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Evolution of industrial symbiosis in an eco-industrial park in China

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ABSTRACT

Industrial symbiosis and eco-industrial park have been developed for decades and have significant economic and environmental effects in China. To research the evolution of industrial symbiosis and eco-industrial park construction, and summary the drivers and characteristics of industrial symbiosis development in China, this study uses the National Demonstration Eco-Industrial Park, namely, the Rizhao Economic and Technology Development Area (REDA), as a case study to introduce the industrial symbiosis development process and to research the evolution of industrial symbiosis and eco-industrial park construction, and summarizes the drivers and characteristics of industrial symbiosis development in China. Based on in-depth investigation of enterprises and the government in REDA, three stages (1991–2002, 2003–2006, 2007–2011) of industrial symbiosis development are identified, 31 inter-firms symbiosis performances involving cereal oil and food, machinery, pulp and paper, textile and garment, wine refining, and biochemical industries were formed since REDA was founded in 1991. Results show the environmental benefits of industrial symbiosis performances in 2011, and argue that economic benefits, mainly resulted from stricter environmental standards, tax preference, benefits from material substitution, and financial subsidies, is the critical driver for the stakeholders to participate in industrial symbiosis. The action of governments in industrial symbiosis development is to constituting strict environmental standards, resource comprehensive utilization schemes, financial support and circular economy and eco-industrial park planning guidance. This article provides some unique characteristics of industrial symbiosis growth in a developing country from enterprises and government aspects.

1. Introduction

From 1984 to 1988, Chinese industrial parks were first built in the eastern coastal areas, such as Tianjin, Yantai, Shanghai, and Guangzhou. After several decades, the number of industrial parks was at least 1568 in 2011 (Shi et al., 2012a). In the same year, the gross domestic product growth rate of industrial parks (30.3%) was significantly greater than that of the national average (9.2%). Thus, industrial parks became one of the major contributors to the economic growth in China. Early environmental pollution control and management measures (such as end-of-pipe pollution control approach and environmental impact assessment), however, were not able to ease the environmental pressure caused by the economic development of industrial parks. Thus, some parks have paid severe resource and environmental costs (Shi et al., 2012a). To resolve the contradiction between economic development and environmental pollution, the Chinese government has adopted the eco-industrial park (EIP) program in the hope of benefiting both the economy and the environment (Xie, 2002).

The EIP concept by the United Nations Environment Program was introduced in China in 1997 (Hashimoto et al., 2010; Shi et al., 2010). EIPs can improve the economic performance of participating companies and minimize their environmental impact (Lowe, 2001). EIP practices in developed countries, such as Denmark, USA, Germany, and Japan, provide useful references for EIP development in China (Geng et al., 2009; Mathews and Tan, 2011; Moriguchi, 2007; Shi et al., 2003). The State Environmental Protection Administration (SEPA) of China launched EIP pilot projects in Guangxi, Inner Mongolia, and Shandong provinces in 2001, and explored EIP planning and construction at the national level in 2003. In 2007, SEPA, the Ministry of Commerce, and the Ministry of Science and Technology jointly issued the *Management Method for the National Demonstration EIP Program* to facilitate the development of Chinese EIPs by retrofitting in national economic and technology development areas and national high-technology industrial development areas (Zhang et al., 2010). Among these national demonstration EIPs, the Tianjin Economic and Technology Development Area (Shi et al., 2010), Suzhou Industrial Park (Liu et al., 2012), Yantai

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Economic and Technology Development Area (Zhu et al., 2010), and the Dalian Economic and Technology Development Area (Geng et al., 2010) are popularly used as typical case studies for EIP construction in China. The research interest on China's EIP includes EIP management, material and energy integration, IS, planning methods, performance assessment, and low carbon development (Tian and Wei, 2012).

The operation of the EIP can impel the theory of industrial symbiosis (IS) into practice (Zhang et al., 2010). IS refers to "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and byproducts, the keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow, 2007). IS provides an analytical frame to comprehend how cooperation among enterprises can realize competitive advantage (Bain et al., 2010). Boons et al. (2011) summarizes the EIP/IS study contents, which mainly include descriptions, models, conceptual frameworks, quantitative evaluations, epistemological discussions, typologies, and methodologies (Boons et al., 2011). Jiao and Boons (2013) conducted a comprehensive review of IS literatures, they present that policy certainly impacts on IS development, but the impact of policy varies in different regions, and there is no "one-size-fit-all" approach to promote IS (Jiao and Boons, 2013). For example, in European Union countries, policy has a positive influence on IS development through indirect incentives and not through direct obligations to improve the environment performances (Costa et al., 2010; Lehtoranta et al., 2011). Financial support from government can also facilitate IS development (Mirata, 2004; Taddeo et al., 2012). Salmi et al. (2012), however, indicate that regulation is a barrier to IS and it is marked-based governance system now (Salmi et al., 2012).

Moreover, in recent years a number of articles focus on factors and drivers of EIP/IS development. Sakr et al. perform an extensive literature review on EIP projects' experiences around the world, and identify the crucial driving and limiting factors for EIPs, which are the creation of symbiotic relationship, information sharing and awareness, financial benefits, organizational structure, and legal and regulatory framework (Sakr et al., 2011). As an example, Yang and Feng summary four actors, raw materials advantages, rational production structures, technical supports and correct diversification, to make IS achievable in a traditional sugar cooperation in China (Yang and Feng, 2008). Van Beers et al. indicate that information availability, economic, region-specific issues, organizational and social issues, regulations, and technical issues are drivers, barriers, and triggers for the IS development in Australian minerals industry (Van Beers et al., 2007).

From this literature overview it is clear that policy influences and drivers for EIP/IS vary because of the different development situations in different regions. And the present researches mainly focus on EIP/IS performances in developed countries, the researches in developing countries especially in China are primarily about EIPs programs and cases rather than special studies on IS network in EIP. Meanwhile, developed and developing countries are in different stages of social and economic development, which leads to different direct targets of circular economy (CE) and IS.

The purpose of this article is to identify the function of government and to determine the drivers of promoting IS performances formation in government and stakeholder aspects through analyzing the evolution history of IS performances in China in the context of a National Demonstration Eco-Industrial Park, Rizhao Economic Technological Development Area (REDA), founded in 1991. Fig. 1 presents the schematic diagram of this research.

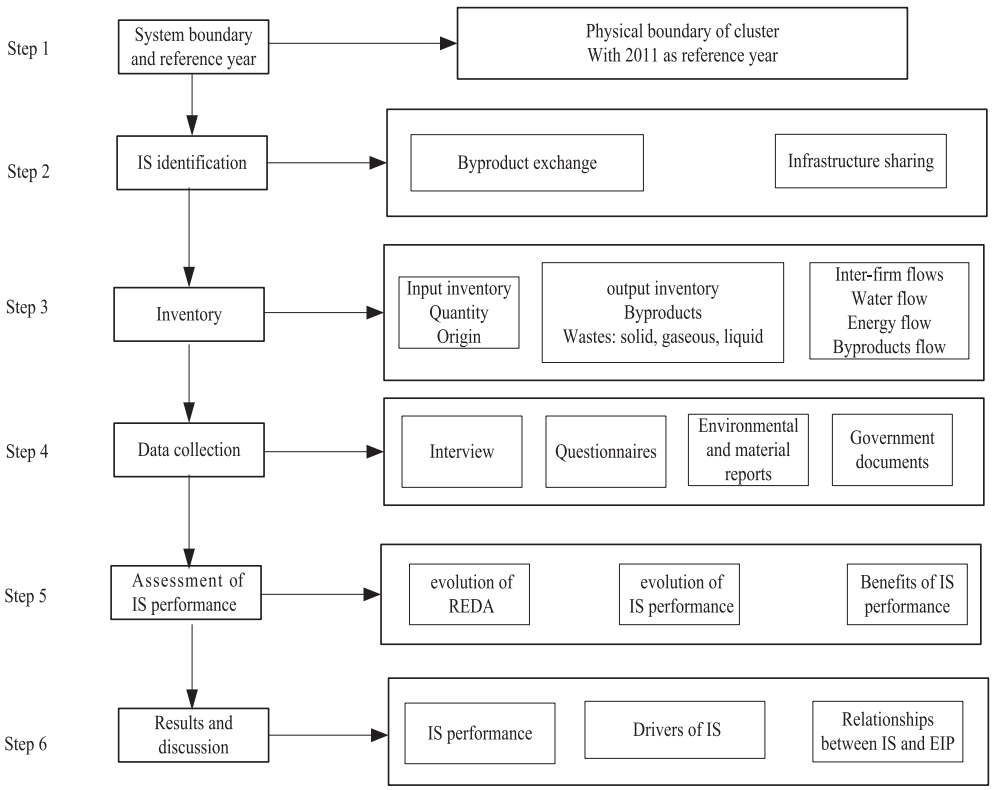

Fig. 1. Schematic diagram of the research.

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