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Comprehensive development of industrial symbiosis for the response of greenhouse gases emission mitigation: Challenges and opportunities in China

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ABSTRACT

Although not yet a global consensus, there is widespread agreement that climate change is the result of anthropogenic sources of greenhouse gases (GHG) emissions. In order to respond to this issue, society has applied such strategies as clean energy development, improving industrial resource efficiency etc. Despite this, GHG emissions are still pursuing an upward trend. As the largest global GHG emitter, China faces a considerable challenge in responding to its agreed target of 40–45% GHG emission mitigation per unit gross domestic production (GDP) by 2020 as compared to 2005 levels. How to practically achieve this is still largely undecided. Comprehensive development of industrial symbiosis around nationwide is considered part of the solution. However, few researchers have studied how to actually implement a comprehensive development of industrial symbiosis for the purpose of GHG emission mitigation. This work intends to address this gap through highlighting the opportunities to develop such an approach for particular application to GHG emissions reduction in China. In addition, this study will also address the challenges ahead associated with the implementation of such a strategy, and outlines the where future research could be focused. Policy implications like establishing industrial symbiosis indicators associated with GHG emission mitigation are proposed.

1. Introduction

1.1. Current situation of GHG emissions globally and in China

Climate change poses a fundamental threat to habitat, species and people's livelihoods. There is a broad consensus that anthropogenic GHG emissions have contributed significantly to global climate change (IPCC, 2007). In the past over 20 years, global carbon dioxide increased rapidly from 2.7 billion tons in 1990 to 33.9 billion tons in 2011 despite attempted mitigation. GHG emission reduction is now seen as the primary mitigative action to combat climate change. In recent years, tracking GHG emissions has become an increasingly important aspect of a global climate change research as such data inform both national and international political, economic and environmental negotiations (Gao et al., 2009). In addition, many nations are taking a sector-based approach to the implementation of such action, targeting specific high-emitting industries with emissions caps, reduction targets or other measures designed to incentivize or regulate emission outputs.

During the past COP21 event, the international community agreed to strive for emissions targets that would limit the global temperature increase 2 °C till 2030. In order to achieve this goal, measures are being taken globally to develop more robust mechanisms for monitoring and influencing national GHG emission trends, thereby determining whether such trends suggest national targets are consistent with collective climate goals (OECD, 2015). For instance, the implementation of carbon tax (or similar eco-fiscal policies) has been one much discussed mechanism. So far, approximately 40 nations, and 23 cities,

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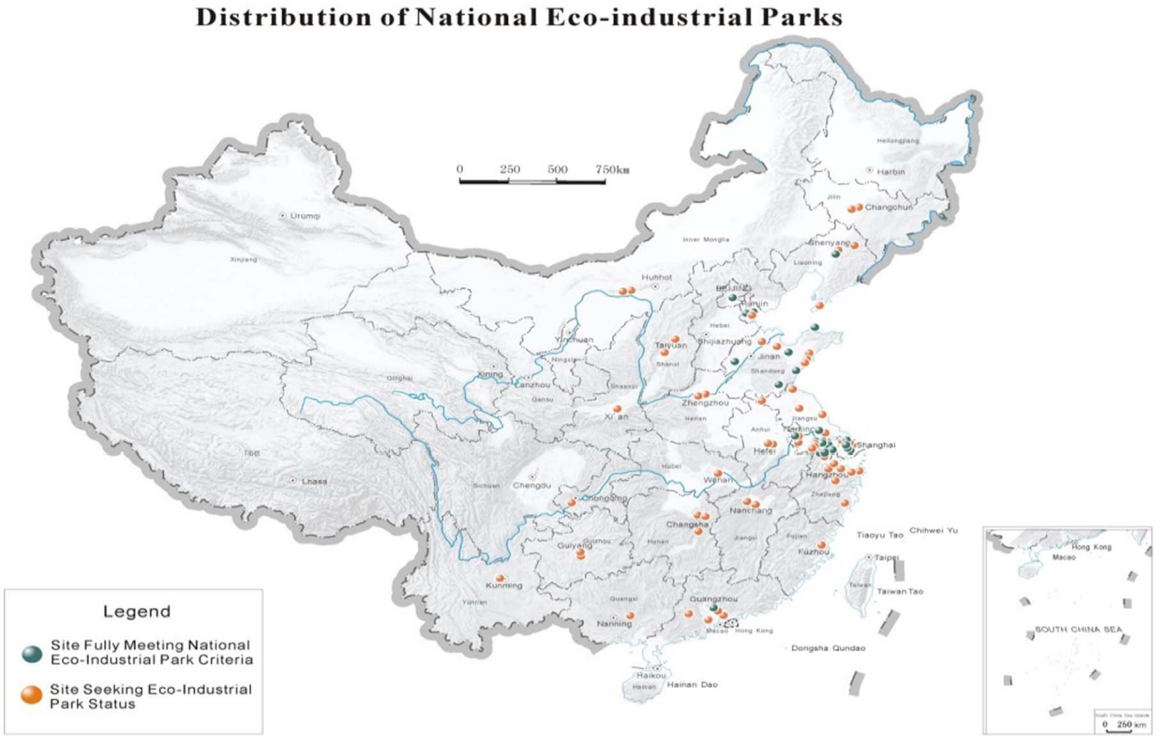

Fig. 1. Distribution of eco-industrial park projects in China.

states and/or regions around the world are using some kind of carbon pricing schemes (emissions trading systems (ETS) or carbon taxes) representing about 7 billion tons of carbon dioxide, or 12% of global GHG emissions (World Bank, 2015).

With rapid economic development and urbanization, China is now the world's top consumer of primary energy and CO_2 emitter. In 2013, China released one quarter of the global total CO_2 emissions, which was 1.5 times that of the United States. Without effective mitigation approach, CO_2 emissions in China will continue to rise by more than 50% in the next 15 years (Guan et al., 2009; Liu et al., 2015a). In order to address this situation, the Chinese government has implemented various energy programs to promote energy efficiency. For instance, the National Development and Reform Commission (NDRC) announced "national energy intensity targets" in accordance with the national "Five-Year Social and Economic Development Plan" (Geng, 2011) aiming at improving energy efficiency across sectors. Likewise, an energy efficiency target of 16% energy intensity reduction was included in the national 12th Five-Year Plan (2011–2015). Renewable energy projects have also been supported and developed by the government leading China to make significant progress in developing clean technology including solar and wind energy. For instance, the State Grid Corporation is actively supporting the development of grid-connected wind power projects. Since 2006, the company initiated to publish 20 guidelines for maintaining optimal wind power standards including aspects such as access, operational scheduling, and network monitoring. In addition, new wind projects are implemented using the most advanced technologies, which ensure every possible effort for the stability of the wind power output application. Wind power forecasting systems, and wind turbine control are also integrated into the systems. (Ma et al., 2013).

In other aspects, local governments have their own reduction targets based upon its GDP level. Under some circumstance, national and local governments have joined together to respond the issue of GHG emission mitigation. For instance, one strategy applied by both national and local governments was to shut down large numbers of inefficient power plants and industrial facilities during 2005–2010, replacing them with higher efficiency operations and equipment. During that period, facilities with a total production capacity of 100 Mt of iron, 250 Mt of cement, 55 Mt of steel, and 50 Mt of coal-burning power generation were shut down or replaced (Xinhuanet, 2007; Liu et al., 2012a).

Unfortunately, despite current efforts of the Chinese government, GHG emissions are still increasing rapidly, suggesting additional strategies will be needed to achieve meaningful emission reduction. One such strategy could involve the comprehensive implementation of industrial symbiosis (IS) as a mechanism for more resource efficient industrial operations and development, thereby leading to lower overall industrial emissions – including GHGs.

1.2. Industrial symbiosis and its link to GHG emissions reduction

Over the past few decades, the rate of resource consumption and depletion has increased rapidly, inextricably linked to accelerating economic growth and poor resource management globally. Industrial ecology emerged within the global scientific community in 1989, as a strategy to de-couple economic growth and resource consumption (Heeres et al., 2004). As one element of industrial ecology – IS has gained increasing attention in this regard. IS has been defined as a physical exchange of materials, energy, water, and/or by-products to promote resource efficiency between traditionally separate industries with the intent of promoting collective competitive advantage (Chertow, 2000). IS can also be categorized conceptually as collective resource optimization based on byproduct exchanges and utility sharing among facilities. In an ideal setting, byproducts (waste) and energy are exchanged by the actors of the system, thereby reducing the consumption of virgin material and energy inputs and the generation of waste and emissions (Sokak, 2011). Over the last two decades, IS has transitioned from a curiosity to a meaningful business strategy, practiced at various scales including eco-industrial parks (Cote and Cohen Rosenthal, 1998; Boix et al., 2012), industrial ecosystems (Cote and Hall, 1995; Bain et al., 2010), industrial recycling networks (Schwartzand Steininger, 1997; Zhang et al., 2011), and by-product-synergies (Zhang et al., 2010).

In China, the IS concept emerged after eco-industrial park (EIP)