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Urban energy flow processes in the Beijing–Tianjin–Hebei (Jing-Jin-Ji) urban agglomeration: combining multi-regional input–output tables with ecological network analysis

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ABSTRACT

Regional disparity is due to economic development, physical geography, and lifestyle. Jing-Jin-Ji urban agglomeration is advocating integrated development, but its development is not so smooth. The goals of this research are to identify the energy utilization characteristics of the three regions and their ecological roles, and to promote the integrated development of this agglomeration system. To do so, we used the concept of "urban metabolism", and abstracted sectors and energy flows as nodes and paths in a network model. Based on multi-regional input–output tables in China in 2002 and 2007, the monetary values in the tables can be converted into physical units. Furthermore, combining these tables with ecological network analysis can assess the indirect energy consumption of each sector, then its embodied energy consumption will be accounted for. Also, this method can reflect the roles (producer or consumer) of the three regions and of the five sectors in each region in regional energy exchanges. The results showed that Hebei had the largest embodied energy consumption in both years, with Beijing coming second. The ecological roles of the three regions did not change greatly between 2002 and 2007: Hebei acted as a producer, and Beijing and Tianjin served as consumers. Exploitation relationships were dominant in both years. This analysis provided insights that will support planning to adjust the industrial structure and future integrated development of the agglomeration.

1. Introduction

With the development of urbanization and industrialization, urban agglomeration system has become an active and potential area in economic development. In the context of China, an urban agglomeration represents a group of cities with similar development processes, cultures, scales, and geographical locations. These adjacent urban systems evolve into a single tightly coupled system with large flows of energy and materials among the components of the system; the agglomeration may develop a single governing body, or each urban system may be governed independently (Qu et al., 2013). The urban agglomeration systems in China are developing rapidly. Their collective area was only 25% in 2012, but has 62% of the population and accounts for 80% of gross domestic products (GDP) (Fang, 2014).

Jing-Jin-Ji urban agglomeration is one of the national key construction projects and also the center of national politics, economy, culture, and technology (Li and Chen, 2009). The Jing-Jin-Ji region of northeastern China lies on the shores of the Bohai Sea (Fig. 1). The total area is 21.67×10^6 ha. It is the most active and developed area in northern China. Its population accounted for 7.1% of China's total, and its GDP accounted for nearly 14.3% of China's total in 2012. However, the integrated development of Jin-Jin-Ji region and their coordination has not yet been so successful. According to <Blue Book of Mega-city Regions (2013)>, based on the economic data, the Pearl River Delta ranked first, then was the Yangtze River Delta, and the last one was Jing-Jin-Ji region. Meanwhile, the development of regional integration was constrained by the administrative system. The imbalance among the three regions is obvious. Beijing is the capital, and Tianjin and Hebei are dependent on it for resource allocation and administrative coordination. And

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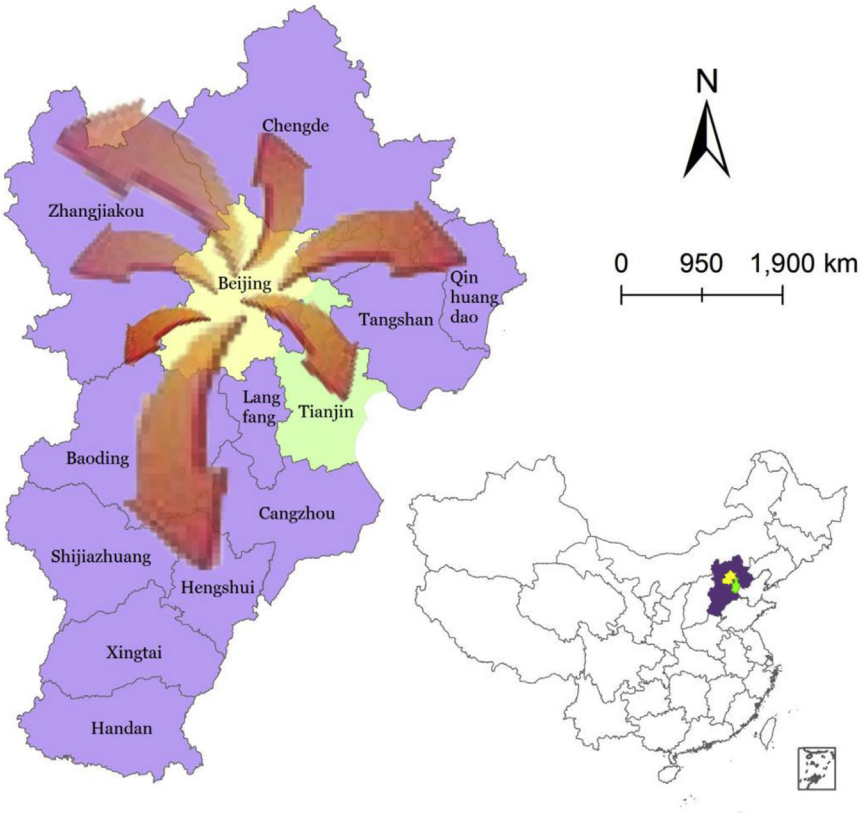

Fig. 1. The location and regions of the Jing-Jin-Ji (Beijing–Tianjin–Hebei) urban agglomeration. The industrial transfer directions (i.e., red arrows that show relocation of industries from Beijing to surrounding areas) are based on the information from <http://www.thfr.com.cn/post.php?id=4327>. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

this influences the integration and cooperation of Jing-Jin-Ji region. Therefore, we will introduce the concept of "urban metabolism" from ecosystem, treat regions as organisms, and analyze the energy metabolic processes of sectors within regions, in order to coordinate the development of three regions and identify their ecological roles on the regional energy utilization.

When Wolman (1965) first proposed the concept of urban metabolism, he regarded the city as analogous to an ecosystem, and proposed that urban metabolism comprised the processes by which materials, energy, and food were imported into the ecosystem while products and wastes were exported from that system. Current analysis of urban metabolism focuses on a single city or several cities in one region. Also, the urban agglomeration metabolism analysis has been developing (CASS, 2006). These researches concentrated on the dynamics of metropolitan metabolic flows, such as the metropolitan metabolic flow analysis of Toronto (Sahely et al., 2003), of 12 cities (Kennedy et al., 2010), and of Asian cities (Ferrão and Fernández, 2013). These analyses showed that different cities have different metabolic characteristics.

Regional disparity is due to economic development, physical geography, and lifestyle (Dong et al., 2015). On the worldwide level, this disparity shows from the perspectives of resource and energy flows, and also includes pollutant emissions among different countries. The analysis of embodied energy is useful for the policy makers to design appropriate energy policies and industrial policy (Cui et al., 2015). Embodied energy refers to total energy consumed in all activities necessary to support a process, including upstream processes (Treloar, 1997). It is an accounting method that aims to find the total energy necessary for an entire product life-cycle (Thormark, 2002). For example, Cui et al. (2015) analyzed the embodied energy flows in import and export between China and other countries from 2001 to 2007, or Cortés-Borda et al. (2015) stated the renewable energy embodied in imported goods/services. On pollutant emission analysis, Mundaca et al. (2015) discussed embodied carbon dioxide emissions in Sweden during 40 years.

Meanwhile, regional disparity is also shown on a national level, for example, in China. With totally various economic conditions, China could be even seen as a "small world", in which the relationship between developing and developed exists within a single country's boundary. Regional disparity in geography and socio-economy brought a great challenge for China's energy and emission reduction (Dong and Liang, 2014), and would influence the effectiveness and efficiency of the control policy (Meng et al., 2011). For example, Liang et al. (2007) divided China into eight regions using data from 1997. They accounted for and compared the embodied energy consumption of all these regions from final consumption, and also predicted their energy consumption in 2010 and 2020. As China is a huge country composed of more than 30 administrative regions with different scales, structures and intensities of energy consumption (Li et al., 2014), the corresponding regional targets and measure should be developed according to the specific characteristics of each region, and as energy consumption has a strong relationship with economic growth (Herrerias et al., 2013) and with the development of secondary industry (Zhang and Xu, 2012) and trade (Liu et al., 2010), the interregional supply chains will impose huge energy resource requirements to other regions (Zhang et al., 2014a).

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