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Methane emissions by Chinese economy: Inventory and embodiment analysis

Bo Zhang, G.Q. Chen*

State Key Laboratory of Turbulence and Complex Systems, College of Engineering, Peking University, Beijing 100871, PR China

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ABSTRACT

Concrete inventories for methane emissions and associated embodied emissions in production, consumption, and international trade are presented in this paper for the mainland Chinese economy in 2007 with most recent availability of relevant environmental resources statistics and the input–output table. The total CH_4 emission by Chinese economy 2007 estimated as 39,592.70 Gg is equivalent to three quarters of China's CO_2 emission from fuel combustion by the global thermodynamic potentials, and even by the commonly referred lower IPCC global warming potentials is equivalent to one sixth of China's CO_2 emission from fuel combustion and greater than the CO_2 emissions from fuel combustion of many economically developed countries such as UK, Canada, and Germany. Agricultural activities and coal mining are the dominant direct emission sources, and the sector of *Construction* holds the top embodied emissions in both production and consumption. The emission embodied in gross capital formation is more than those in other components of final demand characterized by extensive investment and limited consumption. China is a net exporter of embodied CH_4 emissions with the emission embodied in exports of 14,021.80 Gg, in magnitude up to 35.42% of the total direct emission. China's exports of textile products, industrial raw materials, and primary machinery and equipment products have a significant impact on its net embodied emissions of international trade balance. Corresponding policy measures such as agricultural carbon-reduction strategies, coalbed methane recovery, export-oriented and low value added industry adjustment, and low carbon energy polices to methane emission mitigation are addressed.

1. Introduction

As the largest developing country in the world, China has been reckoned as the world's largest emitter of carbon dioxide (CO_2) since 2007 (IEA, 2009), and the issue with greenhouse gas (GHG) emissions in China has become a focus for policy makers, researchers, and other groups around the world (Zhang, 2010).

Methane (CH_4) is considered as the second most important GHG after CO_2 and contributed about 14.3% of the total anthropogenic GHG in 2004 over the world (IPCC, 2007). As to China, the GHG emission inventory for China 1994, according to the Initial National Communication on Climate Change of China (INCCCC, 2004), gave an estimate of CH_4 emissions that totaled 34,287 Gg, accounting for 23.43% of the total GHG emission by the CO_2-eq value.

Direct anthropogenic CH_4 emissions in China have been widely explored. China is the largest producer of rice grain with the world's second-largest area of rice paddies and has a flourishing livestock production with a rapid increase in livestock numbers and the largest meat and egg yields in the world. Over the years, the dominating role of agricultural activities on CH_4 emissions has instigated a large number of studies on CH_4 emissions from Chinese rice paddies (e.g., Cao et al., 1995; Cai, 1999; Wang, 2001; Li et al., 2002; Yan et al., 2003; Huang et al., 2006; Khalil and Shearer, 2006; Wang et al., 2008; Zhang et al., 2009), CH_4 emissions from Chinese livestock in specific years (e.g., Liu et al., 2000; Yamaji et al., 2003; Zeng et al., 2009), or as long time series (e.g., Khalil et al., 1993; Zhou et al., 2007), and total CH_4 emissions from the Chinese agriculture as a whole (e.g., Song et al., 1996; Verburg and Denier, 2001; Guo and Zhou, 2007). Meanwhile, China is the largest coal producer in the world, but effective exploitation of coalbed methane resources in China has been remaining in the assessing and testing stage for a long time (Yu et al., 2007). Many concrete efforts have been made to account the methane emissions from coal mines (e.g., Bibler et al., 1998; Zheng, 2002; Yuan et al., 2006; Yang, 2009) and other sources such as municipal solid waste (MSW; e.g., Xu, 1997; Gao et al., 2006) and fuel combustion of social-economic sectors (e.g., Ji and Chen, 2009). In particular, CH_4 emission inventories of China in some early years such as 1980s, 1990, 1994 (e.g., Khalil

* Corresponding author.
E-mail addresses: gqchen@pku.edu.cn, gqchen_pku@yahoo.com (G.Q. Chen).

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et al., 1993; Wang et al., 1993; Zhang et al., 1999; INCCCC, 2004) and some recent years such as 2005 and 2006 (e.g., EPA, 2006; Cai, 2009; Zhang and Chen, 2010) have been provided.

The embodied (direct plus hidden) methane emissions in economies have been extensively accounted in the multi-scale ecological input–output analyses of environmental emissions and resources use by Chen and his fellows: in his doctoral dissertation Zhou (2008) presented two sets of databases for embodiment intensity of CH_4 emissions, one for Chinese economy 1992 under the Material Product System (MPS) for planning economies of the socialist Soviet style and another for Chinese economy 2002 under the System of National Accounts (SNA) for marketing economies; Chen et al. (2010) accounted the emission embodiment in Chinese economy 2005; Chen et al. (2009) simulated the emission embodiment in the global economy 2000; Zhou et al. (2009) provided the embodiment intensity in the regional urban economy of Beijing 2002. More detailed methane embodiment analysis via IOA remains to be made for the Chinese economy on updated inventory of CH_4 emissions.

The target of the present work is to present a detailed CH_4 emission inventory 2007 covering main sources, including energy production, agricultural activities, waste treatment, etc., and to systematically reveal the CH_4 emission embodiment in production, consumption, and international trade of Chinese economy, with the most recently available input–output table and relevant environmental resources statistics.

The rest of the paper is composed as follows. In Section 2, the estimate method, related data sources, an aggregated input–output table, and the algorithms for input–output analysis and basic embodied emissions are introduced. The CH_4 emission inventory by source and by sector is created and analyzed in Section 3. Section 4 presents embodied emission intensities and illustrates the embodied emissions in production, consumption, and international trade. Corresponding policy implications are addressed in Section 5, and main conclusions are drawn in the ending section.

2. Methodology

2.1. Estimate of direct methane emissions

Direct methane emissions from remarkable sources such as agricultural activities, coal mining, oil and natural gas leakage, fossil fuel burning, industrial wastewater, domestic sewage, and municipal solid waste treatment are estimated mainly according to IPCC (2006). Previous researches about the CH_4 emission factors of different sources are investigated, and specific emission factors are adopted to suit the Chinese situation. Since some specific emission factors are not available, the IPCC default emission factors provided in IPCC (2006) are adopted directly. As the direct calculation of some other emissions is difficult, as a preliminary approximation, some assumptions associated with some recent studies for CH_4 emissions will be made.

2.2. Data sources

Most of the relevant environmental resources data are adopted or derived from the public issued official statistical yearbooks such as China Agriculture Yearbook (CAY, 2008), China Energy Statistical Yearbook (CESY, 2008), China Environment Yearbook (CEY, 2008), China Statistical Yearbook (CSY, 2008), and other databases such as FAO (2009).

To comply with relevant environmental resources data, the 42 sectors covered in the input–output table of China 2007 (NBS, 2009) are aggregated into 26 sectors as listed in Table 1 to compose a revised input–output table for Chinese economy 2007, as partially presented in Table A1 in the Appendix.

Table 1
Sector information for input–output embodiment analysis.

Sector code	Sector category
A1	*Farming, forestry, animal husbandry, fishery and water conservancy (Agriculture)*
A2	*Coal mining and dressing*
A3	*Petroleum and natural gas extraction*
A4	*Ferrous and nonferrous metals mining and dressing*
A5	*Nonmetal and other minerals mining and dressing*
A6	*Food processing, food production, beverage production, tobacco processing*
A7	*Textile*
A8	*Garments and other fiber products, leather, furs, down and related products*
A9	*Timber processing, bamboo, cane, palm and straw products, furniture manufacturing*
A10	*Papermaking and paper products, printing and record medium reproduction, cultural, educational, and sports articles*
A11	*Petroleum processing and coking, gas production and supply*
A12	*Raw chemical materials and chemical products, medical and pharmaceutical products, chemical fiber, rubber and plastic products*
A13	*Nonmetal mineral products*
A14	*Smelting and pressing of ferrous and nonferrous metals*
A15	*Metal products*
A16	*Ordinary machinery, equipment for special purpose*
A17	*Transportation equipment*
A18	*Electric equipment and machinery*
A19	*Electronic and telecommunications equipment*
A20	*Instruments, meters, cultural and office machinery*
A21	*Other industrial activities*
A22	*Electric power, steam and hot water production and supply*
A23	*Construction*
A24	*Transport, storage, postal and telecommunications services*
A25	*Wholesale, retail trade, hotels, catering service*
A26	*Other service activities*

2.3. Input–output analysis and embodied emissions

The concept of embodied emission facilitates a deeper appreciation of the sectoral total emission requirements in terms of both the direct, visible and indirect, hidden emission costs. The input–output model originally introduced by Leontief to analyze the interdependence of economic sectors has been rigorously extended and widely used in the sectoral embodiment analysis of environmental emissions in general (Wiedmann et al., 2007; Miller and Blair, 2009; Wiedmann, 2009), more recently of GHG emissions in particular (e.g., Lenzen, 1998; Labandeira and Labeaga, 2002; Sánchez Chóliz and Duarte, 2004; Mongelli et al., 2006; Peters and Hertwich, 2006; Shui and Harriss, 2006; Fan et al., 2007; Liang et al., 2007; Limmeechokchai and Suksuntornsiri, 2007; Mäenpää and Siikavirta, 2007; Peters et al., 2007; Roca and Serrano, 2007; Tunç et al., 2007; Weber and Matthews, 2007; Guan et al., 2008; Li and Hewitt, 2008; Pan et al., 2008; Peters and Hertwich, 2008; Weber et al., 2008; Chung et al., 2009; Guan et al., 2009; Xu et al., 2009; Guo et al., 2010; Lin and Sun, 2010; Liu et al., 2010; Su et al., 2010; Yan and Yang, 2010; Zhang, 2010), and of methane emissions in special (Zhou, 2008; Chen et al., 2009, 2010; Zhou et al., 2009).

For the input–output table in China, the basic row balance can be expressed as

$$X = AX + F - X^m \quad (1)$$

where X is the total output, in terms of a column vector; A is the technology coefficients matrix or direct requirement coefficient