Energy Policy 39 (2011) 3005–3011

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

CO_2 and pollutant emissions from passenger cars in China

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ARTICLE INFO

Article history:
Received 1 November 2010
Accepted 2 March 2011
Available online 22 March 2011

Keywords:
Air pollution
CO_2 emissions
Passenger car

ABSTRACT

In this paper, CO_2 and pollutant emissions of PCs in China from 2000 to 2005 were calculated based on a literature review and measured data. The future trends of PC emissions were also projected under three scenarios to explore the reduction potential of possible policy measures. Estimated baseline emissions of CO, HC, NO_x, PM_{10} and CO_2 were respectively 3.16×10^6, 5.14×10^5, 3.56×10^5, 0.83×10^4 and 9.14×10^7 tons for China's PCs in 2005 with an uneven distribution among provinces. Under a no improvement (NI) scenario, PC emissions of CO, HC, NO_x, PM_{10} and CO_2 in 2020 are respectively estimated to be 4.5, 2.5, 2.5, 7.9 and 8.0 times that of 2005. However, emissions other than CO_2 from PCs are estimated to decrease nearly 70% by 2020 compared to NI scenario mainly due to technological improvement linked to the vehicle emissions standards under a recent policy (RP) scenario. Fuel economy (FE) enhancement and the penetration of advanced propulsion/fuel systems could be co-benefit measures to control CO_2 and pollutant emissions for the mid and long terms. Significant variations were found in PC emission inventories between different studies primarily due to uncertainties in activity levels and/or emission factors (EF).

1. Introduction

Because of economic growth and accelerating urbanization in China, the vehicle population has increased rapidly and road vehicles are becoming one of the major sources of CO_2 and pollutant emissions (Yan and Crookes, 2007). However, China's per capita ownership of road vehicles, especially passenger cars, is still much lower than that of developed countries and the world average level so the potential for future growth is very high (Wang et al., 2006; Yan and Crookes, 2010).

The population of passenger car (PC) in China increased by a factor of 2.8 between 2000 and 2005, compared with a per capita GDP increase of only 1.2 (Han and Hayashi, 2008; NBS, 2001–2010). Because PCs use a substantial amount of fossil fuel and produce significant CO_2 and pollutant emissions, it will be a challenging task for China to provide enough fuel to satisfy this rapid vehicle growth and prevent a decline in air quality. According to Yan and Crookes (2009), energy demand for China's road transport increased from 57 to 86 Mtoe (million tons of oil equivalent) and associated CO_2 emissions grew from 169 to 255 Mt between 2000 and 2005. The private PCs are found to contribute to nearly half of the increases.

With the rapid increase of vehicle population, vehicular emissions were found to be major sources of air pollutants such as CO, NO_x, VOC and PM in many cities (Barletta et al., 2005; Bo et al., 2008; Liu et al., 2008; Xie et al., 2008; Yi et al., 2007). An increase of nitrogen dioxide in the troposphere over China has also been recently observed from space (Richter et al., 2005). The hourly average concentrations of O_3 frequently exceeded the second class of the national ambient air quality standards in Beijing, Guangzhou and Shanghai during spring and summer between 2000 and 2005. As these pollutants are closely related to the vehicular emissions and due to the high potential for future growth of PCs, it is necessary to establish the emission inventory of PCs, analyze their distribution and project future emission trends.

Since there are no statistical data available for CO_2 or pollutant emissions from road vehicles in China, a number of studies have estimated China's vehicle emissions in recent years (Cai and Xie, 2007; Han and Hayashi, 2008; He et al., 2005; Streets et al., 2003; Wang et al., 2007; Yan and Crookes, 2009; Zhang, 2005). However, these studies usually separated the estimation of vehicular CO_2 and pollutant emissions, and either calculated vehicular emissions for a specific year or for a past period of time. A similar approach was applied in previous studies to derive the energy demand from three factors: vehicle population, fuel economy (FE) and vehicle kilometers traveled (VKT). CO_2 emissions were calculated based on the assumption that all of the carbon in the fuels was converted into CO_2.

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0301-4215/$ - see front matter
doi:10.1016/j.enpol.2011.03.013

Compared to existing vehicular emissions inventories in China, our study has the following major characteristics: (1) CO_2 and pollutant emissions were studied simultaneously for PCs in China; (2) the emission factors of air pollutants and CO_2 were evaluated based on a literature review, portable emissions measurement system (PEMS) data and the COPERT IV model, which enhances the inventory relative to the on-road values and (3) the future reduction potentials of PC emissions were analyzed under various scenarios.

2. Methodology

The emissions of CO_2, CO, HC, PM_{10} and NO_x for PCs were evaluated based on VKT and emission factors. The emissions at the provincial level were estimated and aggregated to represent the national inventories for PCs in the years 2000–2009, using Eqs. (1) and (2). Scenario analysis of PCs' future emission trends were calculated at the national level.

$$Q_{p,i} = EF_{p,i} \times VKT_p \times S_p \times 10^{-6} \quad (1)$$

$$Q_i = \sum Q_{p,i} \quad (2)$$

where $Q_{p,i}$ represents the emissions of pollutant i for PCs in province p, tons; $EF_{p,i}$ is the emission factor of pollutant i in province p, g/km; S_p is the stock of PCs in province p; VKT_p is the annual mileage of PCs in province p, km and Q_i represents the total emissions of pollutant i for PCs in China, tons. The emissions from PCs in Hong Kong, Macao and Taiwan were not calculated in this study.

EFs of PCs were calculated separately for Beijing and Shanghai (provincial-level cities) because of the different vehicle emission standards implemented in these two cities. Table 1 shows the specific timetable for the application of vehicle emission standards in China and the European Union (EU). The other provinces used similar emission factors at national average level. Euro 5 emission standards for PCs in China were assumed to be implemented in 2013.

Table 1
Timetable of vehicle emission standards in China and European Union.

Emission standards	China			EU	Difference between China and EU (years)
	Nationwide	Beijing	Shanghai		
Pre Euro 1	1990	1990	1990	1973	17
Euro 1	2000	1999	1999	1992	8
Euro 2	2004	2004	2004	1996	8
Euro 3	2007	2005	2007	2000	7
Euro 4	2010	2008	2009	2005	5
Euro 5	***2013***	***2013***	***2013***	2009	4

2.1. Population of passenger cars in China

The data regarding the provincial or national population of PC from 2000 to 2005 were obtained from official statistical yearbooks (CAIA, 1997–2006; NBS, 2001–2010). Fig. 1 shows the proportion of PC in each province in China 2005. It shows that the distribution of PCs is unbalanced. Beijing, Shanghai, Jiangsu, Zhejiang, Shandong and Guangdong are the most developed areas in China, while accounting for only 6% of the country's territory; however, they include nearly 25% and 45% of the total human and PC populations, respectively. On the other hand, the western and inland regions containing over 60% of the territory and human population represent only 20% of the PC population.

Using Gompertz curve (Dargay and Gately, 1999) and based on the trends of human population and per capita GDP in China (NBS, 2001–2010), the future stock of highway vehicles (HWV, including passenger cars, buses and trucks) has been forecast as shown in Fig. 2.

Fig. 2 illustrates that the PC population may reach 159 million in 2020, which is over 30 times the amount in 2000. The proportion of PC to the total HWV will continue to increase from 30% in 2000 to nearly 70% in 2020. Our projections are closed to the results (146 million) of business-as-usual scenario in Ng and

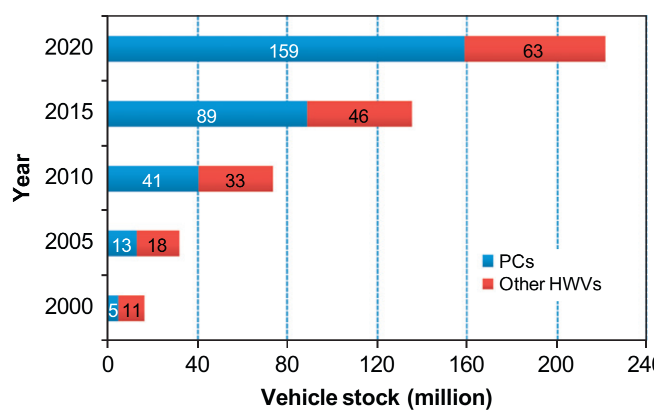

Fig. 2. Trend of PC population in China until 2020.

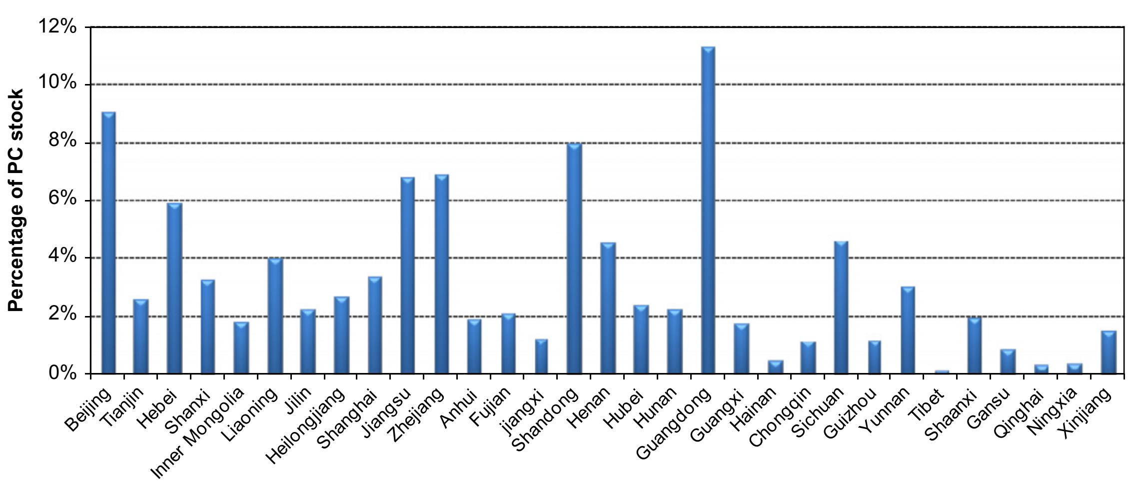

Fig. 1. Distribution of PC's population at the provincial level in China, 2005.