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Methane emissions of energy activities in China 1980–2007

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ABSTRACT

As the largest CH_4 emitter, China produces CH_4 at an increasing rate, especially from its energy activities. Presented in this paper is a detailed inventory and analysis of CH_4 emissions from energy activities in China from 1980 to 2007 covering all the significant sources. The total energy-related CH_4 emissions in China tripled during the period with an average annual increase rate of 4.7% and reached 21,943.1 Gg in 2007, 2.4 times of that in USA. As the largest emission source, coal mining increased its share from 69.2% (4559.5 Gg) in 1980 to 85.8% (18,825.5 Gg) in 2007; The second biggest source was fuel combustion, mainly bio-fuel combustion (2370.3 Gg in 2007); Oil and natural gas system leakage was a minor source but at a rapidly increasing rate. This transient emission structure is quite different from the steady structure of USA, which is dominated by the fugitive emissions from natural gas and oil systems. According to the lower IPCC Global Warming Potential, the annual energy-related CH_4 emissions were equivalent to 9.1%–11.7% of China's energy-related CO_2 emissions, amounting to 548.6 Mt CO_2-eq in 2007 which is greater than the nationwide gross CO_2 emissions in many developed countries.

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1. Introduction

Reckoned as the world's largest producer of CO_2 emissions since 2007 [1], the issue of China's GHG emissions has received much attention internationally in the context of climate change, especially with the rising pressure to reduce the emissions in the post-Kyoto negotiation [2,3]. Committed to GHG emission reduction [4], the Chinese government has set explicitly the goal to cut the CO_2 emission per unit of gross domestic product (GDP) by 40 to 45 percents by 2020 relative to the level of 2005 [5] for the development of a low carbon economy [6,7]. However, the total amount of China's GHG emissions is expected to increase further, due to the rapidly growing economy [8,9]. Extensive studies have been carried out to estimate CO_2 emissions in China and to explore the related mitigation opportunities [10–18].

In contrast to the ever-increasing focus at China's CO_2 emissions, the CH_4 emissions in China have received little attention. Methane (CH_4) as another potent greenhouse gas has a global warming potential (GWP) 72 or 25 times greater than that of carbon dioxide over a horizon of 20 or 100 years [19]. Therefore, stabilizing methane emissions as a potential policy target can dramatically contribute to greenhouse gas reduction in the near-term and to global health benefits in the long term [20–22]. Methane emissions in China are remarkably significant. According to the official GHG emission inventory of China for the year of 1994, methane by the lower GWP factor of 21 contributed 19.4% of the total nationwide GHG emissions in terms of CO_2, CH_4 and N_2O in 1994 [23]. Recently, Zhang and Chen [24] reported that the total CH_4 emissions by Chinese economy in 2007 were 39,592.7 Gg or 989.8 Mt CO_2-eq by the GWP factor of 25, with a magnitude of about one sixth of China's CO_2 emissions from fuel combustion and greater than the nationwide CO_2 emissions from fuel combustion of many developed countries such as UK, Canada, and Germany. It follows that the mere consideration of the CO_2 emissions does not reflect the real situation and full picture of China's GHG emissions [8,25].

As an important anthropogenic source for CH_4 emissions, energy activities have become the largest CH_4 emission source in China, contributing more than 40% of the total CH_4 emissions in recent years [24]. Intentional or unintentional release of CH_4 may occur during the extraction, processing and delivery of fossil fuels to the destination of final use [26]. China is the largest coal production and consumption country, large coal supply has resulted in a high growth rate of coalbed methane emissions, without an effective exploitation of coalbed methane resources [27–29]. Meanwhile, oil and natural gas consumption in China has increased rapidly in recent decades, which is accompanied with considerable fugitive emissions from the mining, processing, storage and transportation [30]. Additionally, fuel combustion is an important CH_4 emission source [31]. In rural China, straw and firewood are the two primary bio-fuels for daily cooking and domestic heating, incomplete combustion of biomass resources causes serious air pollution and releases a large amount of CH_4. All of these activities in energy fields lead to a large amount of CH_4 emissions.

To evaluate adequately the CH_4 emissions of various energy activities in China, specific efforts have been made to account for the emissions from coal mining [32–38], oil and natural gas system leakage [30], fuel combustion of social-economic sectors [39], and bio-fuel combustion in rural households [40–42]. There is clearly a growing body of studies about energy-related CH_4 emissions from notable sources in China, however, the estimations are based on the methods of different tiers and the data from distinctive and scattered sources.

There have also been several studies on the national-scale inventories of CH_4 emissions in some special years or as annual series in some early years, of which some deal with CH_4 emissions from energy activities in the country [24,43–47]. In particular, the issue of direct and indirect CH_4 emissions in China has been widely explored by Chen and his collaborators in a series of works for multi-scale systems input–output analysis of GHG emissions [24,48–52].

Nevertheless, there is still limited knowledge about the CH_4 emissions of energy activities in China. For instance, there are no systematic evaluations covering all the major sources and their specific contributions to the global climate change in a long period of time, especially reflecting the dramatic socio-economic changes since 2000. To understand the potential of emission mitigation and to identify mitigation measures for CH_4 emission reduction in China's energy fields, a quantification of the size and proportion of CH_4 emissions involved in China's energy activities and an assessment of the dynamics of the overall emissions are urgently required.

The purpose of this paper is twofold. First, a detailed estimation of energy-related CH_4 emissions in China during 1980–2007 is performed based on the most extensive, if not conclusive, and the most recent statistical data and research literatures available, covering all the major sources such as coal mining, oil and natural gas leakage, fossil fuel combustion, and bio-fuel combustion. Next, the roles of energy-related CH_4 emissions are systematically delineated in both the national and global GHG emission inventories.

The main context of this paper is organized as follows. In Section 2, the estimation methodology and data sources are described. Section 3 presents the estimates of CH_4 emissions from the main energy activities. In Section 4, the estimation results are organized systematically, and the budgets and inventory status of China's energy-related CH_4 emissions are analyzed. A comparison is made between the emission structures in China and in USA, and the uncertainty associated with the estimation is also discussed in this section. Finally, concluding remarks with policy making implications are made in Section 5.

2. Methodology and data sources

2.1. Coal mining

The CH_4 emissions from coal mining can be calculated as

$$E_{coal} = \sum_i P_i \times EF_i \times t - r \tag{1}$$

where E_{coal} is the CH_4 emissions from coal mining; P is the coal output; EF the emission factors of coal mining and post-mining (m^3 CH_4/t); t the gas coefficient (Gg CH_4/m^3); r the amount of CH_4 recovery; and i the category of coal mines.

There are two types of coal mines, underground coal mines and surface coal mines, with distinctive emission factors [26]. In China, over 95% of coal mines belong to underground coal mines [24,35]. Because of the great depth and high rank of China's coals, underground coal mines have higher CH_4 emissions than surface mines. Also, this special structure of coal mines results in more fugitive CH_4 emissions for the same amount of coal production in China than in developed countries. To calculate the fugitive emissions from underground coal mining, default emission factors provided

Table 1
Emission factors of coal mining in China (m^3/t).

Sources	Coal mining	Post-mining
Underground mining		
High-methane mines	21.83	3.02
Low-methane mines	4.53	1.13
Surface mining[a]	2.5	0.1

[a] Emission factors for surface mining are cited from IPCC default factors [26].