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Article

Eco-Industrial Parks from Strategic Niches to Development Mainstream: The Cases of China

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Abstract: China has implemented eco-industrial park (EIP) initiatives as a mainstream strategy of a circular economy since the turn of the new century. This paper presents the sustainable transition processes and outcomes of three EIP cases, Tianjin Economic and Technological Development Area (TEDA), Fuzhou Economic and Technological Development Area (FEDA) and the Xi'an High-Tech Zone (XHTZ). The cases uncovered four factors key to the transition of EIPs: technological trajectory dependency, spaces for experimentation, government as an enabler and regional embeddedness.

Keywords: eco-industrial parks; strategic niches; sustainable transition; industrial ecology; China

1. Introduction

In 2012, China took the lead as the world's champion in terms of industrial output, surpassing the United States, and became the true "world plant". In the 30-year economic miracle transition, industrial parks have played a great role as "policy pioneers". To break the ice of the planned economy, China promoted industrial development firstly in the form of Economic and Technological Development Areas (ETDAs) in 1984 and then High-Tech Parks (HTPs) in 1988. Up to the end of 2013, China had around 300 national industrial parks, including 210 ETDAs and 113 HTPs.

Now, these industrial parks have become the second round of policy-reforming pioneers as eco-industrial parks from strategic niches to the eco-development mainstream under increasing resource and environment pressures. China implemented eco-industrial park (EIP) initiatives as a strategic niches of the circular economy at the turn of the new century. Some sector-specific industrial parks seek alternative pathways to balance industrial development and environmental burdens, such as chemical parks in the Yangtze Delta Area and sugar-making parks in the Zhujiang Delta Area. After 2004, some leading EDTAs and HTPs joined the pilots, including TEDA, FEDA and Suzhou Industrial Park [1].

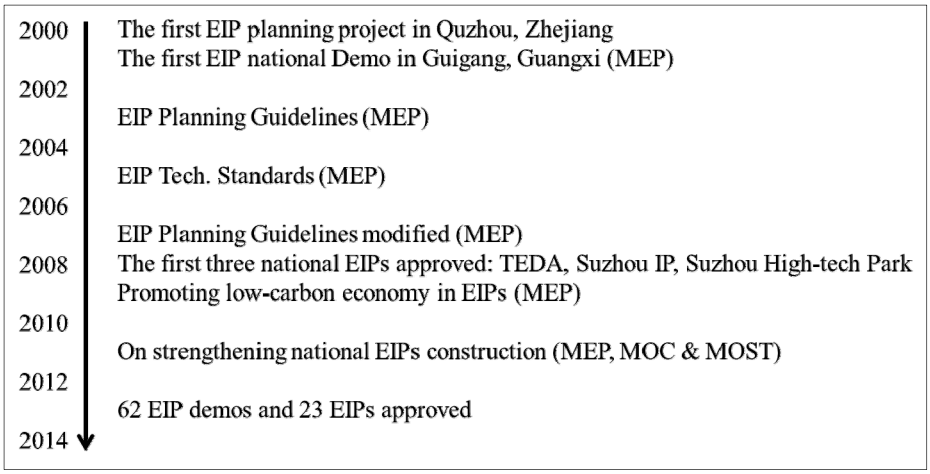
With observations of the European and North American EIP cases, Gibbs [2] found a problematic nature of EIP experimentation. That is to say, most EIPs fail due to diverse problems. Now, for these Chinese counterparts, are they successful or not? This paper explores this question by presenting the transition processes and outcomes of three EIP cases, the Tianjin Economic and Technological Development Area (TEDA), the Fuzhou Economic and technological Development Area (FEDA) and the Xi'an High-Tech Zone (XHTZ).

2. The State of the Art of EIPs in China

To facilitate EIP construction, the Chinese government issued a series of policies and regulations, including planning guidelines, technical standards and evaluation indicators (Figure 1).

With about a 15-year effort, up to now, 85 EIPs pilots have been established under the co-approval of three ministries, the Ministry of Environmental Protection (MEP), the Ministry of Commerce (MOC) and the Ministry of Science and Technology (MOST), and 23 of them have been named after the national EIPs.

Figure 1. The evolutionary process of eco-industrial parks (EIPs) in China (MEP, Ministry of Environmental Protection; MOC, Ministry of Commerce; MOST, Ministry of Science and Technology). TEDA, Tianjin Economic and Technological Development Area.



In the past 15 years, a great number of success stories regarding industrial symbiosis has emerged [3]. Almost every EIP case has implemented or planned waste exchanges, especially for metal scraps, waste plastics, paper or wood scraps, ash and sludge. Some special synergies have also been implemented: for example, a company was recruited to recycle iron-containing sludge in FEDA; a special pulp

making process was developed to recycle cellulose in bagasse in Guitang Park [4]; and a recycling process was established to recover copper from wastewater in Suzhou Industrial Park [5].

EIPs now act as an innovation platform for environmental management, including master planning, industrial layout, environmental risk control, environmental performance reporting, *etc*. [6]. All of this leads to the transition of the environmental management of industrial parks from the end-of-pipe treatment paradigm to a more system-oriented one. For example, TEDA established the Industrial Symbiosis Innovative Technology Alliance in 2011. The purpose of the alliance is to combine the mutual interests of entities, universities and scientific institutions to promote the capacity of technology innovation for waste reutilization and to provide the opportunity for training human resources on the environmental management system and industrial symbiosis.

3. The EIP Case of TEDA

TEDA was one of the first three national eco-industrial parks approved by MEP in 2008. Since its establishment in 1984, TEDA ranks as the top among industrial parks. Shi *et al.* [7] had revealed 81 inter-firm symbiotic relationships formed in TEDA involving the utility, automobile, electronics, biotechnology, food and beverage and resource recovery clusters.

Since 2010, TEDA implemented one EU Switch-Asia Project: Implementing Industrial Symbiosis and Environmental Management System in the Tianjin Binhai New Area. The objective of the project is to establish an industrial symbiosis network with 800 member SMEs. In the past four years, TEDA has organized 464 onsite visits, 22 quick-win workshops and 14 sectoral seminars. Facilitated by the project, more synergies have been uncovered and realized (Table 1)

Table 1. Industrial synergies in TEDA (2010–2013).

Sector	2010	2011	2012	2013
No. of membership	174	536	635	931
No. of synergies	10	27	43	87
CO_2 abatement (tons)	205	11,000	42,000	89,355
Landfill diversion (tons)	50	3000	257,000	321,076
Raw materials reduction (tons)	50	3000	872,000	936,388
Revenue increase (10,000 RMB)	7.23	552	8963	11,040

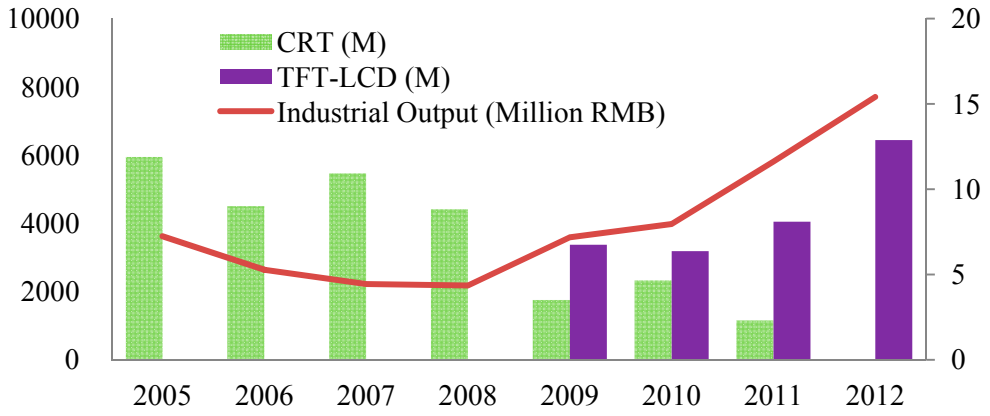
4. The EIP Case of FEDA

FEDA is located at the estuary of the Minjiang River in Fuzhou, the capital of Fujian Province. FEDA is also one of the first 14 industrial parks opened to foreign investment and granted special policy support. In 2006, FEDA was listed as one of the EIP demonstrations by MEP. The GDP of FEDA increased from USD 4.3 billion in 2006 to USD 12.5 billion in 2012. The main industrial sectors include electronics and communications, metallurgy and machining, food production, aquatic feed production, textile and logistic industries. Among them, the electronic and information industrial sector is the top industry, representing about 30% of the whole park's industrial output.

The leading company is CPTF Optronics Co., Ltd. In 2007, CPTF produced 10.2 million color-display tubes and 6.15 million color-screen tubes, ranking third in the world. However, with the sharp decrease

of the Cathode Ray Tube (CRT) market, CPTF had to change its products from CRT to Thin Film Transistor-Liquid Crystal Display (TFT-LCD) in the following three years and, finally, closed all the CRT lines in 2011 (Figure 2).

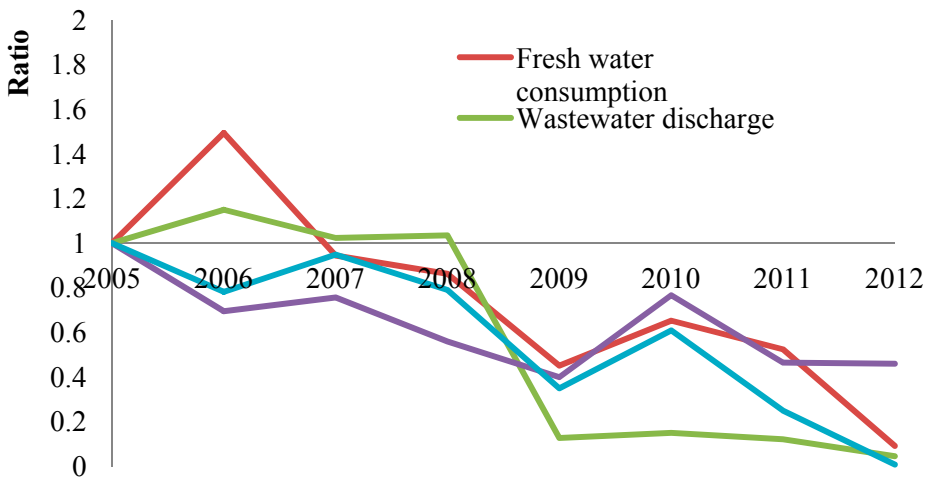
Figure 2. The transition process from CRT to TFT-LCD at CPTF. The TFT-LCD production line emerged in 2009, and the CRT production line was closed in 2011. The industrial output first decreased to its lowest in 2008 and then increased.



With the shift of the leading product, the supply chain network also changed from the CRT-based cluster to the TFT-based cluster, which brought about the complete transformation of the waste exchanging networks, then further significantly improved the eco-efficiencies of the whole industrial cluster.

The industrial water that was consumed in 2012 was 0.21 million tons, decreasing by 94% compared with the maximum 3.48 million tons in 2006. Wastewater emissions also decreased by 96%, especially with a sharp decrease in 2009 when the TFT line went into operation. Both general industrial solid wastes and hazardous waste generation had a remarkable reduction. General industrial solid wastes decreased from 3,785 tons in 2005 to 1,727 tons in 2012, down 46.0% in total; Hazardous waste generation decreased from 1,110 tons in 2005 to only 7.65 tons in 2012, which showed that the TFT module production generated much less hazardous waste than the CRT lines (Figure 3).

Figure 3. The changes of eco-efficiency indicators in FEDA.



5. The EIP Case of XHTZ

Initiated in March, 1991, and located in the southwest of Xi'an, XHTZ is among the first batch of national high-tech development zones. Since 1994, XHTZ maintained its top position among the national hi-tech zones of China in terms of comprehensive development indices. In 2010, XHTZ was listed as the national EIP demo. In 2011, XHTZ realized a fixed assets investment of RMB 33.5 billion and an industrial output value of RMB 342 billion.

XHTZ is host to about 500 active manufacturing companies, which contains more than 10 European leading manufacture bases, including Schneider Electric, Nokia and Siemens. The dominating sectors are the electronic industry, automotive industry, material industry and medical industry. In 2012, the Samsung project with seven billion U.S. dollars of investment, entered XHTZ and will have started operation in the beginning of 2014.

In 2011, 87,800 tons of industrial solid waste were generated by 54 key industries in XHTZ, of which 2282 tons are hazardous waste. With the Samsung project and the new medical industry cluster to be built, waste generation is expected to increase 4–6-times, which brings a serious environmental challenge to XHTZ.

To cope with the increasing burden of industrial wastes, especially hazardous wastes, XHTZ implemented a second round of the industrial symbiosis project with support from Tsinghua University. The project aims to improve resource efficiency, the eco-innovation capability and environmental governance through reshaping the technological and management systems of solid waste at XHTZ.

In November, 2013, XHTZ carried out two quick-win workshops on the electronic industry and automotive industrial sectors, respectively. The main results are presented in Table 2.

Table 2. Quick-win workshops summary on electronic industry and automotive industrial sectors in the Xi'an High-Tech Zone (XHTZ).

Sector	Electronic industry	Automotive industry	Waste recycling
Companies participated	10	8	4
By-products or wastes provided	42	58	-
Infrastructure needed	8	3	-
Potential synergy	20	11	22

The main wastes from the electronic industry include packaging wastes, electronic circuit boards wastes, waste batteries, waste polished resin, sludge, organic solvents, metal scraps, etching solution, waste acid, waste alkali, and others. For the automotive industry, the main wastes include paint residue, waste oil, waste organic solvents, oily waste rags, waste activated carbon, packaging waste, metal scraps, *etc*. Most of the general wastes, such as packaging wastes and metal scraps, have been taken back and recycled by waste-recycling companies. All of the hazardous wastes, according to the local Environmental Protection Bureau (EPB)'s regulation, have been transported to a special company with certification.

For the electronic industry, 13 potential synergies occurred between manufacturing companies and waste-recycling companies, and only seven synergies occurred among the manufacturing companies.

For the automotive industry, the number is nine and two, respectively. More interestingly, one cement company showed great interest in almost all wastes, "we can digest all wastes with our giant kilns".

Some problems were also uncovered at the workshop. For example, some companies wanted XHTZ could provide more utilities, such as steam, oxygen, hydrogen and purified water.

6. Conclusions: The Key Factors for EIPs in China

Distinct from the Kalundborg and other EIPs in Western countries, China's EIP construction has its own model driven by the government. That is to say, China' model is more towards the "planned" end of the industrial symbiosis spectrum mentioned by Chertow [8].

Government plays a large role as an enabler, both at the national level and at the park level. After several years of experimentation, the Ministry of Environmental Protection decided to jointly carry out the promotion and implementation of national eco-industrial parks, together with the Ministry of Commerce and the Ministry of Science and Technology. The three ministries jointly issued a notice on national eco-industrial parks, forming a leading group responsible for the review, approval and coordination of national eco-industrial demonstration parks. A number of standards and guidelines were also issued, including technological standards for sector-integrated parks, sector-specific parks and recycling-oriented parks.

The cases uncovered four factors key to the sustainable transition of EIPs in China:

(1) Government as an enabler; both central and local governments have done a lot of things to promote EIP development.
(2) Spaces for experimentation, to open windows for technological innovation, information exchange, financial support, *etc.*
(3) Technological trajectory dependency; most of the industrial parks in China have involved one or more industrial clusters, and it will be a challenge for them to go through technological uncertainty smoothly; FEDA has provided a success story.
(4) Regional embeddedness; industrial development is a truly complex thing, involving resources, capital, labor, knowledge and many other things.

We do believe EIPs can continually move from strategic niches into the mainstream of industrial development in China. To enable this transition, we recommend that:

(1) government should still act as the enabler, but be careful not to overreach in its role;
(2) spaces for experimentation should be provided continuously, including institutional innovation, technological development and business models;
(3) path dependency should be looked at more closely, and some lock-ins should be avoided, such as the clustering of polluters and the "small but complete" industrial symbiosis model;
(4) last, but not the least, social embeddedness should be fostered to strengthen regional competitiveness.

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Author Contributions

Lei Shi designed and performed research; Bing Yu analyzed the data; Lei Shi and Bing Yu wrote the paper. All authors read and approved the final manuscript.

Abbreviation

EIP	Eco-industrial Park
ETDA	Economic and Technological Development Area
HTP	High-Tech Park
TEDA	Tianjin Economic and technological Development Area
FEDA	Fuzhou Economic and technological Development Area
XHTZ	Xi'an High-Tech Zone
CRT	Cathode Ray Tube
TFT-LCD	Thin Film Transistor-Liquid Crystal Display
EPB	Environmental Protection Bureau

Conflicts of Interest

The authors declare no conflict of interest.

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