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Promoting low-carbon city through industrial symbiosis: A case in China by applying HPIMO model

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HIGHLIGHTS

- Industrial symbiosis could contribute to low-carbon city in terms of co-benefit.
- Co-benefit of IS was in terms of waste reduction and air pollutants reduction.
- Waste plastics recycling and biomass utilization generated large co-benefit.
- Coal fly ash recycling reduced the solid waste while increased air pollutants.
- The prices of wastes and facilities investment affected the total cost-benefit.

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ABSTRACT

China launched low-carbon city strategy to respond global climate change. Industrial symbiosis (IS) could generate both economic and environmental benefits in clustered industries and communities. This research shed light on how industrial symbiosis contributes to city's low-carbon development. An urban-level hybrid physical input and monetary output (HPIMO) model which covers physical energy inputs and air pollutants emissions, is established for addressing case study in a Chinese typical industrial city (Liuzhou). Based on current energy consumption and industrial symbiosis and the application of HPIMO model, scenarios related to industrial symbiosis, including waste plastics recycling, scrap tires recycling, flying ash recycling and biomass utilization are explored. Results show that compared with business-as-usual (BAU) scenario, IS can reduce solid wastes and further contribute to the co-benefits of energy saving, CO_2 emissions reduction and air pollutants reduction. The finding is critical for national low-carbon strategy. Finally, policy implications to support the ever-improvement of IS promotion in China are proposed and discussed.

1. Introduction

China's energy consumption and the related environmental pollutions have become the great concerns. In 2010, China overtook the United States and became the world's largest energy consumer (20.3% of the global energy consumption) (BP, 2011). China also became the world's largest CO_2 emitter in 2007 (IEA, 2009) and the largest SO_2 emitter in 2005 (Su et al., 2011). Under such a circumstance, China actively promotes national strategy on energy saving and emission reduction, aiming at energy conservation, air pollutants reduction and greenhouse gas emissions (GHGs) mitigation(Hong et al., 2013).

With rapid urbanization in China, cities play an important role in terms of promoting environmental protection. Cities account for three quarters of national energy consumption and Greenhouse gas emissions (Liu et al., 2012c), are the hot-spots for addressing mitigation actions and policies. Therefore, promoting low-carbon city strategy has become critical for China's national energy saving and emission reduction plan. Lead by National Reform and

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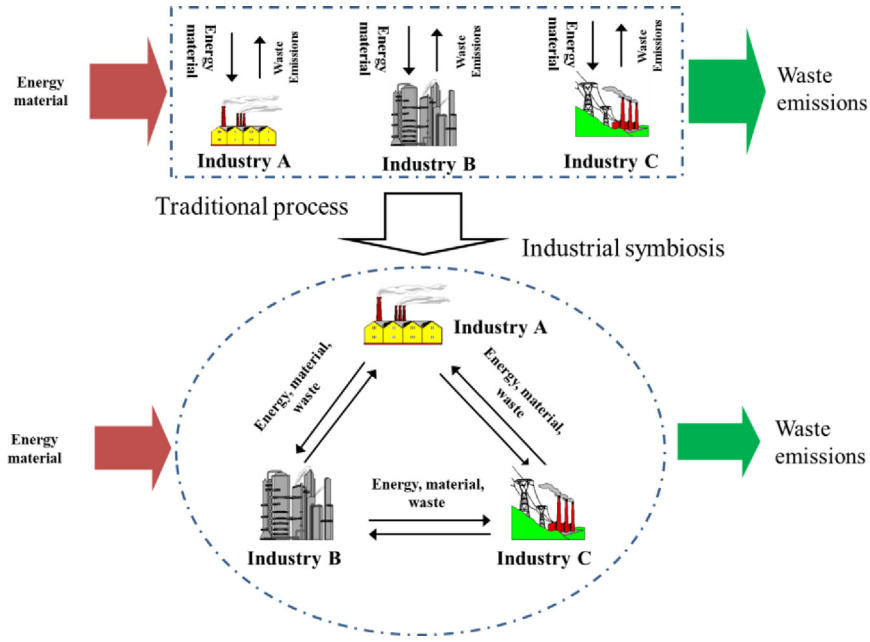

Fig. 1. Schematic diagram of industrial symbiosis.

Development Commission (NDRC), eight Chinese cities have been selected as national low-carbon city pilot project[1] (Su et al., 2012; Yang and Li, 2013). The planned low-carbon oriented measures include industrial structure upgrading, industries relocation, energy structure optimization, energy efficiency technologies application, low-carbon transportation and so on(Cao and Li, 2011; Feng and Zhang, 2012; Lehmann, 2013; Tao, 2011).

Apart from the above mentioned measures, applying industrial symbiosis (IS) could promote low-carbon strategy. Shown in Fig. 1, IS is defined as a relationship in which at least two unrelated industries exchange materials, energy and/or by-products in a mutually beneficial way through the co-operation, leading to a collective benefit greater than the total sum of the individual benefits without a symbiosis could be achieved(Chertow, 2000, 2007; Chertow and Lombardi, 2005; Eckelman and Chertow, 2009; Hashimoto et al., 2010; Jacobsen, 2006). It provides a specific opportunity for industries and communities to improve their eco-efficiency (Chertow, 1998, 2000; Mirata and Emtairah, 2005). In addition, as an extended concept of IS, urban symbiosis, which is a specific opportunity arising from the geographic proximity of urban and industrial areas (Chen et al., 2011; Geng et al., 2010; Van Berkel et al., 2009), could innovatively utilize the urban wastes into industries and reducing the related energy consumption and air pollutants.

The promotion of IS could significantly reduce the carbon emissions at industrial cluster level (Hashimoto et al., 2010; Li et al., 2010; Park et al., 2008; Sokka et al., 2011; Van Berkel, 2010) and city level (Geng et al., 2010; Jacobsen, 2006). In general, as a system innovation, IS could lead to "co-benefits" of energy conservation, GHGs mitigation, solid waste and air pollutants reductions (Aunan et al., 2004; Crawford-Brown et al., 2012; He et al., 2010; Li and Crawford-Brown, 2011; Preval et al., 2010), facilitating city's low-carbon city development.

China's rapid industrialization results in soaring increased manufacturing industries, especially the heavy industries such as iron and steel, cement and chemical industry. Many of these industries locate in the Chinese cities, particularly in the newly established industrial parks (Li et al., 2010; Li and Su, 2012). This provides a great potential for Chinese cities to promote industrial symbiosis as well as low-carbon strategy, requiring a systematical evaluation so that quantitative evidences can be provided for future policy making. However, comprehensive study focus on this topic remains challenging, due to model limitation and data unavailability.

This study tries to fill such a gap by evaluating how IS can facilitate low-carbon city construction from the co-benefits of energy saving, CO_2 and air pollutants reduction through waste and/or byproducts exchange and recycling. Liuzhou city, one typical heavy industrial city in southern China, was selected as the case. Along with business-as-usual (BAU) scenario, four IS (including waste recycling) scenarios were designed and evaluated by applying hybrid physical input–output model at city's level.

The paper organized as below. After this introduction section, research methodology is detailed, including data collection and treatment and calculation methods. Then, the background of case area is illustrated, and then scenario designs presented. After that, research outcomes are shown and discussed. Based on results discussion, policy implications are proposed in order to facilitate the low-carbon city development. Finally, conclusion is given in the last section.

2. Methodology and data

2.1. System boundary

Fig. 2 illustrates the geographical scale of research system boundary. The whole city is divided as the industrial zone and urban community. There are complex material and energy flow exchanges among industries and urban communities. Such exchanges can reduce the total consumption on virgin materials and energy sources, resulting in less CO_2 and other pollutants emissions.

[1] China's National Development and Reform Commission (NDRC) launched low-carbon city experimental project in Beijing on Aug. 18, 2010. The project will be implemented in eight cities, namely Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang and Baoding. Source: http://www.worldbank.org/en/news/feature/2012/05/03/sustainable-low-carbon-city-development-in-china