PROGRESS OF INDUSTRIAL SYMBIOSIS AND ECO-INDUSTRIAL PARKS IN CHINA AND INTERNATIONAL COMPARISONS

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In this paper, the policy and practice's development of circular economy in China is introduced. Up to now, SEPA has ratified five sorts of model-parks. The status of every sort of park is reviewed. Moreover, detailed information of all the sixteen national eco-industrial demo-parks by now is collected, analyzed and listed. According to the aspect of construction phase and the aspect of industry-form, industrial parks could be respectively classified into three sorts. The definition and feature of each sort are explained. The sixteen National Eco-Industry Demo-parks are tentatively classified. The international comparison items of EIP were proposed, and primary comparison between Japan, China and Korea was accomplished.

Key Words: *circular economy, industrial symbiosis, EIP, classification, comparison, China*

In 1989 Robert Frosch and Nicholas Gallopoulos, writing in Scientific American, described an industrial ecosystem in which "the consumption of energy and materials is optimized and the effluents of on process...serve as the raw material for another process". This image has stimulated the imaginations of those interested in applying the biological analogy underlying the concept of ecosystems to industrial activities ever since. The 1989 article "Strategies for Manufacturing" is widely considered to be the first article of today's field of industrial ecology.[1)]

Industrial symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of materials and energy through local and regional economies. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. [2)]

Within industrial ecology, the sub-field of "industrial symbiosis" takes as its starting point a vision of industry organized along the model of an ecosystem. In this way it draws on the concept of biological symbiotic relationships in which unrelated organisms and mutual benefit through the exchange of resources, typically wastes. The term "industrial symbiosis" first appeared in the economic geography literature in the 1940s to describe "organic relationships" between dissimilar industries, including the use of waste products from one as input to another.[3)] There are numerous historical examples of such symbioses, through which a myriad of commercial uses were developed to eliminate waste.[4)] Modern-day industrial symbiosis looks to the environmental, as well as economic, consequences, of the physical exchange of energy, water, materials, and by-products.

In China, industrial symbiosis activities are being implemented through the idea of the "circular economy." The circular economy is a new model of economic development based on the principles of industrial ecology where economic and environmental systems are integrated. The cycling of resources is central to this notion of development. Theoretically, the circular economy is to be implemented through a "top-down approach" where the national and provincial governments plan the agricultural, industrial, service, and other sectors.[1)] The notion of circular economy is introduced into China in 1998 form Germany, and the researches and implementation starts from then on in China. After more than ten years of exploration and efforts, China has made historical change from innovation

of theory to lawmaking, from end-pipe treatment to regional eco-economy, from cleaner production to circular economy, and achieved observable progress in the development and practice of circular economy. State of Environmental Protection Administration of the PRC (SEPA) currently promotes the "3+1" model in the progress of circular economy, viz. small circle, medium circle, great circle and waste disposal and recycle. Small circle is cleaner production within enterprise. Medium circle, based on the theory of industrial symbiosis, is to establish relationship of mutual relying and supporting between enterprises and then develop these enterprises into eco-industrial parks, by means of exchange on material and by-products recycle among these enterprises. Great circle is to establish circular cities or circular community, in which the agriculture and industry, production and consumption are operated environmentally friendly and sustainable.

Circular Economy is the keyword of Chinese economy in 2005. Now, SEPA attaches importance to the progress of medium circle, which is the regional circular economy, and has achieved successes in several fields.

1. Environmental Parks promoted by SEPA

Starting from1990s, in order to spread out the concepts of circular economy and develop environmental industry, SEPA has carried out several types of trailing units such as national environmental industry park, eco-industry park, Environmental industrial base, etc. So far, the primary environmental parks promoted by SEPA include:

(1) National Eco-Industrial Demo Park

An eco-industrial park is a community of manufacturing and service businesses locating together in a common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. 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 goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impacts. This approach is composed of green design on park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; and inter-company partnering. An EIP also seeks benefiting the neighbouring communities to assure that the net impact of its development is positive.[5] EIP is consistent with the notion of cleaner production, circular economy and industrial ecology.

SEPA started to set up trial unit of EIP in 1999, and it was considered as the emphasis of the national environmental protection work in 2002. The <Interim Provisions on Application, Nomination and Management of State Eco-Industry Demo-Parks> and <Guidelines for Planning of Eco-Industry Demo-Parks> were enacted in 2003. Up to May 2006, SEPA has confirmed 16 National Eco-Industrial Demo Parks with different features.

(2) Circular Economy Demo-Zone

Circular economy demo-zone is a model region started to prevent pollution, featured with materials and energy exchange to minimize energy and raw materials use and to reduce waste, and eventually to build sustainable economic, ecological and social relationships.

Both circular economy demo-zone and eco-industrial demo park have been set up as the emphasis of the national environmental protection work in 2002. In 2003, SEPA established <Regulations on Application, Appointment and Management of Circular Economy Demo-zones (on trial)> and <Guide for Programming of Circular Economy Demo-zones (on trial)>. In 2002, Guiyang city and Liaoning province were selected as trialing units of circular economy, followed by Rizhao city and Yima city in the year of 2004. SEPA published the <The List of National Circular Economy Trial Units (the first batch)> at Oct.27, 2005, and this list includes 42 central industries, 17 central domains, 13 industrial parks and 10 provinces (cities).

(3) Resource Reproduction Processing Zone

According to Gazette on Environmental Industry (2004), China has 6,105 enterprises (including all state-owned enterprises, and non-state-owned enterprises and institutes but with income avenue

above 2 million) engaged in waste collecting, reproduction and reusing and 959,000 practitioners. Under the direction of relating national departments and agencies, several provinces and cities practiced "zonal management" for resource reproduction. At present, more than 10 zones have been formed in the area not limited to Jiuluo, Nibo, Ziya, etc. In August of 2003, SEPA nominated Ningbo metal reproduction zone as national trialing zone on zonal management for reproduced-resource import. In August 22 of 2005, Yantai resource reproduction zone was set up as national demo zone for used hardware and cable import.[6)]

(4) National Environmental Scientific and Technological Industry Park

In order to promote the scale of environmental industry, improve the homemade ability on environmental facilities and cultivate new points of economic growth, SEPA has started to establish national environmental scientific and technological industry park and environmental industry base. Up to May of 2006, totally 8 parks have been ratified to be established.

(5) National Environmental Industry Base

The emergence and development of environmental industry base is accompanied by the development of environmental protection and environmental industry in China. The major contents of environmental industry base are research and development on set and systematization of environmental protection equipments. Up to May 2006, there are 3 environmental industry base ratified by SEPA.

Fig.1 shows the association between the 5 types of environmental parks aforementioned. By the analysis and comparison of these parks on their industry structure, corporation type and operation fashion, it is considered that national eco-industrial demo park, circular economy demo-zone, and resource reproduction processing zone are constructed with the notion of circular economy, and they implement the concepts of circular economy in their design and operation. Whereas national environmental scientific and technological industry park and national environmental industry base are the centres of environmental protection industry for research, develop and production, and they could provide technological and product ional support for the former 3 types of parks.

2. The present national eco-industrial demo parks in China

In order to prod the construction and development of eco-industry and eco-industry parks, SEPA has started from 1999 to establish trailing eco-industrial demo park, while cooperating with UNEP on the project of "environmental management of industries parks in China". So far, 16 national eco-industrial demo parks in different types have been under construction, and this provides precious and referable paradigm for exploring new type industrialization and creating industry ecology in China. Table 1 lists the essentialities of these EIPs.

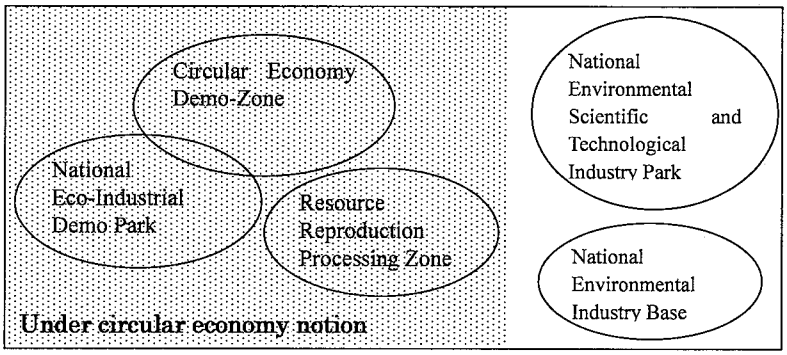

Fig.1 the connection among the 5 sorts of environmental parks.

Table 1 List and introduction of ratified national eco-industrial demo parks in China. (up to May.2006)

NO.	Name	Ratify Time	Dominant Industry	Character
1	Guigang (sugar) EIP	Aug.14,2001	sugar, paper and alcohol making	3 major industry chains form into traversal coupling relationship, to some degree, come into industry net
2	Nanhai EIP(Huanan environmental science and technology industry park)	Nov.29,2001	hi-tech environmental industry	hardware industry cluster, artery industry and venous industry complements with each other
3	Baotou (aluminum) EIP	Apr.18,2003	joint operation pattern of aluminium and electricity	electricity, electrolysis aluminum, aluminum intensive-processing, Aluminum Alloy casting, rare earth hi-tech industry, construction material and other related industries form into industry chain and net, radiating surrounding areas
4	Huangxing EIP	Apr.29,2003	hi-tech industry	12 major eco-industry chains, ecological net with multiple material and energy flow, develops into larger eco-system with related enterprises outside the park
5	Lubei EIP	Oct.18,2003	chemical industry, construct material, light	3 industry chains: ammonium Phosphate produced by phosphor-gypsum; vitriol as by-product and cement as joint-product; multiple use of seawater; and, joint operation pattern of salt, alkali and electricity
6	Tianjin EIP	Apr.26,2004	electric information, bio-medicine, automobile manufacture, foodstuff and beverage	IT, bio-medicine, food and beverage have developed into 3 major industry chains. Other industry chain such as marine chemical industry, marine bio-medicine, marine fine chemical are coming into being
7	Fushun (mining) EIP	Apr.26,2004	coal, comprehensive utilizations of oil shale and coal-bed methane, machining process, and construct material	due to exhausted resource, local economic readjusts itself by utilizing abandoned mine resource and oil shale and coal-gangue to develop alternative industry and substitute industry.
8	Dalian EIP	Apr.26,2004	petroleum chemical engineering, electrommunication, material	Based on metabolizability of production and waste, it constructs industry chains within enterprise and between enterprises
9	Suzhou (hi-tech) EIP	Apr.26,2004	electrommunication	enterprises tend to achieve "zero emissions"; Resources are reproduced thru waste recycle
10	Suzhou (industry) EIP	Apr.26,2004	electric electron, chemical pharmacy	corporation practise cleaner production and attestation of ISO14001, implement medium water re-use and recycling of electronic chemicals
11	Yantai EIP	Oct.22,2004	machine, electric electron, chemical fiber weaving, chemical plastic、foodstuff and bio-medicine	integration management of water resource, efficient utilization of waste, management of hazardous waste, share of establishment
12	Kaiyang EIP	Oct.29,2004	phosphor, coal, energy and related industry	industry, natural and dwellers form ecosystem net, improve the utilizing efficiency of phosphor and coal through industry chain, develop high extra-value chemical production
13	Weifang EIP	Mar.31,2005	marine chemical industry production	congregate industries linked on arts and crafts, form regional ecological recycle
14	Shangjie EIP	Apr.21,2005	aluminum industry	readjust primary corporation fashion and waste treatment methods, achieve integration of material, water-supply, energy and technology and share of information and instruments
15	Baotou (steel) EIP	Dec.8,2005	iron and steel industry, rare earth industry	settle the conflict between economical development and environmental pollution through metabolizing of production and utilization of waste
16	Antai EIP	May.18,2006	coking industry	form industry chains such as electricity generation using coal gas and coal-gangue, slag and coal ash used as construction material

3. Classifying of national eco-industrial demo-parks

According to the construction difference when ratified by SEPA, the national eco-industrial domo-parks could be classified into 3 types, as identified in Table 1:7)

(1) Existing Industry Park: large enterprise, industry region or park possesses eco-industry in some degree when it achieves the EIP ratification. The emphasis of this type of park is to refine existing ecological industry chain and to form steady ecological industry net. For example, Guigang (sugar) EIP is an existing industry park because it achieved ratification on August 14 2001. Guangxi Guitang (Group) Co., the main body of Guigang EIP, was built in 1994 and made great effort on ecological industry for many years.

(2) Newly-built Industrial Park: park that is not built yet or not yet in certain scale when it achieves the EIP ratification. This type of park features to construct a brand new park under circular economy theory in a green field. Nanhai EIP is an example of this type. It was a rudimentary plan when it achieved the EIP ratification in 2001 and the construction was not started until 2003, two years after confirmation.

(3) Virtual Industrial Park: Park without boundary. Enterprises belonging to this type of park form an ecological industry system although geographically they are scattered around. The type of park pays attention to designing and constructing the ecological industry net, maintaining and developing steady material and energy flow among the enterprises. Huangxing EIP is such a type since it forms into large eco-system by cooperating with relating enterprises "outside" the park.

According to the industry structure and character of the park, the national eco-industrial domo-parks could be classified into 3 types as described below:

(1) Sector-specific Industrial Park: the park encircles one or several enterprises in same industry, and industrial symbiosis system is formed among congener enterprises and related enterprises.[8)]

(2) Sector-integrate Industrial Park: the park is composed of several sorts of industry, and mostly ameliorated on hi-tech industrial development park and economic & technology development park.[9)]

(3) Venous Industrial Park: the park is mainly composed of venous industry (resource recycle and reuse industry).[10)]

SEPA promulgated <Standard for Sector-specific Eco-industrial Parks (On trial)> (HJ/T273-2006), < Standard for Sector-integrate Eco-industrial Parks (On trial)> (HJ/T274-2006) and < Standard for Venous Industry Based Eco-industrial Parks (On trial)> (HJ/T275-2006) in Jun.2006, and these standards will take effect on Sep,1.2006 to guide the construction, management and acceptation of EIP in China.

Based on the information about the national eco-industrial domo-parks in table 1, the tentative classification of the 16 parks in terms of construction situation and industry structure is performed and the result is listed in Table 2.

In a country with weak market growth like China, the development and practice on circular economy and EIP take long time. It is difficult to enforce these principles due to lack of understanding at the local area. Besides, there are no adequate guidelines on how to apply these principles into practice. The political and economic driving forces behind the circular economy in China are not yet clear. Circular economy activities are still in the pilot stage in China, but cheeringly, numerous eco-industrial parks have been successfully implemented.[1)]

Table 2 Tentative classification of the national eco-industrial domo-parks in China

Industry Structure / Construction Situation	Sector-specific	Sector-integrate	Venous Industrial
Existing	Guigang (sugar), Lubei, Fushun (mining), Suzhou (hi-tech), Weifang, Baotou, Antai	Tianjin, Dalian, Suzhou (industry), Yantai	
Newly-built	Baotou (aluminum)		Nanhai
Virtual	Kaiyang, Shangjie	Huangxing	

4. International comparison on EIP

(1) Items of international comparison on EIP

In recent years, attention for eco-industrial park development projects has grown enormously among national and regional governments and industries in many countries. 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.[11-13)]

In order to promote the development of EIP and analyze the experience in different countries, it is necessary to make international comparison of EIP in various aspects. Table 3 lists some items used to make international comparison, whose first part is for comparison of primary stage after current status investigation, and the second part is further stage comparison that could reach only with analyses in-depth.

Table 3 Proposal items of international comparison on EIP.

Level	Scope	Item	Explanation
Primary stage	general information	scale	size, company quantity, employee and etc.
		dominate industry	-
		distributing	regional distributing of EIP within a country
		style	new-built or reconstruct of existing park, arterial or venous industry
	establishment	initiated time	-
		base	origination of EIP, such as circular economy, zero-emission and etc.
		qualify department	-
		incentive system	-
	operation and management	object	planning object of reduction of water, energy and waste, industry chains anticipated
		current operation level	-
		management modality	main-body of management and establishment of stage of information exchange
		legal control	-
		related standards and regulation	-
		cooperation level	relationship and partnership among local government, existing industries, NGO and the citizens, the participation of research institutions
	effect	economic effect	-
		environmental effect	-
Further Stage	summarizing and analyses	key-factor on promoting EIP	initiative of EIP is mainly because of the need of economy development, environmental protection or activated by government.
		success factor	-
		deficiency need to improve	-

(2) Comparison between Japan, China and Korea

Since the breakdown of the Bubble Economy, which thrived on the basis of mass production and mass consumption, Japan has been struggling to find an alternate vision to develop itself. Recognizing an eco-industrial approach as a way to realize sustainable development, Japanese leaders have launched various types of eco-industrial projects across the country.

Under the leadership of the National Cleaner Production Centre, Korea takes ambitious initiative to launch its EIP. Six industrial parks or complexes are seeking to qualify to be eco-industrial parks through a variety of strategies, and three of them have been confirmed.

Table 4 lists the comparison of EIP between Japan, China and Korea on several primary items. It is made based on the acquired materials and need to be perfect when further information is reached.

Table 4 Comparison of EIP between Japan, China and Korea

Item	Japan	China	Korea
Quantity of ratified EIPs	26	16	3
Dominate industry	hi-tech machine, electron, cement and waste recycling	hi-tech, chemical, bio-medicine, coal, electrommunication and etc.(multiple industry)	textile, petrochemical, and nonferrous metals
Initiated time	1997	1999	2004
Development base	zero emission	cleaner production, circular economy	cleaner production
Qualify department	(1)Ministry of Environment(ME) (2)Ministry of Economy, Trade and Industry(METI)	State Environmental Protection Administration(SEPA)	Korean National Cleaner Production Center(KNCPC)
Related regulations	(1)the Fundamental Law for Establishing a Sound Material-Cycle (SMC) Society (2)Law for the Promotion of Effective Utilization of Resources (3)Container and Packaging Recycling Law (4)Home Appliance Recycling Law (5)Construction Material Recycling Law (6)Food Recycling Law (7)End-of-Life Vehicle Recycling Law	Regulations on the applying, nominating and management of national eco-industrial demo-park(On trial)	(1)the Waste Control Act (2)the Act on the Promotion of Saving and Recycling of Resources (3)15 year long plan for shifting 18 existing industrial parks into EIPs and & newly design 2 EIPs
Regulated standards	Standard for waste disposal	(1)Standard for Sector-specific Eco-industrial Parks (2)Standard for Sector-integrate Eco-industrial Parks (3)Standard for Venous Industry Based Eco-industrial Parks	standard for packaging materials & packaging methods of products
Main research institutes	(1)Ministry of Economy, Trade and Industry (2)Environment Bureau of Kitakyushu city (3)Toyo University (4)The University of Kitakyushu	(1)the Chinese Research Academy on Environmental Science (2)Dalian University of Technology (3)the University of Tsinghua	(1)Korea Eco-Product Institute (2)Korea Environment and Resources Corporation (3)Korea Institute of Environmental Science and Technology (4)the University of Ulsan (5)the University of Suwon

Several differences of the progress of EIP among China and Japan are emerged through review and analyse on the related reports and article:[14-16)]

Role of government: In China, civilian participation is not sufficient and government plays key role in the progress of EIPs due to weakness of free market. It's in pressing need that government, enterprises and research institutes interact positively with each other. In Japan, enterprises cooperated with each other at the beginning to fulfil laws and regulations about construction of circular society and waste recycling enacted by government. Gradually, several EIPs came into being and by and by kept expanding, eventually government got involved to harmonize and support the progress of EIP.

Type of EIP: EIPs in China consist of various types, or newly built or virtual, while most Japanese EIPs were evolved from former industry parks.

Impacts from high-tech: Application of high-tech is more and more important in Japan and exerts remarkable influence to the development of EIP. Chinese EIPs are still at their preliminary stage of by-product exchange,

and the devotion to research and development on waste reproduction and reuse is far away from satisfaction.

5. Conclusion

China experienced a rapid economic growth in the last decades. Now, the country is facing a series of resource and environment issues that impede its economy in healthy development. As an effective economy and environment win-win strategy, the EIP concept (constructed on the theory of industrial symbiosis) is now in serious consideration by authorities and communities in China. It is still unclear about the political and economic driving forces behind the circular economy, and circular economic activities are still in their pilot stage. Despite the uncertainties, numerous eco-industrial parks have been successfully implemented in China. However, compared with their counterparts in developed countries, there are still a lot of deficiencies and therefore it will be along run for the development of EIP in China.

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