration may be difficult if eco-industrial park includes companies from many different countries and cultures. On the other hand, many large and small companies see such interdependence as a competitive advantage. The possible inability to overcome discrepancies within and between these groups is a major risk.

□ Financial risks

Some of an eco-industrial park's benefits may only become apparent when costs and savings are calculated over a longer time frame. Developers may need to make a strong case for banks to finance a project with a longer payback period. On the other hand, some options for infrastructure may actually cost less to build and maintain. Getting contracts with major companies to locate in the eco-industrial park will help prove the concept to financiers. Calculating costs and savings in a longer time frame, commitment on the part of larger companies to locate, public developer involvement, and obtaining significant signed leases will contribute to gaining the support of financial institutions. A developer with significant signed leases has a bankable project.

Some eco-industrial parks may cost more to develop than traditional parks, depending on the design choices in a project. Added costs may come from the design process, site preparation, infrastructure features, construction processes, and aspects of building design. When this occurs, the additional costs may or may not be offset by savings in operating the park as an eco-industrial park. Public development authorities may be better prepared to bear this increase in development costs than private developers. Or the public sector may fund some aspects of the development with strong public benefits.

Some industrial parks include large numbers of SMEs. While they may benefit from shared environmental services, they are least able to afford any technologies that may be required to improve their environmental performance. This suggests the need for financial service support in the eco-industrial park package.

□ Environmental risks

There is a concern that byproduct exchange may encourage continued reliance on toxic materials and discourage technical innovation as companies invest in exchange infrastructure and customer-supplier relationships. Companies collaborating to reduce transportation or integrate their processes of production may be less motivated to develop more efficient pollution prevention technologies and processes than if they operated independently. The goal should seek continuous environmental improvement by designing products and processes

that reduce the need to extract and use raw materials, thus eliminating the need for recycling and exchange. The cleaner production solutions of materials substitution or process redesign should take priority over trading toxics within eco-industrial park site.

Small local industries outside industrial parks often produce a lot of pollution, because of lack of staff, outmoded technologies, and inefficient resource uses. A broader regional approach is needed to reach such businesses. Often these smaller firms are suppliers to companies in industrial park, who can require them to clean up their processes and perhaps offer training and even investment to support this.

□ Regulatory risks

A number of regulatory concerns have emerged in the planning of eco-industrial activities. There is considerable agreement that the existing regulatory structure poses substantial obstacles to enacting eco-industrial strategies. The eco-industrial development literature discusses the need to increase the flexibility of state and local regulations to support more innovative and holistic approaches focusing more on the ecological system as a whole.

Many environmental policies in developing countries emphasize “end-of-pipe” treatments rather than the more holistic and preventive solutions of industrial ecology. Fortunately, cleaner production and industrial ecology are beginning to impact design of policy. Industrial developers and their associations can lobby for improvements in policy and regulations

that support eco-industrial parks.

□ Inherent barriers

By-product exchange and resource recovery may cause displacement of small businesses. In many countries an extended informal sector profits from wastes and by-products. Establishing recycling or by-product exchange networks among companies could destroy the subsistence of numerous families. Eco-industrial park developers can offer support to such micro-entrepreneurs to strengthen their operations and follow good environmental standards. They could become participants in resource recovery parks or centers.

There are technical barriers, including the possibility that local industries do not have the potential to "fit" together. Informational barriers may also make it difficult to find new uses for waste products, relating to poor information regarding the potential market and supply. In addition, there may be motivational barriers wherein firms, public sector agencies and other relevant local actors must be willing to co-operate and commit themselves to the process. Trust is a key factor here and companies may be unwilling to provide information about production processes and products for competitive reasons. A related problem is that industrial ecology may make the partners in eco-industrial parks over dependent on each other. This may especially be the case if eco-industrial parks are based around an anchor firm. Closure of the anchor firm could be fatal for the rest of the eco-industrial park.

Ⅳ. Examples of Eco-industrial Park Development

1. Daedeok Techno Valley

Daedeok Techno Valley development is chosen for our case study because it is the first eco-industrial development project in Korea. It utilizes a set of development strategies for environmentally friendly eco-industrial park development.

This chapter presents an overall evaluation of the Daedok Technovalley Development Project's progress towards sustainability and suggests several recommendations for future eco-industrial park development.

(1) Transition to Eco-industrial Park Development

The distinctive feature of the earlier original development plan was that one large scale company was planned to use significant portion of its industrial site. And there were consideration for environmental, social and cultural sustainability. This development plan was not carried out due to the late 1990s financial crisis and consequent cancellation of a semiconductor factory development project.

As environmental issues became serious, Daejeon City adopted a new Daedeok Techo Valley development plan in 2002. This eco-industrial park development project aimed to promote an environmentally friendly industrial park and secure economic

efficiency and cultural sustainability as well.

Compared to the High Tech Science Park development plan in 1997, eco-industrial Park development plan in 2002 achieved a significant progress toward sustainability in several ways. Firstly, the eco-industrial park project made considerable progress towards energy and air sustainability. It pursued mixed land use development for efficient energy consumption and air pollution reductions. It has not only basic facilities like industry, distribution and housing, but also recreation, education and cultural facilities often lacking in traditional industrial parks.

Secondly, the eco-industrial park plan adopted a step-by-step development program, which lowered the initial investment level of developers. In addition, it provided a better environment for the establishment of high-tech venture businesses by providing flexible size of industrial land rather than focusing on only per unit of industrial land, as in the former plan. Environmentally friendly site planning and individual building design (e.g. habitat creation, green space network, artificial land planting, solar energy use, etc.) were added in the development plan.

Finally, the eco-industrial park plan upgraded cultural sustainability by increasing sense of community and local identity creation. It also provided diverse types of housing to suit different tastes and family members.

(2) Development Plan

Daedeok Techno Valley is a joint investment project by Hanwha Group, Korea Development Bank, and Daejeon Metro-

politan City. This project is expected to maximize synergy effect through the advanced management expertise of Hanwha Group, the comprehensive administrative support of Daejeon Metropolitan City, and the financial support from Korea Development Bank. In particular, Hanwha Group is responsible for Daedeok Techno Valley development project and management and operation of support programs for residing companies.

The site is located in Daejon Metropolitan City, approximately 150㎞ from Seoul and has an area of 427.1 ha. The majority of the site was used for agriculture purposes before this development. The site consists of small hills, river and greenbelt with a good view and provides pleasant environment. It is expected that the site could create an optimal research complex and succeed in promoting investment because of its proximity to Daedeok Science Park, Dunsan Newtown, and Expressways.

Daedeok Techno Valley development can be a catalyst in providing opportunities for regional development. Linked with Daedeok Science Park, Daedeok Techno Valley could lead regional industry through the efficient development of advanced science and technologies. In addition, Daedeok Techno Valley could facilitate the formation and growth of new businesses in the region because it will be developed as an international high-tech venture business center for domestic and multinational corporations. Accordingto Daejeon City's industry development plan, Daedeok Techno Valley plays a key role in developing Daedeok Valley as an advanced science and technology venture town and connecting the city's

existing industrial estates and the Daedeok Science Park.

Table 3 *Development Plan*

Classification		Use	Area	Ratio
Industrial site		General industry/ quasi-industry	1,369,50㎡	32.2%
Support site	Residential site	Apartments/ townhouses and free standing houses	660,000㎡	15.5%
	Business site	Commercial/ industrial support/ neighborhood residential services/ distribution	204,600㎡	4.7%
	Leisure site	Tourism and recreation/ exercise facilities	359,700㎡	8.4%
	Public site	Schools/ community center, etc.	217,800㎡	5.2%
	Sub-total		1,442,100㎡	33.8%
Common public areas		Green zones/ roads/ parks, etc,	1,448,700㎡	34%
Total			4,260,300㎡	100%

Table 4 *Project Phases*

Classification	Area	Business period
1st Phase	924,000㎡ (22%)	November 2001~July 2004
2nd Phase	1,584,000㎡ (37%)	June 2003~June 2006
3rd Phase	1,749,000㎡ (41%)	April 2005~December 2007

(3) Development Concept

The development concept of the Daedeok Techno Valley is to create a comprehensive and self-sufficient industrial, residential, commercial and leisure complex with production, distribution and supporting facilities. Daedeok Techno Valley intends to invite the most advanced industries like IT, BT, BT, NT, and precision machinery. In addition, it plans to bring to the city, Daedeok Valley Techno Mart, high frequency part support center, robot industry, and an IT-exclusive venture town. It plans to create a pleasant residential environment and state-of-the-art educational facilities. Daedeok Techno Valley will offer about 8,000 apartments, townhouses, and free-standing houses with gardens. It will also create a comprehensive educational environment to include eight elementary, middle, and high schools and the Gwanpyeong River waterside park which will together constitute an ideal family environment. It will work to offer ideal conditions for the development of business, commerce, culture, and leisure activities.

Daedeok Techno Valley is a self-sufficient industrial compound with a goal of the development of future-oriented industrial complex and is different from other conventional industrial complexes in several ways. The complex accommodates a variety ofbusinesses. An ordinary industrial complex invites all manufacturing businesses because these considerations should be taken into account if its plots can be easily sold. In contrast, this industrial complex selectively induces a limited number of businesses which have environment-friendly and advanced technology. Moreover, every effort is

made to allure superior enterprises, which must go through careful investigations and objective evaluation in order not to pose any environmental threats.

It also offerssemi-industrial sites. Most industrial complexes are designated as general industrial quarters, while this industrial complex has its own semi-industrial quarters. Step-wise promotion of the project will help prevent excessive investment, minimize unsold land, and spread long-term ripple effects. Semi-industrial quarters can be utilized in many ways including production purposes since they accommodate the headquarters of an enterprise that has not only factories and research institutes, but also a high-degree of technological development. Moreover, the semi-industrial quarters can recover their investment in enterprises quickly because idle spaces can be easily leased and create a high lease yield. In this regard, the semi-industrial quarters will lay the foundation for Daedeok Techno Valley to be an ecosystem for developed enterprises.

It is also the first industrial complex to apply an ecologically friendly land use ratio. A general industrial complex has its building coverage recognized up to 80%, which makes it seemingly secluded from the outside. In contrast, the Daedeok Techno Valley has applied a district unit plan for the first time as an industrial complex. The plan recognizes the building coverage up to 50~60%, does not allows fences to be erected on the border of the construction site, and allows buildings to be constructed a certain distance from roads, creating more open work conditions and enhancing business efficiency and asset values. Furthermore,

it stipulates power cables be installed underground throughout the complex, providing utilities in a stable manner to an environment-friendly industrial complex.

It offers the ideal ecological environment for new ventures. Daedeok Techno Valley, located at the center of the Daedeok research and development special district, is a R&D hub and benefits from the Daedeok Science Town where some 17,000 top researchers work at the Korea Advanced Institute of Science and Technology (KAIST) and Information and Communication University (ICU). Consequently, it can readily access highly qualified manpower and through the use of various information networks, can efficiently commercialize the local technologies through their research.

Moreover, Daedeok Techno Valley constitutes a positive venture ecosystem, in collaboration with the Daedeok Science Town which itself comprises about 40 state-run research institutes, plus some 30 enterprise-affiliated research institutes, and about 700 state-of-the-art ventures. It provides an environment for new ventures to fully benefit from synergies resulting from active technological and human exchanges among these various entities.

All aspects of the complex emphasize the environment. It encourages energy efficiency and recycling. It offers the possibility for both residents and those who work in the Daedeok Techno Valley to access and enjoy ecologically preserved natural spaces.

(4) Evaluation

□ Energy and material flow

The eco-industrial park plan intends to establish self-sufficient energy and material flow systems within the site. The Daedeok Techno Valley utilizes water consumption reduction methods such as a graywater recycling system and rainwater recycling and reuse system. Water permeable pavement materials are used for streets and roads to facilitate the penetration of rainwater into the ground. Photovoltaic street lights and photovoltaic energy generation plants are also chosen to cut back energy consumption and boost renewable energy generation. To minimize waste production and resource consumption, the park utilizes waste recycling methods.

Such methods would cut down excessive rainwater drainage, water and energy consumption and waste production. The main defect in such plans, however, seems to lack specific detailed targets and indicators regarding water consumption and renewable energy generation.

□ Environmental design

Daedeok Techno Valley takes more strict design measures and technologies to upgrade the quality of the environment. Green spaces have been adopted to provide symbiotic relationship between humans and flora and fauna. For wildlife preservation, biotope creation, ecology park development, ecological waterfront design and artificial land planting have been

adopted in the eco-industrial park plan. The green space ratio has increased compared to that of the High-Tech Industrial Park development plan. The eco-industrial plan also adopted several environmentally friendly building designs such as natural ventilation and lighting systems, non-toxic and recycled material use and rooftop planting.

□ Symbiotic network and cultural identity

Although symbiotic industrial network construction is one of the mostimportant features in eco-industrial development, neither sufficient design strategies, nor technologies have been identified in the site. Daedeok Techno Valley includes a few fundamental policies such as a zero pollution and waste production system and information and resources sharing network construction. However, detailed design targets and strategies have not been identified for establishing effective symbiotic networks of industries within the site.

Compared to the old development plan, the eco-industrial park plan is concerned with awareness of community spirit, local identity creation, and community support facilities. Provision of cultural, recreation and leisure facilities within the park for the quality of life is positive in the eco-industrial park plan. Community amenities identified in the park include ecology parks, shopping center, community center and school.

A few planning and design strategies have been added to enhance the image of the high-tech science town. The eco-industrial park plan suggests a new high-tech transportation system and theme park development. Establishment of an ecology education center and community farming garden within

the site is also added.

2. Cape Charles Sustainable Technology Park

Northampton County, VA, has opened the new kind of industrial facility in which water streams are cycled into revenue streams and in which industrial processes are based on the design of natural systems. This ecological industrial park is the cornerstone of an innovative county strategy by which economic development is protecting valuable environment assets and by which environmental protection is fostering development of a sustainable economy.

(1) Development Background

Despite the county's natural and historic wealth, many of its people live in severe economic poverty. The closure of nearly all of the area's seafood and agricultural processing plants in the 1980s resulted in the loss of more than 1,500 jobs-more than 25% of the county's workforce. Having declined economicallyto one of the poorest communities in Virginia, Northampton county decided to pursue a strategy that would maximize both the economy and the environment. They began to explore ways to invest and protect natural assets.

(2) Sustainable Development Action Strategy

In 1993, the county formally began its sustainable development initiative with a mission to build a strong and lasting

economy by capitalizing on Northampton's rich natural, cultural and human assets. The commitment was to develop in a manner that would benefit business, the environment and all the county's people.

This Northampton County Sustainable Development Action Strategy was developed through an intensive, collaborative process involving community workshops, task forces, meetings and events. As a result of this process, Northampton decided to target the following industry sectors: agriculture, seafood and aquaculture, heritage tourism, research and education, arts and crafts, local product, and sustainable technologies. The community also identified the vital natural, historic and community assets that would need to be preserved and capitalized on to successfully develop and sustain these targeted industries.

One of the keys of the Sustainable Development Action Strategy was to utilize private investment in the county in ways that would build an economic base. It was clear that limited public financial resources would have to be carefully focused to achieve the highest possible return for each dollar invested. To implement its sustainability strategy most effectively, the county had to determine which course of action would yield the highest economic and environmental return. The decision was to create an eco-industrial park to be known as a Sustainable Technology Park.

(3) A World-class Eco-industrial Park

As it began planning infrastructure for business development, Northampton set its goal to build a world-class facil-

ity. The industrial park would have to be developed as one of the first of a new industrial revolution. The goal was to build an eco-industrial park that would share the county's high business, environmental and human equity standards.

To make the eco-park a reality, the planning team was organized. It included designers, architects and engineers; federal, state and local government regulatory and support agencies; public and private potential investors; potential corporate tenants. The eco-park would help to build a diversified economic base by attracting and incubating new companies and by retaining and expanding existing companies. These companies would provide quality jobs with competitive wages, benefits, and opportunities for training and advancement.

(4) Master Plan

The master plan for the park integrated the park with the historic town of Cape Charles and the natural landscape adjacent to Chesapeake Bay. The site centered on redevelopment of former industrial land surrounding the town's harbor. The plan included roads, utilities, sewers, water management, wetland treatment for water recycling. Half of the site was reserved for ecological infrastructure. This preservation is the focal point of a network of natural and created wetlands, woodlands and shrub wildlife habitat especially valuable for the millions of migratory birds. As an ecological industrial park, facilities plans were based on the design of natural systems. Electricity would be generated from sunlight and wind. A water reuse and recovery system was planned to recycle water for industrial use.

(5) Sustainable Technology Incubator

The first phase of Sustainable Technology Park completed in 2,000 is 31,000ft^2 multi-tenant manufacturing and office building. It has an integrated solar photovoltaic roof system that converts sunlight into electricity. With the building operating at full capacity, this willmeet up to half of the building's total annual electrical demand.

Other sustainability features include skylights for natural daylighting, enhanced insulation, interior environmental sensing, carbon monoxide sensors and alarms, low-energy lighting, low-water-use fixtures, porous parking lot paving and native non-irrigated landscaping. Interior space can be divided flexibly to accommodate up to eight companies for the purpose of manufacturing, R&D, office space and other use.

The building's features are designed not only to reduce energy and resource demands, but also to cut down operating costs and to increase occupant productivity and health.

(6) Ecological Infrastructure

In addition to the more traditional infrastructure of roads, utilities, and building, Northampton County and its partners integrated key natural resources into Sustainable Technology Park. A local-state-federal funding package was used to fund the park's ecological infrastructure. Included are a natural preserve, beaches and dunes, a migratory bird habitat, constructed wetlands and ponds, a system of trails and boardwalk, more than 4,000 new trees and a total of 90 acres of protected natural area.

This ecological infrastructure created a synergy between the economic development, environmental protection and community improvement objectives of the park. The natural amenities have enhanced economic development efforts by helping to attract the corporate tenants the county has targeted.

(7) Target Market

The county targeted: companies working with renewable energies, including solar, wind and bio-fuels; companies working on clean water technologies involving purification, desalination, and water reuse and recycling; companies in fish and shellfish aquaculture; and companies involved in adding value to new and traditional local agriculture products.

The county focused on these industry areas and compiled a list of more than 3,000 companies targeted as prospects for expansion or relocation to the Sustainable Technology Park. These companies were seen as the initial building blocks for an industrial ecosystem within the park.

The sustainable technology strategy has attracted diverse companies to the eco-park. The park has also formed an eco-industrial partnership with a neighboring company. In addition to the companies on-site, Northampton's sustainable development efforts have attracted companies located throughout the county.

(8) Toward a Sustainable Future

Building on the success of the Cape Charles eco-industrial park, Northampton is aggressively moving forward with the

next phase of its sustainable development strategy. One key project is the reclamation of the county sanitary landfill as a seaside ecological farm. The county is also investigating the potential of a renewable energy farm that would harvest methane from the landfill, bio-fuels from soybeans grown on county's farms and wind energy from the strong coastal winds. Northampton's strategic plan also focuses on ways to further support the county's growing aquaculture industry, which involves cultivating fish and shellfish for harvest.

Northampton's Sustainable Technology Park is a proof that economic development and environmental protection are not mutually exclusive and that these goals can be pursued simultaneously to enhance the community's overall quality of life. Its experience demonstrates that integrating asset development and protection is a powerful strategy for success. A comprehensive, action-oriented plan provided the framework for launching an eco-industrial park. An extensive local, state, and federal partnership for project financing has been key in leveraging private investment in Northampton's development strategy.

3. Green Industrial Estates in Thailand

The Industrial Estate Authority of Thailand (IEAT) has launched an initiative to make the 28 estates it manages eco-industrial estates. The IEAT invited the German Technical Co-operation Organization (GAZ) to support development of the program that will begin with five estates as pilot sites. The pilot sites reflect both newer and older estates and a

representative cross section of industries in Thailand. The IEAT envisions projects that incorporate by-product exchange, resource recovery, cleaner production, community programs and the development of eco-industrial networks. The GTZ assists through technical transfer and policy development and coordinates with the IEAT initiative.

This eco-industrial initiative appears to be the most far-reaching eco-industrial effort in developing countries. It promises ultimately to influence the environmental, social and economic performance of all industrial estates managed by the IEAT as well as plant operations surrounding the estates. The IEAT is in a unique position to demonstrate the principles and strategies of eco-industrial development. The proposed vision for the initiative is as follows: Through technical co-operation, they intend to improve the environmental performance of selected IEAT industrial estates and develop a policy for eco-industrial development for Thailand.

The first step is for the management of each pilot estate to form its individual vision and business plan and budget required for specific projects. Estate managers have identified utilization of by-products asan early concern, but they are aware that opportunities for exchanges among factories at any one estate are limited. As they develop their estate plans, they will start to explore opportunities for building an eco-industrial network between their companies and suppliers outside the estates. The inter-estate networks would complement the links of each estate to its surrounding factories.

The IEAT and the individual estate teams considered creating potential support structures for their initiatives, including:

- An integrated resource recovery system or resource recovery park
- A system for encouraging and managing the exchange of by-products
- Training and services in all aspects of eco-industrial development
- A coordinating unit to manage eco-industrial network relationships
- A community enhancement office to manage projects with neighboring communities
- One or more business incubators
- Public sector support in R&D, policy development, access to investment and information management

Managers of the individual pilot industrial estates note a number of serious barriers that they encounter in their effort to become eco-industrial estates and to form eco-industrial networks. Policy and regulations for the operation of estates and individual factories are defined by several agencies, including IEAT, the Department of Industrial Works and the Ministry of Science, Technology and the Environment. Eco-industrial development requires coordination of these policies and be flexible enough to enable by-product utilization and exchange. For instance, a re-refining company near Rayong is limited to receive only 5 of the possible 20 solvents that it is designed to recycle. This limits the plant's return on investment, cost savings for factories seeking to use recycled products and the diversion of hazardous materials from the limited landfill devoted to them. Such regulatory barriers are

both economically and environmentally damaging.

Estate and factory managers and recyclers all have a need for R&D to identify new technologies to manage by-products not currently usable in the resource recovery system. They also need guidance on increasing energy efficiency of their operations and possible incorporation of renewable energy technologies, such as bio-gases from food, agriculture and sewage by-products.

The long range plan for this initiative in Thailand includes work at the policy level within the IEAT and among the different ministries to address the needs that estate managers have raised. In addition, it supports development of more effective emergency management systems in the estates, capacity development to help the IEAT to improve organizational performance within an eco-industrial concept and the transfer of technologies required for greater efficiency and cleaner production.

V. Design Plan for Eco-industrial Parks

Major options to be considered in the physical design of an eco-industrial park are presented in this chapter. Many of these concepts and technologies are considered in new industrial facility planning focusing on energy efficiency and pollution prevention.

Some of these ideas will save money over time, such as daylighting facilities to cut down on electric lighting. Some ideas, like a closed loop water system may require a higher initial investment, but cut operating costs for the park. The constraints and special needs of tenant companies will shape their design of buildings, but developers can offer guidelines and support for incorporating design options their own designers may not be familiar with.

In planning site development for an eco-industrial park, several key issues need to be considered. What qualities of the surrounding ecosystem could be impacted by the construction of an eco-industrial park? How can features of the ecosystem within the site's boundaries be preserved? What natural resources at the site can be incorporated into infrastructure and building design?

Industrial park selection usually considers the capacity of regional transport infrastructure to support tenant needs. High priority for rail access as a criterion is desirable.

1. General Environmental Consideration

It is necessary to take into account natural habitats, stability of dominant plant and animal groups, wetlands, and endangered species in developing the site. A primary question is to what extent can the existing ecosystem be preserved and incorporated into the design of landscaping? If the site is damaged from previous use, to what extent can it be reclaimed and restored as an ecosystem? The landscaping of an eco-industrial park will lend itself to recreational uses: walking and jogging trails, picnic grounds, and bird viewing areas.

An often overlooked characteristic of a site is its orientation. Simply noting where the sun rises and sets provides an initial basis for using a building's exposure to sun. Daylighting can reduce the need for electrical lighting, which also lowers the need for air-conditioning. Passive solar heating and cooling can serve office areas, cafeteria, warehouse, and many other spaces.

Getting data on site's microclimate provides valuable guidance to design of infrastructure and landscaping and the form of buildings within the site. Each site may have important variations in wind patterns, temperature, and precipitation. Information of hot, cool, wet, windy and dry places in the site can be used regularly in the planning process and can have significant impact on issues like heating and cooling costs.

Existing native trees, shrubbery, flora and grasses provide clues about the site's climate, hydrology, geology, and eco-

logy. They also can be a core component of the landscaping plan. Introduced vegetation can improve microclimates and energy efficiency by acting as shade and windbreaks. Vegetation with appropriate species in wetlands helps filter pollutants.

Preventing and mitigating environmental impact requires designing eco-industrial parks in a way that considers natural ecosystem conditions and resources. Ecosystem planning principles include land use and efficiency, health and safety protection, and environmental protection.

There are several design guidelines to enable industry to coexist with natural systems.

- Define the carrying capacity of the site, and design with in those limits.
- Maintain the natural areas and indigenous vegetation as much as possible.
- Increase the density of development.
- Design sites considering energy efficiency.
- Create the potential for environmental synergies through locations of the companies.

2. Design of Physical Infrastructure

Industrial park infrastructure encompasses the physical support systems used by most of the tenants of the park. This includes facilities for transportation of materials and people (e.g. road, railroad, docks and harbors); for production and supply of energy (e.g. photovoltaic, wind, electrical distribution

lines, gas pipelines, etc.); for storage, treatment and flows of water to and from site; for telecommunications (e.g. telephone cables, fiber optic networks, satellite dish antennas, etc.).

(1) Transportation

Effective transportation infrastructure is central to industrial park's success. Each tenant requires easy access for its customers, employees, and suppliers. Each needs dependable and economic transport of raw materials to the site and of finished products from the site to the customer's location.

Key objectives in the design of the transportation infrastructure include reducing energy use, air emissions and ground contamination to minimize impact on the land and optimize use of materials.

□ Roads and parking

Porous paving allows water to flow through the surface rather than run off in concentrated flows. A variety of products including recycled plastic blocks, wire mesh, and concrete pavers allow normally paved areas to be solid enough for parking and walking. For solid paving, crumb rubber is added to asphalt to extend asphalt life.

□ Transportation of materials and products

In many cases developers may be able to benefit from the financial, social, and environmental advantages of railroad transportation. If the railroad access in the site criteria is in-

cluded, energy and air emissions burden from transportation can be reduced. Railroad transportation is simply less costly as long as flexibility in the logistics of getting product to market is maintained. Depending on the size of the park, rail passenger transportation for employees may also be feasible.

□ Transportation of people

Movement of employees to and from work is a major use of energy and source of air emissions. Eco-industrial park design can reduce these environmental costs by creating a range of transportation services in coordination with the local and regional transportation system.

Some options for employee transportation include:

- When climate and residential patterns permit, make it easy for people to walk or bike to work.
- Create eco-industrial park services to support car-pooling and offer van transportation, integrated with regional transportation service.
- Consider using vehicles powered by electricity, natural gas, or fuel cells.
- Consider limiting free parking for employees as a disincentive to single-driver trips.
- Encourage tenants to consider staggered shifts or starting times which can significantly reduce peak traffic congestion.
- Telecommuting can be a major contributor to traffic reduction and employee satisfaction.

Some basic services at the eco-industrial park can reduce employee transportation needs: a day-care center for children, a bank branch or ATM machine, a pharmacy, and similar facilities may significantly reduce the need for local travel.

(2) Energy Infrastructure

There are two basic environmental performance objectives for energy infrastructure in an eco-industrial park: optimize total energy use and maximize use of renewable sources. A feasible goal within the first objective could be to reduce energy usage by 50% within the eco-industrial park. The potential for renewable sources will vary greatly from area to area.

□ Optimal energy use

The basic question is how an eco-industrial park creates the greatest amount of work for each unit of energy input through design of park infrastructure. Technologies like energy cascading and co-generation are ways to achieve this at the park level.

There are many opportunities for energy cascading. Co-generation is an example of generating electricity and heat together. The energy used to generate electricity degrades to heat which can then be used in a process where high temperature heat is required. The low-grade steam from this process can be used to heat the office areas or warehouse. Cascading tactics may be used within a single facility or between two or more separate plants. Energy cascading

requires conduits for the steam or hot water moving between plants.

Cooling towers are found in most industrial and commercial facilities. To cool a space or process, heat is discarded into the air. The source or on-site customers can use this waste energy to fulfill needs, rather than buying more fuel or electricity

Electricity for an eco-industrial park may be generated on-site, brought in via high-voltage lines from the local utility, or both. If it is feasible to generate it on-site, there are opportunities for cogeneration and cascading. If a gas turbine generator is used, how the waste heat can be captured and used for process or space heating is an important matter.

□ Maximum use of renewable sources

The level of use of renewable energy sources in the eco-industrial park depends on the region's solar, wind, bio-mass, and other renewable resources. The energy needs of the park's companies determine the role these sources can play.

A major argument for on-site energy generation is the dependability of supply. Production shutdowns due to blackouts and brownouts arevery costly. Photovoltaic or solar thermal energy sources are dependable and clean. The environmental benefit of renewable sources is that they avoid net emissions of greenhouse gases and the depletion of finite fossil fuel resources.

A simple example ofphotovoltaic solar cells in an eco-industrial

park would be using them to power lighting, controls, and environmental sensors at remote locations on the site. This reduces the need for cables and possibly enables more flexible control systems. Acquiring and using such portable solar generators in an eco-industrial parks's power system could lower the peak demand of the park on the power grid. This would reduce the cost of transmission lines to the power grid and to the plants. When not scheduled for park use, these modules could feed electricity back into the grid.

(3) Water Infrastructure

As with energy, the first objective is conservation: reduce demand of external supplies by efficient use and re-use. Multiple-use strategies similar to energy cascading is the best consideration. It is reasonable to set a goal where all water used on the site will be recycled or reused, in so far as there is demand for it.

Water, like energy, has different levels of quality. Traditionally, only two quality levels are considered; drinking water or wastewater, but there are many possible intermediate levels, that can be profitably used in a well-conceived eco-industrial park. These include:

- Hyper - or ultra-pure water(for use in making semiconductor chips);
- De-ionized water(for use in biological or pharmaceutical processing);
- Drinking water(to clean in the kitchen, cafeterias, water fountains, etc.);

- Wash water(to clean delivery trucks, buildings, etc.); and
- Irrigation water(used on the lawns, shrubs, trees in the eco-industrial park landscape).

To implement these approaches to water re-use and conservation, design team will need to consider a more complex network of pipe systems for different qualities of water

On the other hand there are many innovative ways to deal with wastewater recycling. Not only can the water usually be recycled or made suitable for use in other processes, but the treatment facilities may be developed as integral partners of the entire eco-industrial park. The treatment plant may purchase by-product materials from other tenants, or supply them.

The water treatment plant can also become an alternative part of the eco-industrial park site. An ecological treatment plant uses the water for greenhouses, lagoons, and wetlands. These facilities use no toxic chemicals, release no foul odors, produce salable byproducts, and look more like a horticulture operation than a sewage works. Major steps in the processing use plants and micro-organisms are specific to the area.

Storm water runoff is also a source that we can integrate into eco-industrial park's water system, reducing demand on the utility. Purification for road runoff before the water flows out to a neighboring river and wildlife habitat is one possible solution. In a drier climate, wetlands or lakes can be viewed as storage basins, holding water for appropriate uses on the site.

(4) Material By-Products and Solid Waste

Materials handling in a traditional industrial park is usually managedby each company. In an eco-industrial park, it may be useful to provide infrastructure to support the exchange of materials among plants and to handle some by- products marketed off-site. When un-marketed by-products are toxic, eco-industrial park management and tenants would need a clear legal framework around liabilities.

Eco-industrial park materials infrastructure options include:

- Conveyors, pipes, or other means of moving by-product materials from one plant to another.
- Storage structures to accumulate by-products for sale off-site.
- Storage structures to accumulate toxic materials for on-site processing or off-site disposal.
- A toxic storage, treatment, and refining unit.
- A composting operation for landscaping and kitchen by-products.

Infrastructure for moving by-product materials or water within the park needs capacity for rerouting, perhaps by placing tubes and conveyor belts above ground in a shed or they could be placed in an undersurface channel that is easily opened.

Toxic chemicals, heavy metals, batteries, and contaminated materials or equipment are a health and environmental risk that are often poorly managed. With proper handling some

substances can become a valuable stream for resource recovery. To support practices within eco-industrial park companies, overall resource recovery management system and environmental policies need to also include cleaner production training and incentives for phasing out the use of toxic materials in tenant companies. Solutions may be found in product and process redesign.

An eco-industrial park should work with regulatory and development agencies, trade associations and NGOs to create a collection system and treatment facility that makes it easy and cost-effective for businesses. It is not appropriate, though, to recommend specific technologies for treatment because this field is evolving rapidly.

One proven technology is re-refining used oil and returning them to their initial user or to the market. So long as these materials are kept separate by the source company and the processing is done to high standards, this is a more eco-efficient solution than treatment and disposal.

(5) Telecommunications

Telecommunications technologies have an impact on eco-industrial parks comparable to those for making energy and materials products available for re-use. Telecommunications include a wide variety of technologies: video conferencing, the Internet, email, telephone, telex, fax, satellite linkages, and EDI (Electronic Data Interchange).

An eco-industrial park's telecommunications infrastructure can contribute to the success of tenants, especially small to mid-size companies. The system can include tools to support

by-product transactions among eco-industrial park companies and with those outside the park.

A few options for the site infrastructure include:

- Satellite downlink equipment and a site-wide network of fiber-optic cables will connect eco-industrial park to the world for business.
- Employees in the eco-industrial park will be able to use this network for long distance video conferencing and education.
- Water usage can be reduced by installing moisture sensors in the landscape to control irrigation.
- Air and water quality sensors linked to computers can provide a continual record of environmental conditions at site.

(6) The communities

It is important to consider an eco-industrial park as a community of companies. One vital aspect of the infrastructure is physical space that enables their employees to interact. Some possible components of eco-industrial community facilities include:

- An auditorium and meeting rooms suitable for educational and training activities, business meetings, conferences and community meetings.
- A cafeteria, restaurants, and private dining rooms;
- A health or sports and fitness center;
- A library, telecommunications, and audio-visual center;

- A day-care center.

3. Building Design

Buildings, like products, have a life cycle. Effective design demands attention to the full span of a facility's life. For designers the long-term challenge is to consider each stage of a building's life cycle and to seek an overall plan that balances economic and environmental needs through all of these stages. The following describes a few of the many important environmental factors in planning a building and its production system.

□ Constructability

The traditional questions regarding constructability are the availability of budget and the ability of contractors to do the job properly. In an industrial park a design team will also ask what environmental impacts each design choice will impose in terms of the construction process and how they can be minimized.

□ Durability

The objective of conserving environmental and economic resources suggests design for durability. The effective choices of energy and materials enable longer life for the building. The quality of the structure, materials, and construction should be optimized in terms of the function the building

will play.

□ Flexibility

Building owners will be able to extend the life of the building if it is designed with flexibility, making it easy to redesign, expand, and retrofit as uses and technologies change over time. In an eco-park plant, design should readily enable changes needed to accommodate new materials or energy by-products exchanges.

Energy system design should include the capability for using new renewable energy technologies as they become cost-effective. Flexible design enables less durable building components to be readily replaced without impacting more durable structures. Some building techniques facilitate moving interior walls and reusing building materials.

□ Maintainability

Designers can offer building managers cost savings through designs which minimize the need for maintenance and improve the ease of maintenance. These qualities also increase the durability of structures and components and reduce the possibility of costly production shutdowns. Integration of design for maintenance of the building and the manufacturing system is an important consideration. Prevention of failure in either area reduces the likelihood of major losses due to production downtime.

□ Livability

Designers are giving increasing attention to manufacturing, service, and office space as a habitat for human beings. Important questions include: how do we best maintain quality of air and light? What materials choices will insure a healthy environment? Can workers interact comfortably with each other? Do they have access to a natural environment?

□ Energy

Designers seek to new methods for operating buildings with a much higher level of energy efficiency. Designers can draw upon a variety of building automation technologies to conserve energy.

Industrial facilities typically use fossil fuels as their primary source of energy including coal, natural gas, and oil. The efficiency of this use can be increased through cogeneration.

Passive solar energy is a renewable energy option for building design and is frequently employed. Designers apply this energy technology in manufacturing, services, and office buildings for lighting and heating.

Hydrogen fuel cell technology is likely to evolve rapidly in the next decades. Fuel cell systems may take more time, this technology is now suitable as a backup power supply, a resource critical to many industries like electronics manufacturing and food processing.

Ⅵ. Eco-industrial Development Strategy

The policies that will best support the promotion and expansion of eco-industrial development are in many ways the same as policies advocated more generally for industrial efficiency, urban reinvestment, regional planning and the development of liveable communities. This is because it takes a systems approach, eco-industrial development places an additional focus on relationships among firms, the nature of work and the flow of materials within economic and industrial systems.

1. Important Elements of Eco-industrial Development

□ Cost effectiveness

Policies should aim at minimizing economic costs. This will require ensuring that the costs of each extra resources spent are equal across the range of possible interventions. Cost effectiveness allows for the minimization of aggregate costs and the setting of more ambitious targets in the future.

□ Environmental effectiveness

Policies should secure regeneration, substitutability, assimilation, avoidance of irreversibility.

- Regeneration: Renewable resources should be used efficiently and their use should not be permitted to exceed their long-term rates of natural regeneration.
- Substitutability: Non renewable resources should be used efficiently, and their use limited to levels that can be offset by renewable resources or other forms of capital.
- Assimilation: Releases of hazardous or polluting substances to the environment should not exceed its assimilative capacity.
- Avoidance of irreversibility: Irreversible adverse effects of human activities on ecosystems and on bio-geochemical and hydrological cycles should be avoided.

□ Long-term planning horizons

In the absence of an adequate framework for assessing the impact of policies on different types of resources, measures targeted at short-term objectives may be selected even if they have negative long-term impacts. While trade-offs between different goals may prevail in the short-term, in the long-term, both man-made, natural, human and social capital will complement each other in supporting welfare improvements.

□ Delivery of public goods

Many of the benefits from government interventions needed to promote eco-industrial development have the characteristics of public goods(basic research, information, health and education). Also, many of these public goods benefit several

countries. Effective delivery of these public goods requires overcoming obstacles to coordination.

□ Policy integration

Unsustainable practices may result from incoherent policies in different domains. Sectoral policies are often introduced without regard for theexternalities being targeted by environment policies, leading to inconsistencies and spill-over effects. Improving policy coherence requires better integration of economic, environmental, and social goals in different policies.

□ Transparency and accountability

A participatory approach is important to successfully meeting the challenge of eco-industrial development, as the criteria for eco-industrial development cannot be defined in purely technical terms. This requires that the process through which decisions are reached is informed by the full range of possible consequences, and is accountable to the public.

2. Eco-industrial Development Policy

Understanding the policy and regulations is necessary for the successful development of eco-industrial parks. Policy makers should be aware of the policy requirements of eco-industrial developments. Eco-industrial parks and networks provide opportunities for testing new policy approaches in areas like cleaner production. The challenges and benefits of

developing a more integrated policy framework for eco-industrial development are discussed below.

Placed-based policy as a complement to national and sector-based policy is explored. Some of the incentives and research programs needed to support eco-industrial development are also reviewed.

The developers may need to work with government directly to build a policy framework that protects the environment and enables innovative activities that seek cleaner, more resource-efficient development.

(1) Coordination of Policy

Effective environmental protection and industrial development is integration of policy and its implementation. More cohesiveness among the many agencies for environment and for economic development would be helpful in solving differences and conflicts that industry confronts. Separate laws cover air, water, and land and separate offices administer these laws. Often, the solution in one area generates new problems in another.

Environmental and development agencies often appear to be in conflict and fail to recognize the financial and market advantages and business gains from improved environmental performance. A more integrative approach views industry as a proactive participant in the improvement of environmental performance. Developers need a more integrated set of policies and regulations and a more coherent organization to work with. Closer integration among policies and among organizations will reduce the developer's costs and risks at the same

time that it will enable each agency to perform its function better.

Different agencies could create a task force to support the application of available technologies through entrepreneurial firms. Distributed energy generation and fertilizer companies would install and operate generators in rural areas. Pollution would become power. The farms would have a reliable and affordable energy source. The local economy would grow and the energy supply would become more diversified.

Education in industrial ecology and the dynamics of eco-industrialdevelopment would help achieve this objective of integration among policies. Industrial ecology proposes that organizations learn from the functioning of ecosystems and other natural systems. Better understanding of the ecological regulatory processes would improve the design of policy and regulations, the functioning of regulatory agencies, and their collaboration with industry.

(2) Place and Resource-specific Policy

Place-specific policy complements sectoral policy and provides a coordinated frameworkfor implementation with effective communication. Cleaner production programs often face opposition because they lack locatio-specific considerations of the local business community. Eco-industrial parks offer high opportunities for testing and disseminating policy initiatives regionally. Developers of eco-industrial parks can also act as a coordinator to encourage participation of industrial facility managers. With the help of this process, policy-makers can gain essential feedback in the design that help achieve their

goals in environmental and industrial development.

In exchange, policy-makers work through the concrete issues that a park manager or developer should address to create a friendly environment for industry. They should overcome the regulatory obstacles to more efficient use of resources by industry. They also need to streamline permitting processes. What incentives they should provide to encourage environmental consideration in the operation of industrial parks is another worthwhile issue.

Although environmental policy developed from end-of-pipe controls with the cutting of pollution to the environment, policy-makers have added concern with resource issues. However, there is a lack of am overall framework of policy that seeks to optimize utilization while preventing pollution. Companies are considering not just the costs of regulatory pressures but also the opportunity costs of pollution and inefficiency. When companies act upon the opportunities, they save significantly from their investmentsin technical changes that improve environmental and economic performance simultaneously. By eliminating inefficiencies in the use of resources throughout a product's lifecycle, managers can cut costs and create value. These inefficiencies include incomplete utilization of material and energy resources, poor process control, product defects, storage of wastes, and so on. Poor resource productivity also causes the costs of waste disposal and regulatory penalties.

Ultimately resource efficiency will be a factor in national competitiveness, not just the ability of individual companies to compete. A country's products will have to meet stand-

ards imposed by the more advanced countries. The challenge is creating policies and organizations for managing resources with very high efficiency. These policies should eliminate subsidies for raw materials, provide incentives to encourage resource efficiency and recovery of materials and energy, and put disincentives on the disposal of materials as waste. Policy need to encourage full development of resource recovery systems and phase out the dependence on landfills and incinerators.

(3) Incentives

A key instrument of policy is the creation of incentives for eco-industrial park developers, for park managers, and for tenants in eco-industrial parks. This is a form of industrial development that seeks environmental, economic, and social benefits. Public sector should compensate for these benefits by taking measures that reduce the risks and costs of development.

Some of these incentives are as follows:

- Participation by national agencies in public private partnerships supporting eco-industrial park development.
- Creation of revolving loans, grant, and subsidies for environmental investments.
- Incentives for the use of clean technologies and resource efficiency.
- Streaming and integrating of permitting processes.
- Preferences in government procurement for eco- industrial park members with excellent environmental performance.

- Facilitation of financing available for reductions in greenhouse gas emissions and other global environmental issues.
- Research and development to support the clustering of environmental industries.
- Reduction of subsidies rewarding over-consumption of limited resources.

Most medium and small scale manufacturers cannot afford to install pollution control equipment. Therefore, the government needs to subsidize pollution control treatment facilities in industrial parks. Industrial facilities may take a 100% depreciation allowance on devices and systems installed for minimizing pollution or for conservation of natural resources.

In order to encourage industries to move away from congested urban areas, the government should provide tax exemptions on capital gains arising from the transfer of used lands or buildings. This incentive could be used to encourage participants to join eco-industrial parks. Value added tax credit can be extended to manufacturers of pollution control equipment. Donations given to any association or institution for programs on conservation of nature and natural resources could also be tax exempt. Government can offer not just incentives, but also concessions and fast-track approvals for eco-friendly projects.

(4) Research Partnership

The emerging sustainable economy provides opportunities for developing areas to be players in environmental and energy technologies. Several clusters for eco-industrial park recruitment

include renewable energy, resource recovery, green chemistry, and support to sustainable farming. All will benefit from research support.

R&D policy makers should work closely with business and university communities to create an eco-industrial research agenda. Industrial ecology provides the framework for researching technologies needed to achieve key environmental objectives in an economically feasible way. Government support to technological development needs to be guided by awareness of the potential synergies among separate lines of inquiry. Analysis of the flows of energy, water, and materials could support the establishment of eco-industrial networks and the operation of eco-industrial parks. Industrial metabolism is the branch of industrial ecology that studies the inter-linked natural and human systems as a network of resource flows. Such studies enable regional stakeholders to identify critical threats to human and ecosystem health and to pinpoint strategic points for intervention. Given basic policies seeking to optimize resource utilization, such studies can also be used to identify significant business opportunities.

Studies of resource flows in the national economy are also important in setting sustainable resource policy. To develop this systems approach to technology policy and research requires partnering with international aid organizations, overseas universities, and regional research institutes.

(5) The Role of Government

Eco-industrial development uses ecological models to understand how social, economic and environmental systems influence

production. Government policies are a critical component of this network of forces influencing economic and industrial processes. Policy decisions affect the investment, design, production, the consumption patterns of individuals and the spatial patterns of community development. Aligning government policies and programs to promote efficient use of materials and human resources is important. Therefore, understanding the role of public policies and institutions is essential to designing eco-industrial systems.

Government has an invaluable role to play in every phase of eco-industrial development. Public institutions at all levels function as important stakeholders in maximizing public value from investments in production. Clean production and pollution prevention are oftencenterpieces of eco-industrial development, but the policy issues involved are clearly much broader. Regulatory enforcement, appropriate incentives and public access to information all play critical roles in eco-industrial development. Use of flexible regulatory tools that encourage innovation and continuous pollution reductions is desirable. To promote eco-industrial development, the government should lay the policy foundation that will permit system-based approaches to regional economic development.

□ Correcting Market Failures

○ Internalizing environmental externalities through regulation and enforcement

Environmental laws, regulations and enforcement establish a baseline of environmental performance that is needed to

protect the environment. Public policy choices are directly tied to production costs and thus to companies' motivation to minimize waste through recycling and reuse, environmental management systems and other areas of eco-industrial development. Many environmental laws also arise from public mandates to protect public health.

However, reliance on environmental regulations that specify the type of technology to be used rather than allowing firms the flexibility to meet emissions or effluents standards can also impede innovation. Where regulations specify safe pollution levels but grant producers the freedom to meet those thresholds through a variety of cost-effective means, development and diffusion of new technologies is greatly encouraged and the economic burden associated with regulation is minimized. The comprehensive yet adaptable performance-based management strategies advocated by eco-industrial development can improve industrial performance but also can offer insights into improving the process and performance of regulation.

○ Creating and expanding markets

Recycling and re-use of materials are often impeded because there is no efficient way for buyers and sellers of recyclables and waste to find each other. In other words, there are very limited markets for many types of wastes. Government procurement policies can create markets for some recyclables. The market demand created by government preferential procurement policies can allow new economies of scale to be realized, lowering prices and making recyclables

more competitive to private sector purchasers.

Another type of market can also be created. It does not facilitate trading in the waste product itself as a raw material but it allows the sale of a portion of the reduction in pollution levels. Firms that reduce their air pollution to levels below the permitted level gain air emission credits, which may be sold or traded to other companies. Thus the enhanced resource efficiency of eco-industrial development can become a source of income, whereas less efficient producers must pay additional costs for their right to pollute. Pollution charges are particularly useful in reducing pollution that is not subject to regulation.

Eco-industrial networks may reduce their disposal charges, saving costs and leading to lower prices for goods and services than non-networked companies. Without such policies, firms and individuals will see no rewardfor changing behavior, and the costs will be distributed inequitably, regardless of performance. Even small pollution charges can motivate companies to decrease pollution if the resultant reduction in levels reduces their operating costs.

□ Providing public goods

Public goods are necessary economic goods and public services that are available to everyone without restriction or qualification. These products and services benefit a large segment of the public and often require large upfront investments. These public goods include highway construction, public education, information systems and public health.

Eco-industrial developments create opportunities for private entities to come together to create shared solutions to common problems on matters of collective interest. By devising shared institutional arrangements, collective investments in mutual gains become possible. Public-private partnerships are becoming increasingly important tools for governments, developers and industry as they try to coordinate their activities to make development more responsive.

○ Education, training and research

Education and training are public goods because their value to society as a whole far exceeds the benefit that is earned by individuals. With increasing global competition, the costs of providing skill development and career advancement becomes a burden to firms. This disinvestment from the capacity of the workforce can be sustained over the short term, but in the long run it represents a drain on the competitiveness of the industrial base.

As a result, government tries to ensure that less-skilled workers have access to training and opportunities for career advancement. Eco-industrial development is positioned to develop the institutional capacity with community-based educational and research institutions and to support the creation of sustainable wage jobs in growing industries.

Similarly, investments in research will not be undertaken at sufficient levels without public investment. Much of the basic research is government-funded. Applied research and commercialization of experimental technologies are further areas for potential public-private collaboration through eco-industrial

development.

Improving support for efficient and equitable investment in human resources, social capital and education includes the following:

- Protecting workers from production changes toward more efficient methods and from environmental enforcement actions on firms
- Discouraging abandonment strategies by firms toward existing workers, communities and physical infrastructure
- Supporting re-use of current investment in employees, including improved worker training

○ Data and information

Eco-industrial development is a knowledge-based production model that utilizes information on regional inventories, production processes and material and energy flows to add new value to the industrial system. This can require costly collection and analysis of large amounts of data to identify opportunities for material exchanges and energy efficiency. Thus it may be an appropriate government activity to provide access to this public good.

Access to high-quality local data and information management systems are an increasingly critical resource, as businesses should manage production and distribution information in real time. Eco-industrial developments can serve as useful anchors for local data collection and maintenance. The public needs access to information to make better development decisions. The management of industrial environmental per-

formance has been developed through increasing requirements for public reporting and disclosure of information.

Inadequate knowledge of available technology, low levels of environmental awareness and poor enterprise management are often linked to waste and inefficiency. The creation of information centers and the diffusion of new technology via workshops have been strategies used by many governments.

Access to information of all types in production design and decision-making also needs to be improved. Development of core information infrastructure and the use of decision support tools that account for community and environment values are recommended.

(6) Other Policy Options

□ Energy efficiency and renewable resources

Energy systems play a large role in eco-industrial development from the perspective of generation and consumption. By cascading energy flows through multiple uses, one can improve the productivity of each unit of energy consumed and create marketable uses for thermal energy that is currently lost as waste heat.

Design solutions can improve the efficiency of eco-industrial development with strategies such as green buildings and day-lighting, providing cost savings and improved working conditions for employees. Policy decisions regarding energy supply, regulation and pricing can shape the incentives and direction of energy conservation.

□ Pollution prevention and environmental protection

Increased emphasis is placed on voluntary programs in pollution prevention and environmental management systems. It is cost effective and can yield additional benefits in terms of quality of life, worker safety and performance enhancement. Additional environmental policy changes that will support eco-industrial development include the imposition of taxes on pollution and the development of tradable permits. Policies to address global climate change and to reduce greenhouse gas emissions are likely to have apositive effect on eco-industrial development as well, either by encouraging greater energy efficiency or even potentially as a source of revenue through the sale of carbon emission reduction credits.

Programs for the protection of sensitive ecosystems can also be opportunities for partnership or investment funding for eco-industrial development. Because eco-industrial development manages the flow of materials and energy through the industrial metabolism of a firm, it is an ideal strategy for promoting economic development near areas where subtle pollution impacts can have significant impacts on the ecology.

□ Transportation systems and public transport

Transportation systems have a substantial impact on the movement of goods to and from markets and on the planning of infrastructure and other public investment. Industrial facilities need to be closely linked to highway access. Transportation networks can be used as a source of competitive

advantage for regional eco-industrial business clusters. They can also act as an engine for redevelopment by eco-industrial development facilities interested in revitalizing urban communities.

Transportation funds often include resources that can be designated for improving equity, job training and upgrades to public space and pedestrian access.

□ Land use and infrastructure development

Land use decisions are often used as a powerful tool for industrial recruitment along with tax incentives and other favorable treatments. Land use in many ways ties all the other policy areas, as it is the policy framework that organizes activities in particular places where development activity takes place. Zoning can create difficulties for new industrial facilities, but innovative zoning approaches can also be used to favorcleaner industrial development near residential areas or sensitive environments. Brownfield redevelopment involves the reclamation of abandoned and possibly environmentally contaminated land to encourage infill development.

Funding preference to maintenance of the existing physical infrastructure, such as roads and sewer lines, over the creation of new infrastructure in greenfield locations is a good policy. This is an important example of regulatory and budget incentives driving development patterns. Like transportation, public infrastructure investments can heavily subsidize development, and public investments are important for determining industrial location and community development

patterns. Infrastructure development is often a key component of economic development and industrial recruitment strategies.

□ Workforce investment and lifelong learning

Industrial development means jobs, and cleaner production is a better neighborhood. Eco-industrial development is often seen as a strategy for returning a base of industrial jobs to the inner-city and as a potential engine for community revitalization. It has been shown that urban labor and consumer markets are an undervalued and under-utilized resource. The erosion of the industrial base has also undermined the development of career ladders into middle-class professions and skilled crafts.

Eco-industrial development can optimize labor efficiency by emphasizing the development of joint skills training programs. Eco-industrial practitioners consider what types of training and education are available and how partnerships between businesses, educational institutions, and trade associations can meet training needs. By combining training resources, participating firms can reduce their individual workforce development costs.

The particular labor skills required in an eco-industrial park or regional network depend on the types of industries involved. However, joint programs can reduce the training costs of meeting the skills needed. Programs offering tax breaks and other incentives to participating employers can support these efforts.

Investing in the skills of employees and the system of work-

force development are critical elements of eco-industrial strategies. Improving quality and standards for jobs, wages, skill development and workplace safety are key elements of designing industrial systems that maximize the economic vitality of communities.

Building effective training programs to reinvest in the skills of workers and the quality of the labor market can be an effective means of attracting new resources to development efforts. Numerous policies address workforce development as a social program within education policy or as a tool for industrial recruitment.

□ R&D, public-private partnerships

Public investment in R&D is made to reduce the risks of innovation and to ensure that the public benefits from new technologies and business strategies. Such investment can also be a source of capital for economic development. Technology-led economic development is astrategy that combines investments in state-of-the-art infrastructure with establishment of high- technology industries. This strategy has been followed by many regions in their efforts to attract new investment and new tax revenue.

Manufacturing partnerships take this linkage a step further, to ensure that the best available scientific and engineering information is translated rapidly and effectively into improved industrial production practices. This focus on improving the productivity, quality and innovation of private industry through public partnerships is highly compatible with eco-industrial development.

This regional development approach promotes the development of networks of highly interconnected small business and supplies, and it encourages innovation and the development of shared infrastructure and information systems. Because the linkage between public subsidies, private investment and anticipated improvements to the regional economy is explicit in this development strategy, it encourages a basis of public-private partnership that can be very supportive to eco-industrial development approaches.

□ Industrial clustering

Eco-industrial development projects adopt industrial clustering strategies to build more efficient regional ecosystems. Industrial clustering is based on the notion that networks of manufacturers develop cooperative relationship to optimize resources. These clusters evolve from networks of interrelated, geographically concentrated industries and their suppliers and customers.

As the economy continues to shift toward technology-intensive, knowledge-rich, and global industries, clusters of businesses connected geographically develop to become more competitive in the global market. Through this structure, companies both compete and cooperate to make efficient use of human and technological resources to optimize opportunities.

□ Anchor tenant

An eco-industrial park around one or more primary anchor tenants can be established as a way to create a set of pos-

sible inter-connections. The eco-industrial anchor tenant concept is loosely based on the real estate development strategy of using an anchor company to attract other firms to an industrial park or commercial facility.

In the eco-industrial context, the anchor tenant strategy focuses on how an anchor industry can provide significant waste streams to satellite firms that can utilize the wastes in their own production processes. The types of anchor tenant and its byproducts therefore become a comparative advantage for attracting industries.

□ Information infrastructure, community process and civic engagement

Investment in core information infrastructure and regional information management capacity will benefit private business with more targeted industrial recruitment and resource management strategies. Local government and other stakeholders will also benefit thorough better use of location-specific information in public management. They will provide opportunities for citizens to make real choices about the direction in which economic development that will lead their community and their region.

In the rapidly globalizinginformation-based economy, knowledge is a vital resource that must be managed if communities are to preserve their individual character while benefiting from increased opportunities. Information infrastructure forms a critical link between education, physical infrastructure and institutional capacity. Eco-industrial development can form a

bridge in channeling private and public investment into a coordinated and broadly usable resource.

Eco-industrial developers adopt community based planning tools to buildrelationships and inform others of their planning efforts. To build these linkages, eco-industrial practitioners use a number of participatory tools, including participatory action research, search conferences, community visioning workshops, design charities, and surveys, interviews, and focus group discussions. The main function of these activities is to provide mechanisms for stakeholders to share their concerns, interests, and ideas for optimizing community assets and overcoming challenges.

Development plans incorporate these views in ways that both strengthen the outcomes and build public acceptance. Public and private partnerships sometimes require an external agent to catalyze the process of coming together, and so external consultants are often hired to facilitate and synthesize information.

Developing eco-industrial systems has often served as the initiation of a dialogue that builds much wider trust and civic engagement. The physical establishment of eco-industrial parks provides a home for expanding partnerships, restoring the workplace to the centre of civic and community life and offering common ground for communities, business and government to come together and advance their collective interest in building real prosperity.

Ⅶ. Concluding Remarks

Concepts such as sustainable development and ecological modernization have become commonplace in development policy, emphasizing the need to integrate economic, social and environmental aspects. Unlike conventional industrial park development, pursuing maximum economic profits without concerns on environmental preservation, resources consumption reduction and community development, eco- industrial development is a new planning and design strategy towards economic, social and environmental sustainable development.

Eco-industrial development integrates a number of tools and strategies focusing on the design of production processes, products, and physical space like building and landscape, in a way that increases resource efficiency, lowers cost, and mitigates environmental impact. Other strategies emphasize building business-to-business and business-to-community linkages on local and regional scales to facilitate exchange of materials, infrastructure, information, services, energy, water, natural habitat, and other resources. The goal of each of these diverse strategies is to optimize resource efficiency among the collective industries of a park or region and to minimize environmental impact by changingeither the way goods and services are produced or products themselves. The eco-industrial development initiatives are seen not just as a means of increasing the eco-efficiency of participating firms,

but also as a basis of for a new form of local and regional development.

Eco-industrial parks are an example of attempts to apply the principles of industrial ecology in specific locations. Eco-industrial parks adopt environmental management systems to address potential and existing environmental impacts of industrial activities. The park preserves natural and cultural resources, protects habitat and water quality and eliminates waste and pollution. It also maximizes efficient use of resources through industrial symbiosis and eco-industrial networks in which the by-products of one industrial process would serve as raw material for another within the park or the region.

The conceptual model of the eco-industrial park comprises of four parts: the structure of the industrial ecosystem, the classification of the enterprises, mass and energy flows in this industrial ecosystem, and types of interactions between enterprises. The classification of the enterprises as well as the analysis of the mass and energy flows indicate that the diversity of the enterprise in eco-industrial parks is desired. Designing an industrial park as an eco-friendly and self-contained systems is necessary. There is a need to change the current flow systems of many resources, such as land, air, energy, foods and materials, into self-contained systems. The minimum condition required for establishing eco-industrial parks is that at least one industrial producer or decomposer must be involved in the eco-industrial park in order to create the symbiotic interactions between the enterprises within. Establishing a set of effective symbiotic

network of industries, including energy efficient material acquisition, production, distribution and pollution treatment network is essential.

The idea of eco-industrial development and eco-industrial parks is not yetat a full-fledged stage of development. Developers and park managers like the concept, making all and everything eco-industrial. In many places, merely talking about the concept or making a development plan transforms an ordinary industrial park into an eco-industrial park, without any discernable change in the park or tenants. The eco-industrial parks and networks themselves need to generate successes in order to build understanding of this approach among the business community, economic development practitioners, agencies, and communities. Continued research into regulatory, financial, technological, social, and other concerns will inform implementation of eco-industrial strategies and help develop methods for lowering risks and optimizing opportunities.

Eco-industrial development presents a gate to a better future. For business, eco-industrial development offers new avenues for profitable companies. For communities, eco-industrial options lead to good jobs and a cleaner environment. For local and global ecosystems, eco-industrialism promises a lighter load on the environment. Eco-industrialism doesn't solve all environmental or business challenges but instead deploys a systemic scan at multiple levels to find best possible solutions.

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