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STUDY ON COMPARISON OF ECO-INDUSTRIAL PARKS IN JAPAN, CHINA AND KOREA

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Abstract

Over the past decades, the development of integrated economic, social and environmental benefits in the eco-industrial park (EIP) has been achieved almost everywhere. A number of Asian countries have carried out formal EIP projects or initiatives. This paper attempts an international comparison of EIP in Japan, China and Korea on both the national level and the EIP level. Through analysis of information about the scale, background, policy, effects and experience of EIPs collected by researchers from these three countries, features of progress of EIP in different countries with different policy systems and backgrounds emerge.

KEYWORDS: *eco-industrial park(EIP), comparison, Japan, China, Korea*

1. Introduction

In recent years, eco-industrial park (EIP) development projects have gained considerable attention in many countries. EIP is consistent with the notion of cleaner production, circular economy and industrial ecology. It is believed that a well-planned, functioning EIP has the potential to both benefit the economy and substantially relieve environmental pressure in and near the location of its development. (Cote R., 1995; Lowe E., 2001; Martin S.A., 1998)

Over the past decades, the development of integrated economic, social and environmental benefits in the EIP has been achieved almost everywhere (Ehrenfeld J., 1997). In order to promote the

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development of EIP in Asia and analyze the experience in different countries, this paper makes an international comparison of EIP in Japan, China and Korea especially considering the aspects of establishment process and outcomes at national and industrial park level. There are many differences in the management and operation systems of the EIPs among the three countries. Detailed information concerning the processes and main outcomes in the three countries is given and analyzed. Through comparison, this paper offers conclusions about the common success factors and the deficiencies in each country and also conclusions about the experience could help the development of EIP with each other.

2. Background

2.1 Development of EIP in Asia

Over the past decades, the development to integrate economic, social and environmental benefits in the EIP in Asia has been made almost everywhere. Drawing largely upon concepts of industrial ecology and/or cleaner production, EIP seeks to increase business competitiveness, reduce waste and pollution and create improved living and working conditions. EIP has attracted great attentions in many countries for its ecological and environmental efficiency (Ayres R.U., 1996).

A number of Asian countries have developed formal EIP projects or initiatives. In Thailand, the Industrial Estate Authority of Thailand (IEAT) in collaboration with the Germany Technical Cooperation (GTZ) implemented the Development of Eco-Industrial Estates and Networks (DEE+Net) project, with strong international exposure such as the Map Ta Phut industrial park in Rayong. Five of the 29 existing industrial estates have been selected as pilot project sites. Each demonstrates a different aspect of eco-industrial estate development and is implementing at least one important Eco-Industrial Support System (EISS). Funded by the United Nations Development Program (UNDP), in Philippines, the Private Sector's Participation in Managing the Environment (PRIME) project envisions the strengthening of the role of the private sector in environmental management to complement government regulatory mechanisms. The PRIME Project is comprised of four modules: Agenda 21 for Business, Industrial Ecology, Environmental Management Systems, and Environmental Entrepreneurship. Each module has its own mission and key players including staff members seek opportunities for synergy among the modules. Industrial parks in Viet Nam have started to adopt the concept of industrial ecology, which advocates environmental protection through the recycling of materials and waste treatment.

2.2 Progress in comparative research on EIPs

Although the progress of EIP all over the world has grown rapidly and there are many papers in various languages introducing EIPs in every country, there is little research offering international comparisons of EIPs. (Deng N.S., 2001; Geng Y., 2003; Roberts B.H., 2004; Tsuyoshi FUJITA, 2004)

Only a few researchers have made some primary comparisons. For example, R.R.Heeres, W.J.V.Vermeulen and F.B.de Walle published a paper to introduce the EIP initiatives in the USA and

the Netherlands and chose six parks as case study to make the comparison at EIP level (R.R. Heeres, 2004). Another researcher in this field is Rene van Berkel, one of whose reports made a comparative analysis on synergy projects, mainly on heavy industry all over the world (Rene van Berkel., 2006). In addition, Anthony S.F. Chiu and Geng Yong published a paper about the industrial ecology potential in Asian Developing Countries (ADCs), and also analyzed the common SWOT faced by ADCs (Anthony S.F. Chiu, 2004). There are also other researchers working on the international or national comparison of EIPs (Zhao R.X., 2003). All these efforts might be considered the fledgling efforts of the international comparison research on EIP. But most of these papers just made primary comparison between the parks. Even if the authors tried to make comparison between counties, they just listed the basic information of the progress of EIP in these countries. This paper attempts to do a comparison of EIP both between countries and parks, and more comprehensive and detailed information of the development of EIP in these countries has been collected and analyzed, based on the existing work of all the authors of this paper, who come from the three countries involved.

3. National-level comparison of EIP in Japan, China and Korea

3.1 Basic information of the progress of EIP in each country

First, we will offer a brief overview of the progress of EIPs in these three Asian countries, making comparisons among the three countries at the national level.

3.1.1 EIP in Japan

In 1997, the Japanese government approved a Zero-Emission project to reduce waste from Japanese household and industrial activities by using waste as resources for neighboring industries. This project is called "Eco-town" in Japan, rather than EIP. Eco-towns in Japan originated through a subsidy system established by the Ministry of Economy, Trade and Industry in Japan (METI) and the Ministry of Environment in Japan (MoE) and currently 26 Eco-towns are in operation. The central government hopes to reduce Japan's demand for imported resources and realize zero-emission and create benefits for local residents and businesses. (Global Environment Centre Foundation, 2005)

3.1.2 EIP in China

China has maintained rapid economic growth over 20 years, which has caused heavy environmental burdens and severe resources issues. Central government and many scholars in China have suggested developing eco-industrial parks as a strategic approach to transforming the economic growth model, to implement Scientific Concept of Development and to achieve harmony between human beings and nature.

In China, it is the State Environmental Protection Administration (SEPA) that is in charge of the nomination and management of National Eco-industrial Demo-Parks (NEIDP). SEPA started the pilot work of eco-industrial parks in 1999, and approved the first NEIDP (Guigang sugar NEIDP) construction plan in 2001. Up to now, SEPA has approved 26 NEIDPs, and provincial EIPs are even more numerous.

3.1.3 EIP in Korea

In 2003, Korea launched an eco-industrial park initiative with the help of the Korean National Cleaner Production Center (KNCPC). It targeted the Korean EIP establishment for infrastructure of Cleaner Production with the support of the Ministry of Commerce, Industry, and Energy (MOCIE). EIP development consists of three phases, and each implementing phase requires five years. Based on the successful experiences during Phase I and II, the construction of two newly designed eco-industrial parks is scheduled in Phase III. Currently, five EIP centers as well as the KNCPC play an important role in realizing their objectives of transition to EIPs through a variety of strategies and tools with the help of a number of academic experts supporting the individual projects. Also, the centers are trying to link cleaner production and industrial ecology, seeking a comprehensive approach to improving environmental, social, and economic performance in Korean industry. Success in implementing this approach will have profound implications for competitiveness of the industrial park and the Korean economy.

3.2 Comparison of the three countries

Information concerning the development of EIPs in the three countries is listed in Table 1. Some items in the table are interpreted below (Huang K., 2003).

- Number: number of pilot projects in the EIP (Eco-town) initiative in the country
- Geographical distribution: location of each EIP (Eco-town) on the map of the country
- Type: popular classification of the EIP (Eco-town) in the country
- Background: the political, social, economic and technical background of the initiating of the EIP (Eco-town)
- Administration agency: administrative organization in charge of the establishment, ratification, policy-making and standard of progress of EIP (Eco-town) on the national level
- Incentive mechanisms: economic or other favorable policies provided by the government to promote the progress of EIP (Eco-town)

3.3 Discussion

Every country has its own background for the development of EIP (Eco-town), but one factor is shared by all, the resource crisis. The energy and resource issue around the global brought out concerns about the pattern of energy resource utilization, and thus the importance of the recycling of energy and resources emerged.

From the initiating of EIP (Eco-town), all the three countries encourage its progress by economic incentive mechanisms, though they are different in method and intensity.

Compared to efforts in Japan and Korea, the promotional efforts of the government, especially the central government, for the construction and development of EIPs has been more prominent and more fundamental in China. Also, China has created a better legislation and standards system than others to guide the progress of EIP, but the practicability needs to be tested and enhanced.

The participation of the public is more thorough in Japan, which make the awareness concerning

EIP (Eco-town) broader and more intelligible.

Lack of practical technology (including cleaner production technology, pollution control and abatement technology, waste reuse and recycle technology, EIP planning and assessment technology, etc.) is one of the most pressing problems in EIP development in China (Wan J.A, 2005). Furthermore, the whole society's scientific awareness of development and environmental protection must be further raised; especially among enterprisers and officials, and the correlative policies must be more harmonious and more effective. Those policies that hinder EIPs must be modified, such as the lack of an environmental index in achievement testing of governors, low prices of natural resources and pollution discharge fee.

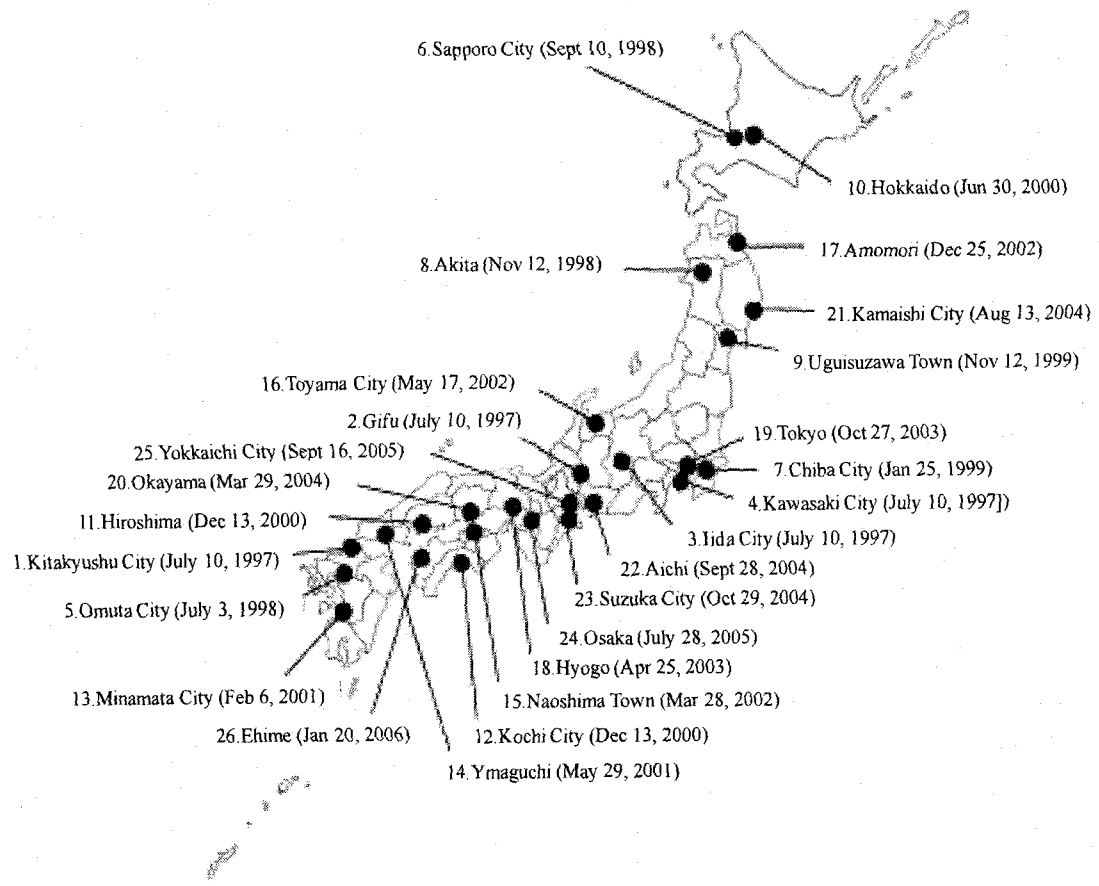

Figure 1. Geographical distribution of Japanese Eco-towns

Table 1. Common information of the development of EIP in the 3 countries*

Primary stage	General information	Number	26	26	5
		Geographical distribution	Figure 1	Figure 2	Figure 3
		Dominant industries	• Material industry • Manufacturing industry • Environmental industry • Venous industry • Steel industry • Chemical industry • Ceramics industry • Automobile industry • Cement industry	• Sugar making • Electrolytic aluminum • Chemical industry • Steel industry • Aluminum oxide • Mineral resource utilization • High & New Tech industry • Environmental Protection Industry • Venous industry	• Oil refining • Motors • Shipbuilding • Petrochemical • Primary metal • Machinery • Semiconductor
		Type	• Revival of the existing enterprise • Cluster of venous industry • Community type	• Sector-specific • Sector-integrated • Venous Industry	• Sector-specific • Sector-integrated
	Establish-ment	Initiating time	1997	1999	2003
		Background	• Consciousness of the problems caused by mass production and mass consumption • Based on environmental symbiosis, growth of economic importance • Because of challenge of industrial establishment and scarcity of waste disposal sites, zero-emission system was considered important	• The strategy for industrial pollution control be shift from end-of-pipe treatment to total-process control • Implementation of cleaner production • Promotion of the eco-industry as an approach to regional environmental pollution integrated control • Rapid and extensive economic growth caused heavy environmental burdens and severe resource issues	• Sustainable development of industrial complexes • Co-existence of nature and human beings (Industrial complexes) • Realization of cleaner production and zero-emission through material and energy circulation and minimization of resource use
		Administrative agency	Ministry of the Environment (MOE) Ministry of Economy, Trade and Industry (METI)	State Environmental Protection Administration (SEPA)	Korean National Cleaner Production Center (KNCPC) / Korea Industrial Complex Corp. (KICOX) **

	Operation and management	Incentive mechanisms		• Software and hardware subsidies, but software subsidies stopped in 2006, hardware subsidies stopped in 2005	• Tax, price, loan, and charge mechanism • Other incentive mechanisms related to land and honor	• Tax abatement • Land grants
		Laws and regulations	direct	No information available	• Regulation for application, nomination and management National Eco-industrial Demo-Parks (on trial), SEPA, 2003.12.31 • Guidance for Eco-industrial Parks Planning (on trial), SEPA, 2003.12.31	No information available
			related	• Law for the Promotion of Effective Utilization of Resources • Container and Packaging Recycling Law • Home Appliance Recycling Law • Construction Material Recycling Law • Food Recycling Law • End-of-Life Vehicle Recycling Law	• Regulation for application, appointment and management Circular Economy Demo-zones (on trial) • Guidance for Circular Economy Demonstrate Area Planning (on trial) • National Demo-zone for ISO14000 managing method	• Act of site selection and development of industrial complex • Act of environment management within the industrial complex • Act of Industry structure in the industrial complex • Act of (solid) waste disposal in the industrial complex
		Standard	direct	No information available	• Standard for Sector –integrate Eco-industrial Parks (on trial) 2006.9.1 • Standard for Sector-specific Eco-industrial Parks (on trial) 2006.9.1 • Standard for Venous Industry Based Eco-industrial Parks (on trial) 2006.9.1	No information available
			related	No information available	11 cleaner production industry standards	No information available
		Public participation		• Public support of Eco-town • Lots of recycling support for collecting resource • Information concerning Eco-town is provided for environmental education	• The public can participate in the process of EIA and planning of an EIP • The public, stakeholders and experts are entitled to get the basic information of the EIP and put forward their ideas and request	• Keep pace with EIP, resolve the civil appeal and find how to improve the regional economy

	Effects	Economic effects	• Eco-towns create new businesses and new jobs.	• Increase in the production and income, and local development promotion.	• Improved corporate images • Increased competitiveness via reduction in production costs • Contribution to the regional economy
		Social effects	• Formation of communities (e.g.Minamata) • Promotion of environmental activities. (e.g. education)	• Increased social awareness of environmental protection and sustainable development	• EIP co-exist with the community • Pleasant living environments
		Environmental effects	• Eco-towns cut down waste generation and CO_2 exhausts • Zero-emission system constructed • Eco-town establishes connection with other companies for promotion of environmental techniques	• Deceases in pollution and resources exhausted per product and increases in actions of environmental protection • Increased infrastructure for environment protection	• Establishment of cleaner production systems • Zero-emissions through resource recycling • Harmony between the natural system and industrial system
Later stage	Success factors		• Government support (e.g. subsidies) and promotion of environmental techniques and social systems	• Central government and local governments attach importance to the construction of EIPs and promote them	• Spontaneous involvement of companies • Government support to EIP • Establishment of information system for industrial symbiosis
	Problem areas		• More exchange companies needed • Laws and regulations for securing regular resources	• Lack of practical technology • Greater social awareness of environmental protection needed • Better coordination and more effective policies needed • the whole society's consciousness of environmental protection should be further raised and the correlative policies should be more harmonious and more effective	• Lack of incentive system • Transparent data from companies needed • Enactment of EIP code required • Lack of EIP experts

* This table is composed by authors of this paper based on the information collected through investigation and hearing.

** Korea EIP is administrated by KNCPC before Nov. 2005, and then the administrative right is transferred to KICOX.

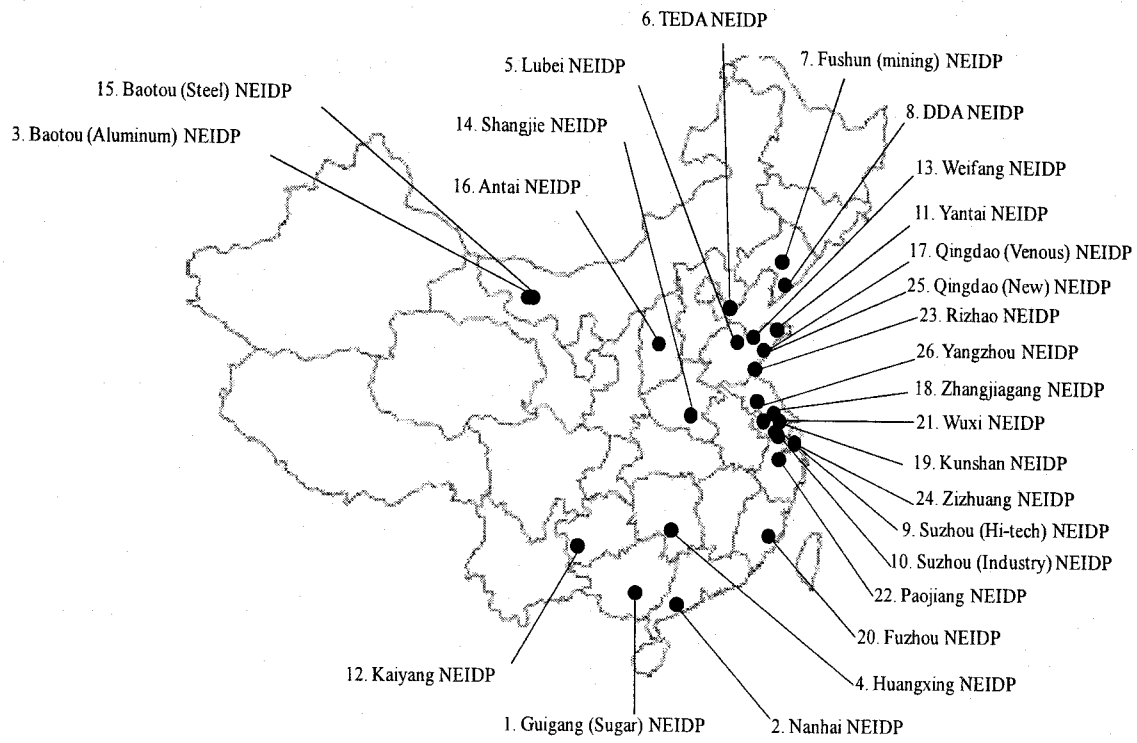

Figure 2. Geographical distribution of Chinese EIPs

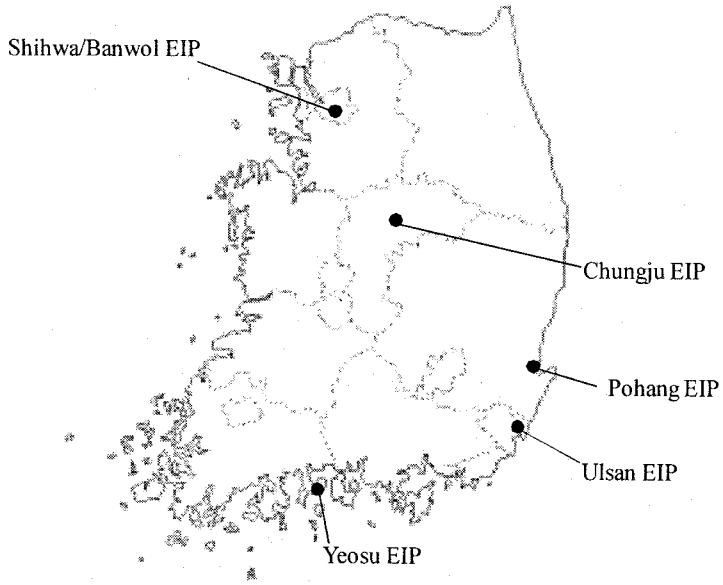

Figure 3. Geographical distribution of Korean EIPs

4. Comparison of six EIPs in three countries

To illustrate in a more specific way of the progress of EIP (Eco-town) in the three countries, we chose six parks from the three countries to make comparisons on the park level. All the six parks are pioneers in the practice of industrial ecology and can be considered as successful models in their own countries.

4.1 Brief introduction of the 6 EIPs

■ Kitakyushu Eco-town

Kitakyushu Eco-town was the first Eco-town in Japan, approved as an Eco-town Project by the government in 1997. The Eco-town Center, Hibiki Recycling Complex and the Comprehensive Environmental Complex were at first the only targeted areas of the Eco-town Project. Kitakyushu City then applied for a change in their Eco-town plan so that the area could be expanded into the whole Hibikinada area (2000 ha) in 2002, and into the whole Kitakyushu City (48,500ha) in 2004. The expansion was intended to attract new recycling businesses and incorporate existing industries.

Kitakyushu Eco-town aims to be "Asia's International Resource-Recycling and Environmental Industry Base City." The "venous industry" had been clustered as a unique regional development measure to integrate environmental conservation with industrial promotion in the first phase of the plan (1997~2002). Kitakyushu City formulated the second phase of the Eco-town Plan in 2002. The city has given priority to the following points: to enrich the experimental study areas, to invite reuse and rebuild industries, to strengthen capacity building, to develop the businesses based on the existing infrastructures, and to create next-generation environmental industries with new energy technologies and nanotechnologies.

■ Kawasaki Eco-town

Kawasaki Eco-town was approved in 1997, also as one of the first Eco-towns in Japan. Five facilities have been approved as Eco-town hardware projects. In addition, several recycling facilities have been set up, such as home appliances recycling facility and cement manufacturing with recycling processes.

Kawasaki Eco-town Plan targets an area broadly defined to include almost the entire stretch of the Kawasaki coastal area, and aims at creating a sound material-cycle society, and aims also at revitalizing the coastal area. This concept envisions that the industrial companies that will be located in the area will minimize their operations' impact on the environment. More specifically, to concretize the concept, it intends to develop a zero-emission industrial park. The individual companies within the industrial park not only will reduce their own emissions, but will also effectively utilize or recycle the emissions from other facilities located there into usable resources. Other recycling facilities will also be built around the industrial park in order to promote cooperation, in terms of resource recycling with the existing companies.

■ Tianjin Economic and Technological Development Area (TEDA)

The establishment of TEDA was approved by government on December 6, 1984. As one of the country's first state-class development areas, TEDA has developed into one of the country's most influential hotbeds for high-tech and new industries. But TEDA has a more ambitious goal for the new century: to build "Asia's biggest and China's best modern industrial area in the 21st century". To

make that dream come true, TEDA has embarked upon another arduous pioneering journey and jump-started diverse projects zeroing in on a better investment environment, cityscape and habitability of this young urban area.

TEDA runs four pillar industries: the electronics communications industry represented by Motorola, GS, Samsung, Hyundai and LG, the biomedicine industry represented by Novo Nordisk and SmithKline Beecham, the machinery manufacturing industry represented by Toyota and Volkswagen, and the food and beverage industry represented by Tinghsin Group, Coca Cola and Pepsi Cola.

TEDA's prime geographic location, vast expanses of land and big investments in infrastructure have combined to guarantee a sustained economic growth. It's been long since TEDA has had in place a fully developed market mechanism supported by a sound legal system, policy framework and transparent and supportive government. By attracting outside investments, TEDA has developed into one of the country's most influential hotbeds for high-tech and new industries.

■ Dalian Economic and Technologic Development Area (DDA)

DDA is located on the Dagu Mountain peninsula, in Dalian City of Liaoning Province of northeastern China. DDA is also one of the first state-level economic and technological development zones established in 1984 by the State Council, and it is also one of the development areas which has urbanization characteristic, great influence and economic strength. The Dalian Municipal People's Government established a Management Committee in the zone to provide unified leadership and management on behalf of the Dalian Municipal Government In April 2004, SEPA approved the DDA as a 'National Eco-industrial Demonstrate Park'.

At present, the area of DDA is 56km^2 and it is divided into nine functional districts: industrial district, commercial district, commercial centre area, port and logistics district, ecological agriculture district, settlements district, tourism and entertainment district, research and education district and public facilities district. It has gained great ecological, economic and social benefits from important eco-projects, such as: solid waste integrated utilization, regenerated water utilization, galvanization industry, fly ash utilization, domestic refuse sorting and recycling for gas, compound material production from waste timber and plastic, waste paper utilization, industrial byproduct recycling, materials reclamation and recycling and so on.

■ Ulsan Eco-Industrial Park (UEIP)

Beginning in 2005, Ulsan EIP, under the leadership of Prof. Hung-Suk Park from the University of Ulsan, has developed to facilitate the implementation of EIP, resulting in enhancing business performance and improving environmental quality for businesses, individuals and organizations located in Ulsan/Mipo Onsan national industrial complex (Hung Suck Park., 2006). In this context, the current projects are about process diagnosis and assessment, environment management, training, and disseminating the development results. Also the center is involved in developing long-term eco-friendly business strategies and planning to increase their global competitiveness by taking proactive measures to comply with the international environmental standards and regulations.

In particular, the UEIP Center is focusing on the establishment of an information database system for industrial symbiosis on materials, by-product and wastes. Currently, the center is carrying out seven projects with the help of various academic experts from universities and companies, and more than eleven companies and nine affiliations including the city of Ulsan are involved in establishing

the Ulsan EIP. The UEIP Center is taking the lead in designing and providing economic, environmental and social benefits called triple bottoms to the companies within the industrial complex and nearby communities in Korea.

■ Yeosu EIP

Yoesu EIP has had a great effect on the national and local economy with production of 26,375 million USD and export of 6191 million USD. 1437 companies are in operation near the city of Yeosu, and their employee number 18,767. Above all, Yeosu EIP has a good geographic location because it is close to the Gwangyang Bay.

The Yeosu industrial complex is ready to transfer to EIP. It is also expected that the effect is also very big in the pilot complex that makes network and exchanges the material and the energy. The most important task of the Yeosu EIP is to set up an effective and practical plan for its 5-year pilot project. For this purpose, detailed data concerning raw materials, products and by-products, energy, and process/waste water are being collected; exchange networks for by-products, energy, and water are being planned; and implementation methods are being discussed to make the plans applicable. The final goals are the establishment of an ideal EIP with maximization of resources use and reduction of pollution.

4.2 Comparison of the six EIPs

Here we have collected comparative information concerning the development of these six parks, including 22 items of comparison (Yuan J.L., 2003). A brief presentation of information about the six EIPs in the three countries is provided in Table 2.

4.3 Discussion

The emphasis on promoting the development of EIP varies. For example TEDA and DDZ EIPs developed some special projects to promote the development of EIP, such as solid waste management and water resource integrative management. But in Korea the two EIPs target an information exchange system and then use it to achieve by-product exchange.

The status of government participation varies. In China, EIPs are so big that, generally, every park has its own separate governing agency (often called the management committee of development area). The government has the dominant influence in the building and implementation of EIPs. In Korea and Japan EIPs are promoted by the government from the beginning, but after stable operation is achieved, the role of the government turns from manager to the supporter.

The measure of management also varies. In China administrative measures are the main tool to manage the EIPs and economic methods are secondary. But in the other two countries the emphasis is the reverse.

During the process of establishment and implementation of every EIP, public participation has been emphasized in different degrees, but, in all EIPs, broader and deeper public participation are required.

The situation of the publicity and communication of the information between enterprises within and beyond the EIPs vary significantly. Ulsan EIP made the paradigm of it, but the park achieved it with hardship and mainly depended on the support from government.

Table 2. Common information of the six EIPs*

Indicators	Kitakyushu Eco-town	Kawasaki Eco-town	TEDA EIP	DDZ EIP	Ulsan EIP	Yeosu EIP
Location	Kitakyushu, Japan	Kawasaki, Japan	Tianjin, China	Dalian, China	Ulsan, Korea	Yeosu, Korea
Initiated time	1997 (enlarge to the whole city in 2004)	1997	2003	2004	2005	2005
Established time	1901	1913	1984	1984	1962	1967
Dominant industries	• Iron and steel industry • Chemical industry • Electrical equipment industry • Energy industry • Venous industry • Biomass industry	• Metal-processing • Paper • Plating • Forging • Stamping enterprises • Venous industry	• Electronics and telecommunications • Machinery and manufacturing • Biomedical industry • Food and beverage	• Modern petrochemical • Communication and electron • Equipment • Machinery • Biopharmaceuticals • New materials	• Non-ferrous metal • Oil-refinery • Petrochemical • Shipbuilding • Motors	• Petrochemicals • Machinery
Type of EIPs	Cluster of venous industry	Recycling business clusters by existing enterprises	Sector-integrated	Sector-integrated	Sector-integrated	Sector-specific
Size	28.6km^2	28km^2	41km^2	56km^2 (planned 388km^2)	63.468km^2	31.3km^2
Companies	7,110	71 (area over 0.9ha)	3518	5203	737	125
Employees	115,358	N/A	288,000	149,700	95,670	12,145
Added Production Value per year	$5,456million	N/A	$8,025million per year	$5,626.25million per year	$46,600million per year	$36,000 million per year
Management department	Kitakyushu Municipal Government, companies, NPO and so on	Companies themselves	Management committee of TEDA	Management committee of the DDA	Korea Industrial Complex Corp (Kicox)	Korean Industrial Complex Corp (Kicox)

Initiative mechanism for EIPs	• Subsidy for environmental technology • National and local government subsidized part of the expense for establishment of institutions within the Eco-towns	• Subsidy for the feasibility study as an software project • Subsidy for 99 percent of the hardware project costs • Kawasaki City provides advanced treatment sewage water	• Development fund and subsidies for circular economy • Interim provisions on construction of waste water treatment company • Interim provisions on using new-style water sources	• ISO 14000 subsidies • Cleaner production auditing Subsidies • Special fund for environmental protection projects • Favorable policies for infrastructure construction projects • Favorable taxes	• Tax abatement • Land grants • ISO 14000 subsidies	• Tax abatement • Land grants
Barriers and obstacles	• High cost of new technology • Networking between companies	• Many SMEs not located in the park are not concerned with Eco-town and its actualities	• Lack of resources and energy is influencing sustainable development of EIP • Weak capabilities for solid waste treatment • Stability of the eco-industrial chain • Weak technological support system	• Difficulty of getting financial support from banks • Hard to import the key technique or attract key companies within a short time	• Reluctance to release information • Policies for waste exchange • Lack of active participation of enterprises	• Hard to analysis material flows because companies keep their own information • Lack of relationships with local residents weaken the participation of local residents • Lack of the EIP experts
Land use intensity	$191 million/km^2	N/A	$225 million/km^2	$100.47 million/km^2	$734 million/km^2	$1,150 million/km^2
Water consumption per year	52.36 million tons/year	N/A	34.46 million tons/year	69.84 million tons/year	246.3 million tons/year	89.79 million tons/year
Energy consumer per year	3.20 million TOE/year	N/A	0.94 million TOE/year	2.29 million TOE/year	17.4 million TOE/year	4.34 million TOE/year
Solid Waste generation per year	303,891 tons/year	N/A	0.20 million tons/year	0.274 million tons/year	3.49 million tons/year	0.125 million tons/year

Technology needed	• Cooperation between companies, government, universities and citizens • Technology for utilization of energy • Production and development of recycling goods	• Clustering of various companies possessing manufacturing technologies • Use waste plastics as fuel for blast furnaces • Recycling of industrial wastes and by-products with high temperature incineration technology	• Waste steel recycling technology • Waste water recycling technology • Electronic waste recycling technology • Regional coagulation of vapor recycling technology • Plumbum waste recycling technology	• Torch gas recycling technology • Waste rubber plastic recycling technology • Electric waste utilization and innocuous treatment • Synthetic ammonia production technology	• Wastewater reuse system for petrochemical industry • Production of bio-resources from industrial waste sludge • Process Diagnosis in Mipo/Onsan EIP • Establishment of an information system for Ulsan EIP	• Process analysis • Optimal EIP network design techniques • Real-time optimization of by-products, wastes, and utilities • Stabilization of biological waste treatment • Reuse of nutrients in high-concentration wastewater for de-nitrogenation processes
Public facilities	• Recycling port • Seaport • Sewage treatment facility • Airport • Electric power generation with refuse incineration • Landfill site • Eco-town center for visitors	• Recycle port • Seaport • Sewage treatment facility • Eco-town center for visitors	• Waste water treatment companies (2) • Reusing water treatment • Desalination • Waste incineration • Gas-fired heat source	• Water supply plants (2) • Water treatment plants (2) • Mid-water recycling plant • Heat and power plants (3) • Dangerous solid waste treatment	• Easy access to seaport, airport and rail • Industrial water supply plant • Wastewater treatment plant • Energy	• Industrial water supply plant • Electric power plants (2) • Harbors (12) • Waste Water Treatment Plants (2) • Waste Treatment Plants (2)
Public participation or cooperation	• Annual environmental events by government NPO, citizen, and company	• The partnership among industry, municipality, academia and citizens was established when citizen representatives joined the "Committee for Revitalizing Kawasaki Costal Area"	• Participation of research institutions • Organizing the environment-protect pioneer and developing environment protect activities	• Waste minimization club • Information placards • Public supervision	• 2 NGOs participate. • Citizen's committee gives advice on decision making. • Green Ulsan 21 plays a role in building an environmentally sound and sustainable community	• Companies (20), expert groups (4), local communities (3) and other groups participate in the management of the park

Communication of information	• Environmental events • Internet, television and magazine resources • Eco Technology Exhibition in Kitakyushu	• Foundation of an NPO to contribute to activating industries and providing solutions for energy and environmental issues by collaboration among stakeholders	• Internet resources for industrial solid waste exchange	• Establishment of an information forum • Companies upload their information to the database for other companies to read with allowance in some extent	• Establishment of database for information sharing • The database includes data about by-products, waste and utility information	• A brochure about Yeosu EIP has been made and distributed and internet homepage are provided • Publicity efforts for the national EIP pilot project including Yeosu EIP through mass media
Factors essential to success	• Cooperation of industry, government and citizens • Effective industrial infrastructure • Technology and experience, and abilities in overcoming pollution • Networking among industry and academia and government • Networking of a series of companies and utilization of by-products	• A basis for cleaner and safer technologies • Strong awareness of the public and administration • Public-private partnerships	• Regulating industrial structure • Introduction of projects to promote waste recycling • Exerting dominant functions of government • Developing environmental education and promoting public participation	• Integrated management among the water, energy and solid waste • The Dongtai waste treatment company's important role • Government investment in the infrastructure • Foreign investments and advanced cleaner production technologies • Collaboration with the experts and NGOs	• Cooperation among the national agencies • A long-term vision of the whole system • Cooperation between management authorities and business associations • Strong support for environmental technology • Policy in support of the EIP initiative	• Enhanced exchange concerning emissions between companies • Cooperation between companies and local areas for the synergy effects
Factors causing problems or failure	• Lack of transmission of information • Demand of new industrial technology • Scarcity of sound plan of Eco-town	• Citizens and NGOs are not fully involved with Eco-town Projects • Companies should actively hold site-tours and other events to promote information disclosure and opinion-exchange with citizens and NGOs	• The ability of solid waste treatment is weakness • Unstable of eco-industrial chain • The support system of technology is weakness	• Incompact cooperation and unstable chains among enterprises • Lack of policies for waste exchanges among the industrial parks • Outdated management measures and technologies • Weakness on audit	• False or inaccurate data • Lack of systemic approach • Old facilities	• Lack of support for SMEs • Lack of environmental experts • Old facilities • Expensive labor • Time delays in constructing facilities • Public grievance

* All the data in this table are based on the information collected up to now. The data for Kitakyushu Eco-town indicate the whole Hibikinada area, and the data for Kawasaki Eco-town indicates Kawasaki coastal area.

* This table is composed by authors of this paper based on the information collected through investigation and hearing.

To promote the progress of EIPs, feasible and detailed standards are very important.

All the EIP face the same problems such as openness of information, scarcity of concrete technological support from governments and know-how concerning the establishment and development of EIPs.

5. Conclusions

As an effective economic and environmental win-win strategy, the EIP concept is now under serious consideration by authorities and communities in Asia and around the world. But with different polity systems and different development backgrounds and processes, the situation of the EIP exhibit great diversity. Research offering international comparison of EIP is just in the exploration stage but pioneer.

From the comparison of the development of EIPs (Eco-towns) among the three Asian countries and among the six parks in these three countries, we could conclude that:

1) The origins of development of industry ecology are different in these countries, but they all consider EIPs as a potential notion to resolve the growing resource crisis;

2) To promote the development of EIPs, government support is very important and helpful;

3) Implementation of industrial ecology could bring the park benefit not only on environmental aspect but also economic and social aspects;

4) Establishing an effective communication system in the park is necessary for sharing information and technology;

5) The current situations in the development of EIPs in Asian countries vary greatly, but the barriers and problems encountered are nearly the same. It is very difficult to find one solution to a problem suitable for all countries. Every country-even every EIP-should look for its own way, but cooperation and communication are surely significant and helpful.

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