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Review

Air pollutant emissions from vehicles in China under various energy scenarios

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ABSTRACT

Estimations of air pollutant emissions from vehicles in China under different energy and emission abatement policy scenarios are presented in this paper. Three scenarios are designed: (i) “business as usual” (BAU); (ii) “advanced fuel economy” (AFE); and (iii) “alternative energy replacement” (AER). The CO, VOCs, NOx, PM_{10}, and CO_2 emissions are predicted to reach 105.8, 5.9, 7.5, 1.1, and 3522.6 million tons, respectively, in the BAU scenario by 2030. In the AFE scenario, the CO, VOCs, NOx, PM_{10}, and CO_2 emissions in 2030 will be abated by 23.8%, 18.6%, 25.3%, 18.2%, and 24.5% respectively compared with the BAU scenario. In the AER scenario, the CO and VOCs in 2030 will be further reduced by 15.9% and 6.1% respectively, while NOx, PM_{10}, and CO_2 will be increased by 10.7%, 33.3%, and 2.0% compared with AFE. In conclusion, our models indicate that the emission abatement policies introduced by governmental institutions are potentially viable, as long as they are effectively implemented.

Contents

1. Introduction

With the rapid growth of the number of vehicles in operation, the air pollutants emitted from these vehicles have contributed to urban air pollution in recent years, especially in large cities such as Sao Paulo, Detroit, and Tokyo (Morishita et al., 2006; Mukerjee et al.,

Abbreviations: AER, alternative energy replacement; AFE, advanced fuel economy; BAU, business as usual; LDGV, light-duty gasoline vehicles; CNG, compressed natural gas; IVE, international vehicle emission.

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Table 1
Survey of vehicle emission factors with CNG and hybrid power.

Fuel type	Vehicle type	Air pollutant	Emission factor	Reference
Hybrid power	PCs	CO	0.22	Song et al., 2007
		VOCs	0.02	
		NOx	0.01	
		PM_{10}	/	
		CO_2	102.931[a]	
	Buses	CO	4.439	Li et al., 2010
		VOCs	0.197	
		NOx	10.427	
		PM_{10}	0.14	
		CO_2	786.27[a]	

[a] Calculated with formula.

2009; Yorifuji et al., 2011). In New York, the fine PM concentrations on mornings with traffic were 58% higher than mornings without traffic (Whitlow et al., 2011). A model simulation indicated that the contribution of NO_2 from vehicular sources accounted for a range of 9% to 39% of that concentration in atmosphere (Banerjee et al., 2011). In China, vehicle emissions in Beijing contributed to approximately 71%–85% of the total CO concentration, 67%–71% of the total NO_X concentration, and 26%–45% of total VOCs emission amount (Hao et al., 2000; Wang et al., 2009; Cai, et al., 2010). NO_X emissions from vehicles accounted for 35.4% to 75.7% of the total emissions in Hangzhou (Zhang et al., 2008a). The studies in Shanghai and Guangzhou also showed that traffic emissions contributed significantly to the impact of air pollution (Li et al., 2012, 2006). The transportation sector has become a major source of urban air pollution. Therefore, it is necessary to control air pollutants emitted from vehicles.

There are many methods for abating air pollutant emissions from vehicles. One of the most efficient methods is to improve vehicle fuel economy (FE, fuel consumption per 100 km travel distance, in the unit of L/100 km) (MacLean and Lave, 2003; Zhang et al., 2010). The FE in China remains comparatively higher than the FE in other countries, such as Japan (50%) and continental Europe (14%) (Wang and Jin, 2008). Furthermore, hybrid electric vehicles can reduce fuel consumption by 60% and air pollutant emissions by 40% (Fontaras et al., 2008). Vehicle deterioration is the major factor increasing air pollutants from vehicles. It has been shown that nearly 60% of vehicular emissions come from the 20% of vehicles that are older than 10 years (Guo et al., 2006). Vehicle emission studies in different countries have shown that the CO emission factor for light-duty gasoline vehicles (LDGV) in Beijing is 95–271 g/kg fuel (Westerdahl et al., 2009; Zhou et al., 2007), which is 2–5 times that in the USA (Pokharel et al., 2002). It was not until the National Standard IV imperative was implemented that emission factors from vehicles began to decrease (Zhang et al., 2008b). Energy replacement, such as compressed natural gas (CNG) used to replace diesel (Aslam et al., 2006), is another efficient method for reducing air pollutant emissions from vehicles. Successful policy packages including stringent emission standards are also a powerful tool to control air pollution from vehicles (Nesamani, 2010; Bandivadekar et al., 2008). In China, a series of policies has been made imperative by the government, including emission limit improvement (CMEPGO, 2010), the elimination of vehicles pre-National Standard I (Zi, 2009), clean energy replacement (Pan et al., 2007), and the use of electric and hybrid electric buses and taxis (Tang and Zheng, 2011; Si, 2008). All these technologies and policies aim to improve fuel economy and promote pollution control. However, it is not clear which policy is the most efficient and to what degree air pollutants will be abated under these different policies.

In this paper, we estimate the emissions of CO, VOCs, NOx, PM_{10}, and CO_2 from vehicles with modified IVE (International Vehicle Emission) in China from 2009 to 2030 under three scenarios: "business as usual" (BAU); "advanced fuel economy" (AFE); and "alternative energy replacement" (AER). In the AFE scenario, fuel economy is based on government regulation. In the AER scenario, liquefied natural gas (LNG) and electricity are used as alternative energies. Vehicle ownership from 2009 to 2030 was predicted in our previous research (Zhang et al., 2010). The year 2009 is used as the base year, and the vehicles are divided into the following twelve categories: passenger cars that use gasoline (g-PCs); passenger cars that use diesel (d-PCs); passenger cars with hybrid power (h-PCs); light trucks that use gasoline (g-Lts); light trucks that use diesel (d-Lts); heavy truck with gasoline (g-Hts); heavy trucks with diesel (d-Hts); buses that use gasoline (g-Buses); buses that use diesel (d-Buses); buses with hybrid power (h-Buses); buses with LNG (n-Buses); and motorcycles (MCs). Dynamic emission factors of gasoline and diesel vehicles are established to improve the accuracy of the future emission inventories (Zhang et al., 2008b). The emission factors of other vehicles are from the studies of other researchers. Finally, emission abatement will be compared under different scenarios.

2. Methodology

2.1. IVE model

Accurate motor vehicle emission factors are essential for estimating air pollutant emissions from the vehicles of a given country. In

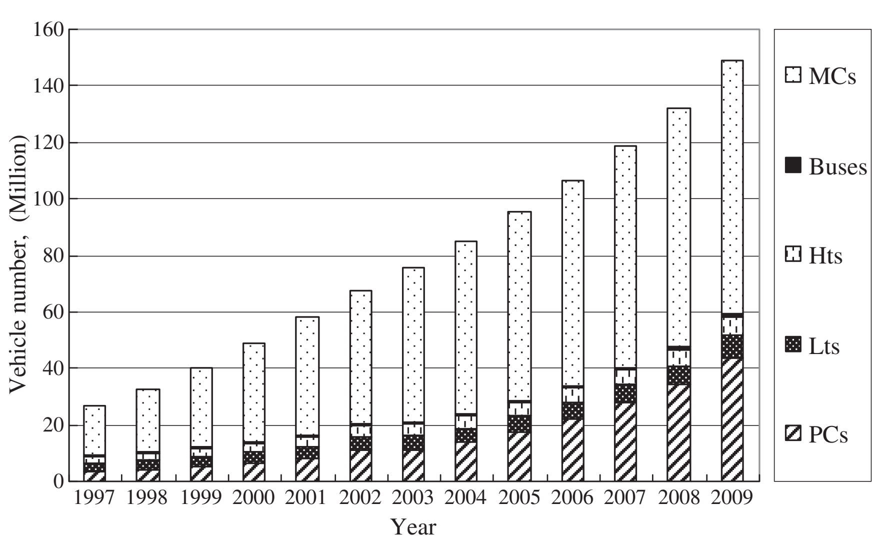

Fig. 1. The number of vehicles in China from 1997 to 2009.