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Review

Featured chemical industrial parks in China: History, current status and outlook

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ABSTRACT

Development of eco-industrial parks (EIP) is an effective method for recycling, reuse and conservation. Facing resource shortage as well as stringent energy saving and emission reduction targets, the importance of EIPs are getting ever-increasing attention in China. In this paper, the history and current status of EIPs in China are reviewed. The synergies in several unique chemical industrial parks are delineated. The critical factors for the development of chemical industrial parks in China are discussed and the outlook for the path forward is presented.

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1. Introduction

Development of industrial ecosystems (IE) is an effective method for recycling, reuse and resource conservation (Garner and Keoleian, 1995; Jin and Arons, 2009). This mechanism converts the industrial process from a linear process to a cyclic process where the waste generated by one industry can be used as a resource by another industry (Ehrenfeld, 2004). Since the establishment of the agro-chemical ecosystem in Kalundborg, Denmank, many industrial ecosystems have been established worldwide.

Facing resource shortage as well as stringent energy saving and emission reduction targets, Chinese policy-makers decided to restructure its economy and energy mix. As addressed in the national targets in China's 12th five-year plan (2011–2015), based on the achievements accomplished during the past 11th five-year plan period (2006–2010), China aims for a 15% reduction in energy consumption and CO_2 emission per unit of GDP and a 10% reduction in total COD and NO_x emissions. More specifically, for the petrochemical and chemical industry in China, comparing with the levels at the end of the 11th five year plan, by 2015, energy consumption and CO_2 emission per unit of industrial added value should be reduced by 15%, total COD and NO_x emissions should be reduced by 10%, total discharge of ammonia and nitrogen should be reduced by 12%, total SO_2 emission should be reduced by 8% and waste water discharge will meet standard. The comprehensive utilization rate of solid chemical wastes should be 75%, and the effective treatment rate of the solid chemical wastes should be 100% (CPCIF, 2011).

Establishment of eco-industrial parks is a viable approach for resource conservation and emission reduction (Ehrenfeld, 2004). In the 12th five-year plan, the importance of developing

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Fig. 1. Locations of the chemical industrial parks presented in this paper.

circular economy is re-emphasized. Learning from the structures and operations of the established regional networks will provide valuable information to the engineers, corporate leaders, regulators and decision-makers and it will lead to the future advancement of IE.

In the following sections, the history and current status of EIPs in China will be reviewed. The structure and operations of several unique chemical industrial parks will be presented in the following sections.

2. History and current status of eco-industrial parks in China

A decade ago, Chinese government started to realize the value and importance of industrial ecology and many EIPs, ranging from national-level to provincial-level, were established since 2000. A study conducted by the former China Petroleum and Chemical Industry Association (now renamed as CPCIF – China Petroleum and Chemical Industry Federation) in 2004 listed 17 chemical industry parks in China. Among them, the ones in Shanghai (Cao-jing), Nanjing and Tianjin (TEDA) are national level parks, and the others are managed at the provincial level (Hauthal and Salonen, 2007). Many of the networks in these chemical industrial parks are similar to those in a typical petrochemical complex in North America and Europe. By February 2009, more than 200 national level EIPs and regional chemical industrial parks were established.

Due to resource availability and product/byproduct compatibility, several unique chemical industrial parks were constructed. The structure and operations of them are presented in the following sections. These include:

A. A coal-based eco-industrial park in Shanxi Province.
B. A coal–chemical-integrated, closed-loop chlorine recycling network in Daxie Island, Ningbo, Zhejiang Province.
C. A fine chemical park in Hangzhou Bay, Zhejiang Province.
D. A sugar cane and cassava based agro-chemical ecosystem in Guangxi Province.
E. A sea salt and phosphor based cultivation-chemical industrial park in Shandong Province.

The locations of these 5 featured chemical industrial parks are depicted in Fig. 1.

Table 1
CCPC's coal mining facilities and capacities (Gui and Qi, 2010).

Facility	Quantity	Unit capacity
Surface coal mine	2	20 million t/year
Underground coal mine	4	10 million t/year
Coal preparation facility	5	16 million t/year (average)
Railway	3	29 million t/year (average)
Surface coal mine with preparation facility (under construction)	1	20 million t/year

2.1. A coal-based eco-industrial park in Shanxi Province

The booming of coal chemical industry is a unique phenomenon in China. In 2010, totally 4.2 Tera kWh electricity was consumed in China, among which more than 80% was supplied by coal. This energy mix is significantly different from the worldwide average: coal-based power 41%, oil-based power 5%, natural gas based power 21%, hydro power 16% and nuclear power 13% (International Energy Association, 2010). In the following several decades, coal will remain as the No. 1 energy source in China unless a major breakthrough in alternative energy is achieved. Therefore heavy investments have been continuously made to develop the coal chemical industry.

Comparing with the aboriginal dirty coal industry several decades ago, China has made significant improvement. As reported on February 18th, 2011, a power plant in Shanghai achieved a coal-energy efficiency of 279.39 g/kWh in 2010 and broke its own world record (Zheng, 2011), accompanied with significant reduction of waste, which is far beyond the world's expectation. The originally discharged waste streams, such as slags, off-gases and tar, have been recycled and reused. Many clean coal technologies and ecological restoration projects have been implemented. One typical example is the synergy in ChinaCoal Pingshuo Coal Co., Ltd. (hereinafter referred to as CCPC).

CCPC, located in Shanxi Province, built a nice eco-industrial park centered by the largest surface coal mine in China, Antaibao Coal Mine. The park covers an area of 380 km^2. The details of CCPC's mining facilities are listed in Table 1 (Gui and Qi, 2010).

The two core value chains of CCPC's eco-industrial park are: "coal – electricity – silica – aluminum – coal chemicals – building materials" for industrial development and "land reclamation – farming – greening – cultivation – herb – tourism" for ecological restoration. The realization of these two value chains successfully integrates industrial activities and restoration of land in harmony.

CCPC has converted the wastes into resources and products through different pathologies. CCPC cooperated with a few companies to build power plants close to the mines. These plants take coal gangues and lower-grade coals as fuels for power generation. CCPC is expected to have a power generation capacity of 1240–4180 MW/year from 2010 to 2015, in which approximately 600 MW/year is to be derived from lower-grade coals and coal gangues. This will consume 6–20 million t/year coal sludge, lower-grade coals and coal gangue (Gui and Qi, 2010). The fly ash generated from power plants is used as the raw material for downstream production. CCPC has applied its patented technologies of using fly ash to produce silica, alumina, cement, etc. (Qin and Gu, 2010; Wang et al., 2010). A 200,000 t/year fly ash recycling project will be scaled up in 2012 (Shanxi Provincial Environmental Protection Department, 2010) and it will be further scaled up to 750,000 t/year in the long run. What is more, CCPC developed a machine for recycling coal sludge via press filtration. This will recycle approximately 6 million t/year coal sludge, solve the problem of pollution and improve the productivity. To satisfy the specific needs of mining, CCPC has established facilities that can produce 160,000 t/year dilute nitric acid and 200,000 t/year porous