ANALYSIS ON ECO-INDUSTRIAL PARK FOR PROMOTING CIRCULAR ECONOMY IN CHINA -Comparative study in Baotou, Suzhou and Shanghai-

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Eco-Industrial Park (EIP) is an important component of Circular Economy (CE) which promotes sustainable development in practice. To grasp the current status and challenges of EIPs, field surveys have been carried out at Baotou Industrial Park, Suzhou Industrial Park and and Shanghai Chemical Industry Park, all of which are located at different regions with different resources and economical characteristics. From the study, we found that the three EIPs are basically successful in applying the principle of CE; promoting cleaner production at individual firms and effective ecological chain within the park. Widespread application of the good practices of EIP to other regions is the key to the development of CE in China.

Key Words : *Eco-Industrial Parks, Circular Economy, sustainable development, cleaner production, ecological chain*

1. INTRODUCTION

Along with the rapid economic and population growth, the shortage of energy and resources as well as serious environmental pollution are forcing the Chinese government to make great efforts to find a new path of sustainable development - Circular Economy (CE).

To ease the resource and environmental problems, the Chinese government clearly laid out in the 11th five year plan that China must create a new economic system that economizes on resources and promotes CE and an environmentally-friendly society. As an important pillar of CE, Eco-Industrial Parks (EIP) have been built and are growing rapidly in China.

Since Robert A. Frosch and Nicholas E. Gallopoulos coined the industrial ecology concept in 1989 [1)], EIP has been increasing rapidly in the world. Kalundborg, perhaps the most known example of EIP, lies along the coast of Denmark. In this EIP, there is a complex web of waste and energy exchanges that was established through the voluntary partnership of industries and the municipality [2)]. Since great attention was paid to the reuse and recycle of the resources, the park has obtained great economic and environmental benefits: 1.2 million tons in water saving, 19,000 tons in fuel saving, 30,000 tons in coal saving; 130,000 tons in CO_2 emission reduction each year.

Since EIPs could offer both economic and environmental benefits, promoting their development and spread will have a significant positive impact on the implementation of CE. Aware of this situation the Chinese government has been encouraging the development of EIPs across the country.

To grasp the current status and challenges of EIP, field surveys have been carried out at three representative project sites, i.e. Baotou Industrial(Aluminum) Park, Suzhou Industrial Park and Shanghai Chemical Industry Park, all of which are located at different regions, with different resources, policy systems, management, master planning, investment, high-tech degree and economical characteristics **(Fig. 1)**. This paper will review the current situation of CE and EIP in China, show and discuss the 3 parks' characteristics and

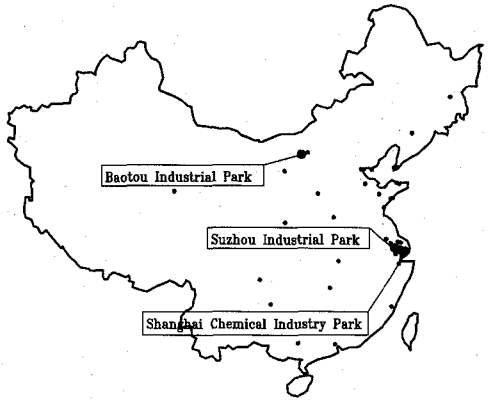

Fig.1 Location map of 3 EIPs in China

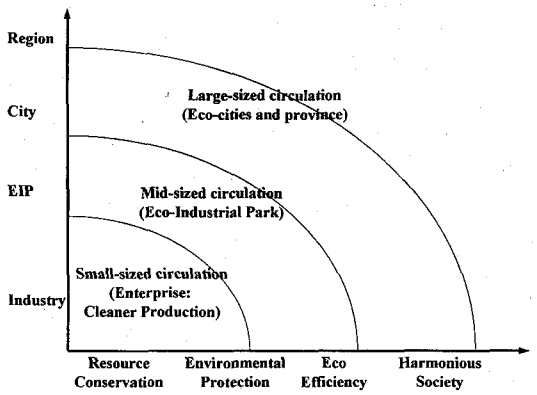

Fig.2 Circular Economy concept framework in China

conceptual framework of CE, analyze and compare the economic and environmental benefits, and the way they overcomed their practical difficulties in the design of the EIP. Finally, the paper will propose the successful methods for promoting the CE through EIP.

2. CIRCULAR ECONOMY (CE) IN CHINA

2.1 CE concept and process in China

CE is in essence an eco-economy, which features low consumption of material and energy resources, low emission of pollutants and high efficiency.

In the 1990's, economic activities, such as the recycling of the newspapers, scrap metal and other materials have spread throughout China. But CE was not regarded as a national strategy. In 1998, the theory of the CE in Germany was firstly introduced by Shanghai government. In 2003 the CE theory was stipulated in the National Scientific Developmental Plan of China. In March, 2004, the president of China Hu Jintao announced the CE concept at the "Population-Resource-Environment" conference. In September 2004, the government published the general plan to promoting CE in China at the 1st CE Conference held in Beijing. In 2005, China announced the overall strategy of CE. According to this strategy it will take nearly 50 years to build a comprehensive, natural and harmonious integration society which aims to save resource and promote CE all over the country. By 2010 (the short-term objectives) the country plans to build the first group demonstration projects and set up sound policy and technological innovation systems of CE.

China's State Council gave a strong indication that CE will play a central role in economic development when it transferred the mission to implement the CE strategy from the State Environmental Protection Agency (SEPA) to the State Development and Reform Commission (NDRC) in 2004.

In China there are several CE models with different circulation levels: small-size, mid-size and large-size ones. The small-size circulation promotes cleaner production (CP) within individual firms. Mid-size circulation promotes eco-industrial parks. Large-size circulation promotes the CE in cities, province and regions (**Fig.2**).

2.2 Results of CE in China

China has already established specific laws on CE. The practice of CE has been extending from enterprise, EIP to cities and regions. For example, regarding the policy framework, China has established the Law of the People's Republic of China on Conserving Energy (1997.11), the Law of the People's Republic of China on the Promotion of Clean Production (2002.6), the Law of the People's Republic of China on the Environmental Impact Assessment (2002.10), the Law on Renewable Energy (2005.2) and other relevant laws. The CE integral Law is being prepared and will be announced next year. Regarding the practical application of the CE concept there are many firms, cities and regions that are actively adopting the concept in their activities. Currently there are more than 8000 enterprises registered under ISO 14000. In EIP level, From 2001, there are 26 EIPs ratified by SEPA (2007.5). In city/province level, Liaoning Province, Guiyang City, Panjin City, Rizhao City and Yima City have passed the examination by SEPA as of December, 2004. In October, 2005, the 1st list of entities promoting CE was released. The list includes important industries and sectors (the collection of the recycled resource, reutilization of wasted metal, recycle of electricity product, remanufacturing), 13 Industrial parks (Tianjin, shanghai chemical industrial park, etc) and 10 provinces or cities (Beijing, Shanghai, Jiangsu etc).

3. OVERVIEW AND CONCEPTUAL FRAMEWORK OF CE IN THE 3 PARKS

Table 1 and **Table 2** show the overview of the three selected parks.

3.1 Baotou Industrial (Aluminum) Park (BIP)

BIP was founded in 2001, and was identified as a national ecological industrial Park by SEPA in April, 2003. It is located in Baotou City Donghe District near Daqing mountain and Yellow River. The total planned area is 23.6 km^2. Of the 4 big industrial complexes (over 10 billion Yuan) operating in Baotou, BIP is the only EIP. Currently it is managed by the local municipality. Its core enterprise is Baotou Aluminum Industrial Group. The park's main industrial activities are aluminum-electric joint, plus aluminum processing, deep processing, construction material industry **(Table 1)**.

BIP benefits from the preferential policies of both state and autonomous region. The enterprise sector enjoys a preferential income rate tax of 15% (because it is located in the western region of China) and the autonomous region preferential electricity and gas prices. The environmental protection enterprises can get relief in tax, high-tech enterprises will gain import license-free for the production of export products and import raw materials and spare parts. It also can establish bonded warehouses, bonded factories through the improvement by customs.

BIP has seven types of utilities and landfill and other services **(Table 2)**.

From 2004, the natural gas began to be put into use as clean energy in BIP, which was the first enterprise to use this resource in Baotou City. The high pressure steam from the power plant is provided to the production of packaging enterprises, while heat is used as central heating for enterprises and nearby residents. The main solid waste in the

Table 1 Overview of the 3 parks－1

	Location	Management organization	Major industries or characteristics	establish year	Ratified year	experimental type	area (km^2)		population(hundred thousand people)	total enterprise number
							constructed	goal		
BIP	Baotou , Inner Mongolia province	Municipality	"aluminum electric joint"is core, plus aluminum processing, electric power, deep-machine, construction material industry etc .	2001	2003	EIP*1	6.31	23.6	0.8	33
SIP	Suzhou, Jiangsu province	China and Singapore govt.	electronics, IT, software, chemical, pharmaceutical, heathcare	1994	2004	EIP*1	70	288	2.7	11,400
SCIP	Shanghai	Municipality	petrochemical-dominated	1999	2005	EIP*2	29.4	60	0.6	68

*1 State-level eco-industrial development projects ratified by SEAP until early 2007 in China

*2 State-level circular economy pilot industrial park projects ratified by NDRC, SEAP, MOST, MOF, MOFCOM and STATS on Oct 27, 2005 in China

NDRC: State Development and Reform Commission, SEAP: State Environmental Protection Agency, STATS: National Bureau of Statistics of China

MOF: Ministry of Commerce of the People's Repubic of China, MOFCOM: Ministry of Finance, MOST: Ministry of Science and Technoligy of the People's Repubic of China

Table 2 Overview of the 3 parks－2 (facilities and services)

	infrastructure and public facilities	transportation network	water plant capacity (t/d)	power plant capacity (mw)	sewage system capacity (t/d)	tax	services
BIP	seven typies utilities (road, electricity, water, gas and stream supply, wastewater treatment, telecommunication, site preparation) and land-filling	Express way, railway	— *1	600	— *2	nation 15%	The special financial organs like China Bank, industrial and Commercial Bank of China,Construction Bank of China, Agriculture Bank of China and the postal saving deposit unit,etc providing a convenient and rapid financial service.
SIP	nine typies utilities(road, electricity, water, gas and stream supply, wastewater treatment, telecommunication, site preparation, customs, accident prevention unit) and land-filling	Express way, railway, inner river and airlines	600,000	3,600	500,000	nation 15%, local 3%	SIP cultivated a "highly efficient, transparent, fair and standard" service-oriented government and provides whole-process, full-day and all-round quality services, including: Fast and convenient one-stop approval service, Social service commitment and complaint scheme, 24-hour hotline and duty scheme, All-round investment consulting service, Regular visits to companies, Minimum administrative fees.
SCIP	ten typies utilities(road, electricity, water, gas and stream supply, wastewater treatment, telecommunication, site preparation customs, accident prevention unit, incinerator) and land-filling	Express way, railway, inner river and sea	industrial: 200,000 domestic: 7,000	600	industrial: 200,000 domestic: 7,000	nation 15%, local 3%	"One stop"authority coordinated services with customs, inspection, and quarantine, administration of in dustry and commerce, taxation, administration of foreign exchange are provided together with full-scaled services with security supervision, calamity protection, environment monitor, bak, e-commerce, exhibition and logistic services.

— *1: no water plant — *2: no data

park is fly ash generated by the power plant.The fly ash has been used as the raw material to manufacture bricks by two building materials enterprises within the park. Therefore, 1) Coal-aluminum, aluminum deep-processing products; and 2) Coal-fly ash-new building materials are the two main industrial clusters have been formed in the park **(Fig.3)**.

3.2 Suzhou Industrial Park (SIP)

SIP lies at Jinji Lake, the east of Suzhou. It has a total jurisdiction of 288 km^2, of which, the China-Singapore cooperation area covers 70 km^2. China and Singapore governments established SIP in 1994 and both governments manage it. SIP was identified as the National Ecological Industrial Park by SEPA in 2004 **(Table 1)**. The total investment has reached 536.5 billion Yuan. SIP is a large community including the production, residential and commercial sectors. SIP has completed its master planning and detailed plans, setting down and modifying more than 300 specific plans. The main industries are electronic information and precision machinery electronics, IT, software, chemical, pharmaceutical, and healthcare.

SIP enjoys high efficiency in terms of project approval since it normally takes 3 working days to complete a company incorporation process. SIP possesses efficient and flexible foreign affairs administration power, it owns a sound social security system, and owns a complete and modern logistics system.

SIP has nine types of utilities and land-filling and other services **(Table 2)**, including water plant, power plant, sewage treatment system plant and customs. The sewage system has enough capacity to deal with waste water not only from the park but also part from the local city. In addition, with the virtual airport mode using the Air-Land Trans-shipment Model, the customs clearance and freight transportation time from port-to-door can be further shortened to 5 hours. It has convenient traffic and excellent services systems.

In the areas of IC, TFT-LCD, automobile and aviation parts production, SIP has obtained a certain competitive ability in the international high-tech industry clusters, which consists of semiconductor, opto-electronics industry and electrical mechanics. and has become China's largest export base for LCD panel and chip packaging & testing base, a large buses and chip production, which is one of the top three national bases. The resource recycling system within the enterprises has formed including electric appliance waste (e-waste), water cycle use, waste heat utilization, and sludge incineration resource **(Fig.4)**.

3.3 Shanghai Chemical Industry Park (SCIP)

SCIP lies at the north coast of Hangzhou Bay, the south of Shanghai. The total planning area is 29.4 km^2. Shanghai Municipal Economic Commission established it in 1999. It was identified as the first State-level · circular economy pilot industrial park projects by NDRC, SEAP, MOST, MOF, MOFCOM and STATS on Oct 27, 2005. It is the first industrial zone specialized in the development of petrochemical and fine chemistry businesses, and also one of the four industrial production bases in Shanghai **(Table 1)**. The total investment has reached 9.84 billion Yuan. Now BP, BASF, Bayer, Degussa, Huntsman, SUEZ, Vopak, AIR LIQUIDE, Praxair and other world-famous multinational petrochemical and utilities corporations have their projects in SCIP.

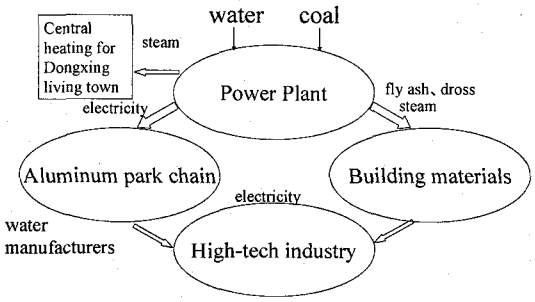

Fig.3 Conceptual framework for BIP of CE

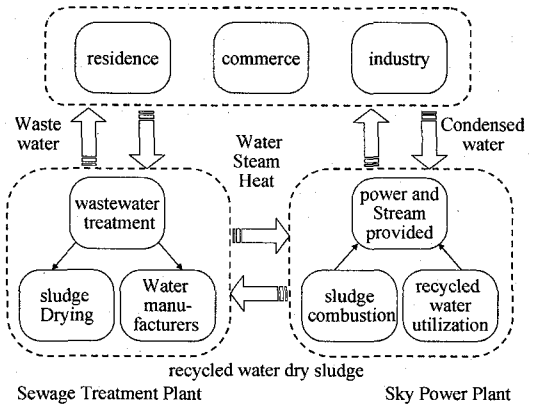

Fig.4 Conceptual framework for SIP of CE

SCIP has ten types of utilities and land-filling and other services **(Table 2)**, including its own water plant, power plant, sewage treatment plant and incinerator. The power plant can provide the industrial and domestic water; it has an excellent traffic system and "One stop" services.

SCIP follows three main principles to set up the park, it not only promotes clean production mechanisms at the enterprise level, but also

establishes a complete material recycling system within the park, which flow from upstream products such as naphtha, ethylene, to the mid-stream products such as isocyanate, polycarbonate and the downstream products such as synthetic materials **(Fig.5)**.

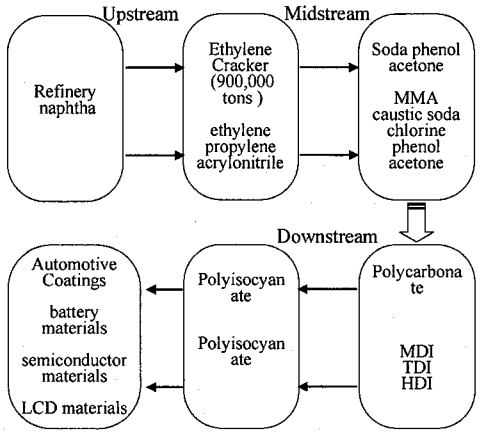

Fig.5 Conceptual framework for SCIP of CE

4. ECONOMIC AND ENVIRONMENTAL BENEFITS

The 3 parks succeded in applying the principle of CE which promotes not only cleaner production at individual enterprises level, but also ecological chains within the parks. The parks' per capita GDP has reached 2-10 times of the local per capita GDP **(Fig.6)**. They actively attract foreign investment, use foreign technology, promote high-tech production, save resource and reduce emission. They obtained not only economic benefits but also environmental benefits. The SIP and SCIP's economic and environmental benefits are higher than BIP because performance of the EIPs in the developed area is generally better than those in less developed area.

Because BIP lies in a water shortage area in the north of China, the price of the reutilization is only half of the water from the water plant, making it an important incentive for enterprises to actively use the recycled water. The ratio of the waste water utilization reaches 85.3%, and it is the highest in the 3 parks. BIP reduces wastewater discharge by about 1 million tons every year, saving more than 60 million Yuan. The casting aluminum refined from the waste aluminum and slag by the aluminum group is about 200 tons, saving nearly 4 million Yuan. And the asphalt fumes emission is reduced by 6.2 kg per ton of aluminum every year. The core enterprise-Aluminum Group obtained the ISO 14001 environmental management system certification in 2004. From the ecological benefit point of view, per 10000 yuan GDP, 1500 Kwh of elctricty are consumed, only 1/10 of the average level.

BIP's investment in environmental protection is the lowest. At the same time, the consumption of material and energy is the highest, resulting in poor economic and environmental benefits (Table 3 and Fig.6-8). In order to improve its performance, BIP is attracting foreign investment from high-tech and environmental enterprises.

SIP lies in the developed east area of China, it was certified the ISO14000 national demonstration zones in 2001 by SEPA, and since it was established based on the Singapore master plan and management as well as their high-tech production, it has achieved significant economic benefits. 13 years ago SIP's total GDP was only 1 / 522 of Singapore's. In 2006 it has reached about 69.6 billion Yuan, which is about 1/15 of Singapore. In 2006, its per capita GDP was 114, 000 Yuan (per capita GDP is 57,900 Yuan for Suzhou City residents) **(Fig.6)**.

In SIP, the foreign investment has reached over 95% of the whole investment, which has played a significant role in the park's ecological procedure. there are over 2,400 foreign-funded enterprises of which 66 are the top 500 world enterprises and established 102 branches in SIP. 170 enterprises have obtained the ISO14000 certification, 100 enterprises have carried out cleaner production plans. The water consumption per 10,000 Yuan is only 5.8 tons, electricity is 400 kwh, and standard coal is 0.34 tons, making this park the most efficient in terms of resource use **(Fig.7)**. At the same time the centralized sewage treatment rate is 100%; and the solid waste disposal rate is 94% **(Table 3)**.

Now SIP aims to introduce the electronic information, mechanical and electrical integration, precision machinery, bio-manufacturing and new materials-based high-tech industrial projects. According to the principle of CE, the introduction of the related enterprises will form preferential industry clusters and strengthen ecological chain.

SCIP was built with international advanced development conceptions and large-scale Chemical Park. Since it lies at the north coast of Hangzhou Bay, it owns the best transportation network, so it can reduce the transport costs. Foreign investment is 81.8% **(Table 3)**. From the ecological benefit of view, per 10,000 Yuan GDP, 11.05 tons of water, 450 kwh of electricity, 0.3 tons of coal are consumed. In SCIP, resources utilization indicators have reached the international advanced level.

Centralized sewage treatment rate is 100%; solid waste disposal rate is 100%. The wastewater discharge of 10,000 Yuan GDP is 5.2 tons. The average waste water discharge of the same industry is about 41 tons. The exhaust gas per 10,000 Yuan GDP is 46,000 m^3 and the average level in China is 121,000m^3. SCIP is set out to be one of the largest and the most integrated and advanced world petrochemical bases in Asia.

Table 3 Comparing on economic and environmental benefits of the three EIPs

	total GDP(10000 yuan)	ratio of foreign investment (%)	ratio of environmental investment (%)	ratio of industry solid wastes utilized (%)	industrial waste water utilization (%)	centralized urban sewage treatment rate (%)
BIP	52,290	0.0	1.04	85.3	83.7	80
SIP	680,000	95.0	3.00	94.0	65.0	100
SCIP	350,000	81.8	3.00	100.0	80.6	100

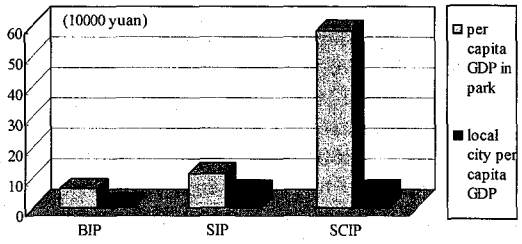

Fig.6 Per capita GDP in 3 parks and local cities

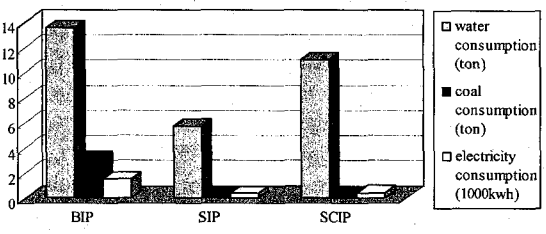

Fig.7 Water, coal and electricity consumption (per 10000 Yuan) of the three EIPs

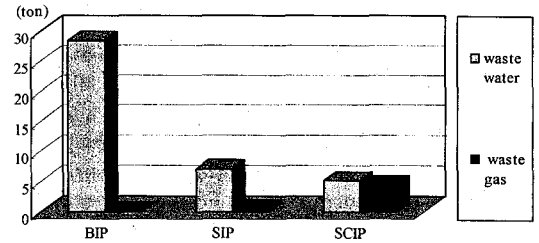

Fig.8 Discharge of waste water and gas (per 10000 Yuan) of the three EIPs

5. CONCLUSIONS

As a new mode of economic development, CE in China has developed very quickly and has achieved very significant results in policy and practice.

From the study, we found that the three EIPs succeded in applying the principle of CE, which promotes cleaner production at individual enterprises level, but also ecological chains within the parks. They obtained not only economic but also environmental benefits. Moreover, the policy system, location, traffic convenience, the park's overall layout and the industrial structure, foreign investment, high-tech degree and the ecological chain have a direct impact on the EIPs' economic and ecological benefits.The performance of SIP and SCIP (located in the developed area) are generally better than BIP (located in less developed area). But because of lack of incentive mechanisms, the ratio of the waste water utilization in SIP and SCIP are lower than BIP.

In order to build or develop a sound EIP, the following points should be carefully considered:

1) In policy, EIPs should be established with a preferential policy system which combine their corresponding characteristics under national policies. Policy must also provide some incentive mechanism to promote the reuse of material and energy resources.
2) In practice, the parks should actively attract foreign investment, use foreign technology, promote high-tech and cleaner production to obtain the ISO14000 certification; actively add the ecological chain within the park, promoting the effective use of material and energy resources and strengthening ecological management in order to promote the maximum implementation of the CE in EIP.

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