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Greenhouse gas emissions of motor vehicles in Chinese cities and the implication for China's mitigation targets

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HIGHLIGHTS

- Predict baseline GHG emissions of different motor vehicles of Chinese cities.
- Different kinds of fuels are considered when accounting GHG emissions.
- A comparative analysis on four case cities of China is conducted.
- New energy will have different growth patterns due to diverse policies and resources.
- Policy implications are given based on the analysis results.

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ABSTRACT

Along with rapid development of economy, urbanization and industrialization in China, the transportation sector especially road transport accounts for the quickest growth of energy consumption and greenhouse gas (GHG) emissions across the country. This paper selects four representative cities (Beijing, Shanghai, Guangzhou, and Chongqing) in the north, east, south, and west of China as targets of case study. It predicts future motor vehicle population in various cities using the Gompertz Model, and predicts and analyzes fuel consumption and GHG emissions of different types of motor vehicles in the case cities by 2035. The results indicate that besides gasoline and diesel, in the future uses of various types of vehicle fuels will follow different patterns among these four cities due to diverse resources endowment, economic strength, technology levels and geographical features. Based on predicted vehicle population and fuel consumption, it is found that from 2013 to 2035, GHG emissions from tank to wheel (TTW) and well to wheel (WTW) in all cities will continuously increase yet at different rates. If there is no interference from new policies, around 2020 Chongqing is expected to replace Beijing as the city with the highest volume of GHG emissions of vehicles among four case study cities. Therefore, the four cities especially Chongqing need urgently to develop or adjust low-carbon policies in road transportation sector, in order to achieve China's future greenhouse gas reduction targets. Some policy implications to reduce GHG emissions of the road transportation sectors of the case cities are suggested based on the analysis results.

1. Introduction

In 2013, the transportation sector accounted for 63.8% of the entire oil consumption, and 27.6% of terminal energy consumption globally [1]. The World Energy Outlook [2] reported that the transportation sector will account for 30% of the growth in petroleum consumption between 2004 and 2030. In China, along with rapid development of economy, urbanization and industrialization, the transportation sector accounts for the quickest growth of energy consumption (especially oil consumption) and greenhouse gas (GHG) emissions across the country as vehicle sales in China are growing very fast and have become the largest all over the world since 2013 [3]; and early in 2005, consumption of standard oil in the transportation sector reached 98 million tons, which is 21 times of that in 1980 [4]. In November 2014, in the U.S.-China Joint Announcement on Climate Change, China agreed to peak its CO_2 emissions around 2030 while striving to peak early, and boost the share of non-fossil fuel energy to around 20% [5].

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However, some studies showed that China could peak its total CO_2 emissions around 2030, while the transportation sector may continue the growth [6], which will surely become a big challenge for China.

Existing studies on GHG emissions of road transportation sector are usually based on bottom-up accounting model [7–13] for GHG emissions of the use of vehicles or top-down accounting model [14–20] for GHG emissions of passenger and freight transport turnover. Most studies adopted the first model, and analyzed and predicted energy consumption and GHG emissions of vehicles of China in the future through the collection or calculation of vehicles population, vehicle kilometers traveled (VKT), fuel economy and other data [7–13]. For instance, He et al. [7] predicted energy consumption and CO_2 emissions from road transport in China by 2030 according to various fuel economy levels, and they found that under the low and high-fuel economy improvement scenarios, 55 and 85 million tons of oil will be saved in 2030, respectively. On the basis of this research, Zheng et al. [8] elaborated the research dimension to the provincial level of China, the authors proposed an integrated policy set to assure the objective of peak national vehicle GHG emissions be achieved around 2030, which involves decreasing the use of urban light-duty vehicles by 25%, improving fuel economy by 25% by 2035 comparing 2020, and promoting electric vehicles and biofuels. Based on different development patterns across the world, Wang et al. [9] predicted fuel consumption and carbon emissions by road transport in China by 2050, according to the different development patterns of increase rates of different vehicles of different countries. Ou et al. [10] predicted and analyzed carbon emissions of vehicles in China by 2050 based on different scenarios of the promotion of different types of fuels, and it is suggested to support sustainable biofuel and high efficient electric-vehicles, and the deployment of coal-based fuels accompanied with low-carbon technology. With the same method, Ajay Gambhir et al. [11] conducted a detailed decomposition research of the additional costs and CO_2 emissions savings of each low-carbon vehicle type and calculated the marginal abatement cost of each vehicle and drivetrain type in 2050. On the regional level, Wang [12] and Huang et al. [13] analyzed road transport carbon emissions in Tianjin and Guangdong respectively using bottom-up methods, and focusing on these two areas, the researchers suggested the governments to promote new technologies, control the growth of vehicles, encourage residents to travel by bus and improve their transportation management capacities.

There are some other studies that anticipate GHG emissions of road transportation sector based on passenger and freight transport turnover [14–20]. A commonly used formula is as follows:

$$CO_2 \text{ emission} = \text{transport turnover} \times \text{energy consumption per unit} \times CO_2 \text{ emission factors} \quad (1)$$

For instance, on the basis of GDP, urbanization rate, and passenger and freight transport turnover, Zhang et al. [18] predicted energy demands of the transportation sector in China using partial least squares regression. Based on historical data in the transportation sector and statistics of economy growth, Liu [19] applied the method of linear regression, and establishes a linear regression model according to GDP per capita to anticipate passenger and freight transport turnover in the transportation sector in the future, on the foundation of which energy consumption and carbon emissions from this sector as well as the potential for saving energy were calculated. Zhu and Shao [20] estimated carbon emissions by the transportation sector in Shanghai based on transport turnover and energy consumption per unit, and applies scenario analysis to calculate and assess carbon emissions by 2020 under the persistence scenario, the high efficiency scenario, and structural optimization scenario. Their paper proposed strategies for low-carbon development of the transportation sector in Shanghai which consists of coordinated planning of the total amount of travel and trip distance, optimizing the travel mode structures, increasing transportation efficiency, improving the technical aspects of energy saving and promoting alternative fuels.

There are also some studies on road transportation related energy consumption and carbon emissions that adopt other methods. Based on the numbers of buses, taxis, subways, and private cars as well as their respective traffic volumes in Tianjin between 2000 and 2009, Li [21] applied system dynamics model and Vensim software to construct models to simulate and predict vehicle number and traffic volume as well as energy consumption and carbon emissions in transportation sector. Cheng et al. [22] presented solutions for a sustainable urban transportation system by establishing a simplified system dynamics model with a timeframe of 30 years to simulate the effects of urban transportation management policies and to explore their potential in reducing vehicular fuel consumption and mitigating CO_2 emissions in a city of Taiwan. Based on a life cycle assessment (LCA) method, Orsi et al. [23] proposed an energy-based well-to-wheels analysis to compare different passenger vehicles, based on three key indicators: petroleum energy use, CO_2 emissions, and economic cost. Five representative national scenarios are considered but their results show that there is no fundamental difference in the fossil fuel pathways among the five national scenarios. López et al. [24] also used the LCA method to carry out a study on different kinds of fuels of trucks in Madrid, and Ou et al. [25] calculated fossil energy consumption (FEC) and GHG emission intensities of major alternative vehicle fuels (AVFs) in China by the same means of full life-cycle analysis.

Some other related studies focused on fuel-consumptions or CO_2 emissions analysis on some particular types of fuel on a country or a city instead of the whole road transportation sector, such as petrol-fueled passenger vehicles in Japan [26], light-duty natural gas vehicles in the US [27], LNG heavy vehicles fuel in Europe [28], light-duty CNG-fueled in Europe [29], hydrogen and electric vehicles in Tuscany [30], electric vehicles in Beijing [31], and battery electric vehicles in China [32]. These studies mainly focused on calculating the fuel consumptions or CO_2 emissions of a certain vehicle type or fuel type, which may provide technical theories or methods to calculate the whole vehicle population in a certain area in the future.

Many of the existing studies on current situation and prediction of road transport GHG emissions focus on national level or on one area in a country, and most studies only calculate GHG emissions by fuel consumption of vehicles which use gasoline or diesel. In fact, different regions or even different cities all over the world have different resources endowment, economic strength, technology levels and geographical features, so the motor vehicle development or growth patterns are also quite different in different areas, and some studies showed that the use of national average parameters for projection may lead to either under- or over-estimation of GHG emissions due to uneven regional development [33,34], but now there lacks comparative analysis on energy consumption and GHG emissions from various types of motor vehicles in various cities.

This study selects four representative cities (Beijing, Shanghai, Guangzhou, and Chongqing) in the north, east, south, and west of China as targets of case study. It predicts future vehicle population in these cities using the Gompertz Model, and then predicts and analyzes fuel consumption and GHG emissions of vehicles of these cities by 2035, and based on the analysis results, we discuss and suggest some policy implications of how to reduce GHG emissions in transportation sector for the case cities in order to achieve China's GHG mitigation targets in the future. The methods adopted in this study could also be considered in prediction on GHG