Energy Policy 47 (2012) 298–308

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

CO_2 emission inventories for Chinese cities in highly urbanized areas compared with European cities

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HIGHLIGHTS

- ► An exemplary study of GHG emission inventory for Chinese cities.
- ► Estimate CO_2 emissions of Chinese city in highly urbanized areas from 2004 to 2010.
- ► The studied Chinese cities contribute higher per-capita emissions than European's.
- ► Emissions of residential sector and private transport in China are growing rapidly.
- ► Several policy suggestions considering regional disparities are provided.

ARTICLE INFO

Article history:
Received 13 February 2012
Accepted 29 April 2012
Available online 26 May 2012

Keywords:
Emission inventory
Highly urbanized area
Comparison analysis

ABSTRACT

The international literature has paid significant attention to presenting China as the largest emitter of greenhouse gases (GHGs) in the world, despite having much lower per-capita emissions than the global average. In fact, the imbalance of economic development leads to diversity in GHG emissions profiles in different areas of China. This paper employs a common methodology, consistent with the Sustainable Energy Action Plan (SEAP) approved by the Covenant of Mayors (CoM), to estimate CO_2 emissions of four Chinese cities in highly urbanized areas from 2004 to 2010. The results show that the CO_2 emissions of all four cities are still rising and that secondary industries emit the most CO_2 in these cities. By comparing these data with the inventory results of two European cities, this paper further reveals that Chinese cities in highly urbanized areas contribute much higher per-capita emissions than their European competitors. Furthermore, the per-capita CO_2 emissions of the residential sector and private transport in these Chinese cities are growing rapidly, some of them approaching the levels of European cities. According to these findings, several policy suggestions considering regional disparities are provided that aim to reduce the CO_2 emissions of highly urbanized areas in China.

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1. Introduction

The statistical data from the IEA highlight China's role as a global polluter, who has overtaken the United States in 2009 to become the world's largest energy user, accounting for 17% of the world's demand, and has been predicted to reach 22% of global demand by 2035 (IEA, 2010). This conclusion draws significant criticism on the Chinese government when the world community struggles to organize a post-Kyoto climate regime and achieve their promises with respect to climate change. China has announced its national emission reduction target till 2020 in the Copenhagen Climate Conference, however, it rejects accepting the Measurable, Reportable,Verifiable (MRV) principle by citing *common but differentiated responsibility*. Without an open and clear evaluation on its CO_2 emission, it might be hard to convince the global community to believe China's endeavors and achievements on carbon mitigation. Hence, it is significant to execute a research on emission inventories in China and compare the results with its global partners.

A bewildered cognition about emissions volumes in China is useless to assist the right policy decision for curbing climate change. IEA considers the China's emission issue from national perspective, while the opposing viewpoints of Chinese senior officials and some scholars asserts that, on a per capita basis, China's CO_2 emissions of 3.9 t in 2005 are only one-fifth those for the U.S. (19.5 t). Neither national emissions nor per-capita emissions can precisely describe the status quo of GHG emissions in China, because China is such a gigantic country with a large land

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0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.04.071

mass and huge population that it is misleading to view it as a monolithic entity (Huang and Todd, 2010). Significant intercity and regional disparities exist regarding economic development, industrial structure and energy usage, all of which are fundamental to the energy consumption differences between Eastern and Western China. Thus, studying China's GHG emissions, especially CO_2 emissions, at the city level considering regional disparities is important.

Cities are recognized as playing a significant role in the global climate action, because they are the major sources of energy consumption based on their being centers of wealth and resources with high population densities. For example, in China, urban areas accounted for 75% of the national primary energy demand and 85% of the national commercial energy demand (Dhakal, 2009). Both the sources of GHGs and the opportunities for controlling their emissions exist at the local level (Wilbanks and Kates, 1999). Thus, cities should assume the responsibility for GHG emissions reduction to mitigate the effect of global climate change. To achieve this goal, quantifying the amount of CO_2 generated by energy consumption, i.e., creating a CO_2 emissions inventory for each city is an important first step.

A number of studies have been carried out to investigate energy consumption and CO_2 emissions in China, especially CO_2 emissions, from a national perspective (Wei et al., 2006; Wang et al., 2010; Zhang et al., 2009). Several of these studies focused on emissions from a sectoral perspective, such as the transport sector (Cai and Xie, 2007; Yan and Crookes, 2009; Wang et al., 2007) and the building sector (Chen et al., 2008a; Chen et al., 2008b). Few studies have investigated cities' emissions in China, and those that did so, such as Li et al. (2010), only explored the mega-cities. Although Dhakal (2009) produced a general snapshot of urban energy use in 35 Chinese cities, very few scholars have tried to evaluate overall CO_2 emissions of Chinese cities as Kennedy et al. (2011) and his colleagues did for global cities and metropolitan regions. The lack of comparative emissions investigations in cities blurs the emission situation in China and obstructs the development of appropriate policies to fit the disparities among different regions in China.

The main aim of this study is to estimate the CO_2 emissions inventories of four Chinese cities in a typical region by collecting statistical data, analyzing the characteristics of emissions in recent years, and deducing future trends. Furthermore, after comparing results with emissions data for European cities in same period, this paper will propose several polices to assist Chinese cities in reaching their goal of switching to low-carbon development. The remainder of this paper is organized as follows. In the next section, we introduce an IPCC-based method by SEAP for estimating city CO_2 emissions that has been widely used in Europe, discuss the data collection process, and employ this method for four Chinese cities. The main results of the emissions inventory are reported in Section 3, and the corresponding analyses are also presented. In Section 4, several policy implications are given according to the comparison between European and Chinese cities. Finally, several conclusions are drawn in Section 5.

2. Methodology

2.1. Method selection

Global concern regarding climate change has led a variety of entities to develop approaches to monitor and reduce emissions at both national and local scales. Some of these approaches are widely accepted and universally employed throughout the world, such as the International Local Government Greenhouse Gas Emissions Analysis Protocol (IEAP) (ICLEI, 2009), the GHG Protocol (WRI/WBCSD, 2004), the Greenhouse Gas Regional Inventory Protocol (GRIP) (Carney et al., 2009) and the Sustainable Energy Action Plan (SEAP) by the Covenant of Mayors (CoM, 2010). In general, all of the emission evaluation methods established by these entities essentially obey the Intergovernmental Panel on Climate Change (IPCC, 2006) guidelines under UNFCCC. Because IPCC guidelines are the international standard for national GHG inventories and reporting, these four approaches are established for inventories of local governments or corporations with adaptations or simplifications. Table 1 presents a comparison of the four approaches with respect to their methodological distinctions.

A complete emissions inventory includes reliable data sources with appropriate methodological complexity (tiers) as well as the careful tracking of the operational boundaries (scopes). With respect to the accuracy of calculations, the concept of tiers is particularly important. The tier represents the level of complexity in methodology, and the higher tier methods generate more accurate results. However, acquiring high-quality databases is time and resource intensive, so the most basic estimation methodologies are the common choice for all approaches at the city scale. In order to avoid the possibility of double counting and misrepresenting emissions, the World Resources Institute/World Business Council for Sustainable Development (WRI/WBSCD) defined three scopes for government operations and community-scale inventories, which are now widely employed by all of the emissions evaluation approaches to express emissions in relation to the spatial boundary of a city. Scope 1 emissions include those that are produced by direct emission sources within city boundaries, such as fossil fuel combustion, industrial consumption, residential and municipal use and Scope 2 emissions include indirect emission sources limited to electricity, district heating and steam and cooling consumption, which are mainly produced outside of city boundaries. While, Scope 3 emissions cover all the direct and indirect emissions, including those out of boundary. According to Table 1, the present study employs the SEAP inventory method established by the CoM because it offers a moderately difficult technique for estimation, which is sufficiently robust and compatible with the IPCC guidelines, and because it investigates within an appropriate scope, which is closely related to city activities. Such method can be easily implemented by Chinese cities.

In addition, SEAP also provides consistency for international comparisons and communication on the reduction experiences of global cities. For urban spaces, an open, global and continuously

Table 1
Comparison of the methodology used by the four approaches.

Operational boundaries		Methodological complexity		
		Tier 1	Tier 2	Tier 3
Scope 1	In boundary emissions			
Scope 2	Scope 1 emissions and in boundary energy use		SEAP	
Scope 3	Scope 2 emissions and out of boundary energy use (and further out of boundary emissions)	GRIP	GHG protocol*	IEAP

* Not available for geopolitical boundary.

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