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Energy consumption and GHG emissions from China's freight transport sector: Scenarios through 2050

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HIGHLIGHTS

- A bottom-up model was established to predict energy consumption and GHG emissions from China's freight transport sector.
- Energy consumption and GHG emissions may experience 3.3 and 2.8 times increases under BAU scenario.
- GHG emissions may reach the peak as early as around 2030 under aggressive scenario.

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ABSTRACT

China's freight transport volume experienced rapid growth over recent years, causing great concerns over its energy and environmental impacts. In this study, by establishing a bottom-up accounting framework, a set of scenarios reflecting the possible future trajectories of energy consumption and Greenhouse Gas (GHG) emissions from China's freight transport sector are developed. According to our estimation, GHG emissions from China's freight transport sector were 788 mt CO_2e in 2013, roughly accounting for 8% of nationwide GHG emissions. Under Business-As-Usual (BAU) scenario, energy consumption and GHG emissions in 2050 will be 2.5 and 2.4 times the current levels. GHG emissions will peak by 2045 at the level of 1918 mt CO_2e. With all major mitigation measures implemented, energy consumption and GHG emissions in 2050 can be reduced by 30% and 32%, respectively. Besides, GHG emissions will peak earlier by around 2035 at a much lower level than under BAU scenario. Our study suggests that in order to keep in pace with China's overall mitigation agenda, aggressive efforts should be made to reduce GHG emissions from freight transport sector.

1. Introduction

Freight transport is defined as moving freight from one location to another, normally driven by economic activities. Road, rail, water, aviation and pipeline are the major motorized freight transport modals. Freight transport is an important source of energy consumption and Greenhouse Gas (GHG) emissions. As reported by the 5th assessment report (AR5) from Intergovernmental Panel on Climate Change (IPCC), global freight transport consumed 40 EJ energy in 2009, accounting for about 45% of total transport energy consumption (Sims et al., 2014). More specifically, heavy duty vehicles consumed over half of total energy by freight transport. Energy conservation and GHG mitigation have become the most important agenda in the global freight transport sector.

Driven by the fast economic development, China's freight transport volume experienced rapid growth over recent years, from 4.4 trillion ton-kilometer (tkm) in 2000 to 16.8 trillion tkm in 2013, with an annual growth rate of 10.8% (NBS, 2014). During the same period, the numbers of road trucks, locomotives and aircrafts had been increased by 1.8, 0.4 and 3.1 times, respectively. Also, the total length of pipelines had been increased by 3 times. Such a growth in freight transport caused great increases of energy consumption and GHG emissions (Guo et al., 2014; Hao et al., 2011c). As estimated by DRC (2013), energy consumption by China's freight transport sector increased from 79 megaton of coal equivalent (mtce) in 2005 to 142 mtce in 2010, with an annual growth rate of 12%. Freight transport is likely to continue its growth trend in the coming decades. Under such a circumstance, it

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is critical to predict the future growth pattern of China's freight transport and prepare appropriate policies to address the related energy and GHG emissions issues.

The energy and environmental impacts from transport sector have been intensively studied over recent years (Geng et al., 2013; Hao et al., 2014, 2011b). Regarding freight transport, existing studies were typically based on bottom-up accounting frameworks. International Energy Agency (IEA) established the Mobility Model to estimate CO_2 emissions from global freight transport (IEA, 2012). Under the Mobility Model, CO_2 emissions were decomposed into freight transport volume, energy intensity and emission intensity. One major merit of this approach is its low data requirement to populate the model. Freight transport volume can be normally collected from national official statistics. Energy intensity and emission intensity have been well captured by existing studies, and can be well transplanted from one region to another by making some adjustments. Fu et al. (2011) projected the energy consumption of China's freight transport sector by employing a three-factor decomposition approach, under which energy consumption is decomposed into total freight transport volume, modal mix, and energy intensity. Future trends were presented with one Business-As-Usual (BAU) scenario and multiple alternative scenarios reflecting different policy impacts. Factors that were addressed include transport volume change, energy efficiency improvements, etc. However, their study focused on energy consumption only, and did not incorporate emissions factors into estimating emissions. Furthermore, the base year of their study was 2008, which could not reflect the fast changes of freight transport characteristics in China over recent years. As a result, their study tended to underestimate China's freight transport volumes and associated energy consumption. DRC (2013) also estimated energy consumption of China's freight transport sector based on a bottom-up approach. Future projections were presented through one Business-As-Usual (BAU) scenario and one low-carbon scenario. However, the assumptions behind the scenarios were not explicitly explained.

One major gap of existing studies is the limited coverage of mitigation measures and the lack of synthesis among various measures. Under such a circumstance, it is difficult to quantify the impacts from each measure and possible combinations of different measures. In order to fill such gaps, a transparent bottom-up framework is established to provide comprehensive policy insights. Several scenarios with different energy consumption and GHG emissions from China's freight transport sector are developed, with focuses on predicting the impacts from different mitigation measures, performing policy simulation and delivering explicit policy implications. This study will contribute to extending the scope and improving the transparency of mitigation measure evaluation. The whole paper is organized as follows. After this introduction section, the study scope, accounting framework and scenario development methodologies are described. Then the research results are presented and discussed, with a focus on detailing the comparisons between BAU scenario and the alternative scenarios. Finally, policy recommendations are raised.

2. Methodology and data

In this section, the overarching methodology is firstly introduced. Then three essential factors, including freight transport volume, energy intensity, and GHG emissions intensity, are elaborated. Each factor is introduced in the order of history and future projection.

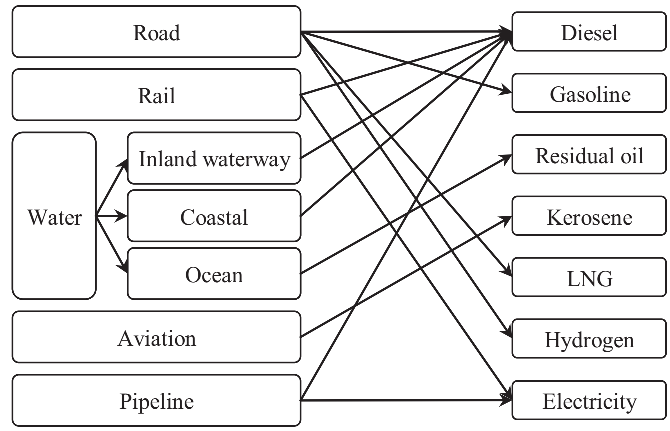

Fig. 1. Transport modals and fuels covered in this study.

2.1. Accounting framework

Fig. 1 presents the scope and accounting framework of this study. Five transport modes are included, namely, road, rail, water, aviation and pipeline. Water transport is further categorized into inland waterway, coastal and ocean transport. Seven transport fuels are covered, including diesel, gasoline, residual oil, kerosene, liquefied natural gas (LNG), hydrogen and electricity.

Eqs. (1) and (2) show the overarching methodology of this study. The bottom-up approach described in the Mobility Model (IEA, 2012) is employed as our accounting framework. Energy consumption is decomposed into freight transport volume, technology share, energy intensity, and energy share. GHG emissions are obtained based on energy consumptions and the GHG emissions intensities. Note that the GHG emissions intensities quoted in this study are based on the life cycle perspective, with both direct emissions from energy use and indirect emissions from energy production included.

$$EC_{i,r} = \sum_{p} FTV_{i,p} \cdot TS_{i,p}^{i,p,q} \cdot EI_{i,p,q} \cdot ES_{i,q}^{i,q,r} \tag{1}$$

$$GE_i = \sum_{r} EC_{i,r} \cdot GI_{i,r} \tag{2}$$

where, $EC_{i,r}$ is the energy consumption of type r fuel in year i (MJ); GE_i is the GHG emissions in year i (t CO_2e); $FTV_{i,p}$ is the freight transport volume by mode p in year i (tkm); $TS_{i,p}^{i,p,q}$ is the share of freight transport volume by technology set q out of total freight transport volume by mode p in year i; $EI_{i,p,q}$ is the energy intensity of technology set q of mode p in year i (MJ/tkm); $ES_{i,q}^{i,q,r}$ is the share of energy consumption of type r fuel out of total energy consumption of technology set q in year i; $GI_{i,r}$ is the GHG emissions intensity of type r fuel in year i (t CO_2e/MJ).

Scenario analysis is the common method of predicting future trends and identifying key influencing factors for freight transport sector (Zanni and Bristow, 2010). The major characteristics of China's freight transport, such as freight transport volume, energy intensity, etc., are in the process of rapid changes. The future trends of these factors are quite uncertain, and can pose significant impacts on our estimations. For these reasons, multiple scenarios are assumed for these factors so that future emission patterns under different policy and technology contexts can be presented.

2.2. Freight transport volume

2.2.1. History

Fig. 2 shows China's historical freight transport volume from