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Urban passenger transport energy saving and emission reduction potential: A case study for Tianjin, China ☆

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ABSTRACT

With rapid growth of the vehicle population, urban passenger transport in China is largely responsible for increases in energy consumption, greenhouse gas (GHG) emissions, and also atmospheric pollutants (NO_x, CO, HC, PM). In this paper, we first develop an urban passenger transport energy saving and emission reduction potential evaluation model using the "Long Range Energy Alternatives Planning (LEAP)" tool; and then take Tianjin city as an empirical case to evaluate the reduction potential of final energy consumption, GHG emissions and pollutants emissions of Tianjin's urban passenger transport sector between 2010 and 2040 under four scenarios, i.e. BAU (business as usual) scenario, PP (the 12th five-year plan policy) scenario, CP (comprehensive policy) scenario and HP (hybrid policy of PP and CP) scenario. The results show that due to the public transport promotion, energy consumption and CO_2 emissions in 2040 can be reduced by 22% and 22.6% in the PP scenario, compared to BAU. The largest reductions in energy consumption, CO_2 and atmospheric pollutants emissions can be achieved under CP scenario, in which vehicle population regulation is the most effective to be implemented. Emissions standard regulation is the most effective measure to reduce atmospheric pollutant emissions in all the scenarios and green energy promotion is especially effective to reduce NO_x and PM.

1. Introduction

The transport sector is one of the most significant contributors to energy consumption and pollutants emissions throughout the world. In 2007, energy consumption in the transport sector accounted for about 61% of total oil consumption and 28% of total final energy consumption in the world.[1] In the same year, the transport sector represents the second largest share (22.9%) of annual global CO_2 emissions.[2] With ongoing and rapid demand growth and infrastructure development of the global transport sector, especially in developing countries, the energy and environmental consequences are increasingly severe, thus understanding true energy saving and emission reduction potential in the transport sector is an urgent issue.

Many previous studies have considered the nature of energy consumption and emissions in the transport sector, of which key representative studies of transport energy consumption and emissions are presented in Table 1, briefly summarizing their specific features. Bose et al. investigate several possible policies to help save energy and reduce emissions in the passenger transport sector of Delhi, India using the LEAP (Long-range Energy Alternatives Planning system) model [1]. The authors indicate that improvements in public transportation system will achieve the desired impacts but if reinforced by policies to restrict the movement of private vehicles. Pasaoglu et al. employ a bottom-up modeling approach to study the CO_2 reduction potential of promoting alternative fuels and vehicle technologies in Europe's vehicle fleet [2]. Their study shows that the careful deployment of alternative vehicle technologies could contribute very positively to the achievement of energy and climate change policy targets of the European Union, but much effort is needed before implementation

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would be possible such as defining roadmaps for strategic transport technologies, reducing technology costs and changing consumers' attitudes. Using a Kaya framework, David et al. decompose transportation CO_2 emissions into four main source of effect/drivers: population, travel demand, vehicle fuel consumption and fuel carbon intensity [3]. The results show that with respecting to the long-term target for making deep cuts in US transportation GHG emissions (50–80% below 1990 levels by 2050), light-duty vehicles offer the greatest potential for emission reductions, with deep reductions in other subsectors also being possible. Al-Ghandoor employs a bottom-up ANFIS (Adaptive Neuro-Fuzzy Inference System) model to examine the potential benefits of introducing diesel passenger cars to Jordan's transport sector, demonstrating that it is an effective and feasible option for cutting down CO_2 emissions [4]. In addition to the above studies, the COPERT (COmputer Programme to calculate Emissions from Road Transport) emission inventory model has also seen wide use in estimating vehicle pollutant emissions in European countries or cities [5–9], with largely similar policy conclusions and recommendations.

China's vehicle population has experienced a dramatic increase in the past three decades, resulting in huge energy use and pollutants emissions throughout the country. From 1980 to 2007, energy consumption in the domestic transport sector grew rapidly with an average annual growth rate of 7.0% [10]. In 2009, China exceeded the U.S. in vehicle sales and became the largest vehicle market in the world [11]. Vehicle emissions have become the main source of air pollution in large and medium-sized cities in China.[3] Thus, exploring the energy consumption and pollutants emissions in urban transport is urgent, especially for city regions where a huge vehicle stock exists. Therefore, the problem regarding energy consumption and emissions in China's transport sector has been the focus of many previous studies. Yan et al. use the LEAP model to investigate the reduction potential of different policy measures on energy demand and GHG emissions in China's road transport sector [12]. The authors conclude that private vehicle control, fuel economy regulation and fuel tax are the most effective measures to reduce energy demand, petroleum demand and GHG emissions. They also indicate that promotion of diesel and gas as well as biofuels would not be very effective in reducing energy demand and GHG emissions, but would have a significant contribution to reducing petroleum demand because of the substitution from petroleum-based fuel to CNG and biofuels. Huo et al study the well-to-wheel (WTW) energy use and GHG emissions of motor vehicles in China within a bottom-up FEEI (Fuel Economy and Environmental Impacts) model and point out that fuel economy improvements, especially in trucks and heavy-duty passenger buses, has the greatest potential for saving energy and reducing GHG emissions [11]. Similarly, Ou et al. analyze the life cycle energy demand and GHG emissions in China's road transport sector and indicate that the promotion of biofuel, high efficiency electric-vehicles and coal-to-liquid based fuels with CCS (Carbon Capture and Storage) technology are feasible options for China's sustainable transport [10]. Fu et al. employ the MOBILE highway vehicle emission factor model to assess vehicular pollution in China and their results show that vehicle emissions are concentrated in highly populated major cities, such as Beijing, Guangzhou, Shanghai and Tianjin [13].

Unbalanced regional development patterns in China, with some regions/cities growing faster than others, coincides with unbalanced distribution and growth of the vehicle population, transport infrastructure construction, transport policy, etc. Thus, studies which discuss the transport sector from the national perspective may not accurately reflect region/city specific characteristics. Some researchers correspondingly focus on the region or city level problem in China. Liu et al. estimate Shanghai vehicle emission factors based on the MOVES (Motor Vehicle Emission Simulator) model and find that the emission factors for several pollutants from light vehicles in China are 2–15 times larger than those in the US [14]. Che et al. assess the impacts of five possible motor vehicle emission control measures on ambient air quality in the Pearl River Delta region using the Model-3/CMAQ (Community Multi-scale Air Quality) model [15]. Their results suggest that integrated and location-specific pollution control strategies considering co-control of multi-pollutants are needed. Huo et al. use IVE (International Vehicle Emission) model to simulate the vehicle emission inventory in 22 Chinese cities of different sizes and development stages and provide the spatial distribution of China's vehicle emission inventory at the city level [16]. Owing to common problems faced in the urban transport sector, Beijing, Shanghai and Guangzhou have each implemented a series of similar policy measures including traffic control, vehicle licensing restrictions and public transport promotion, which have showed considerable benefits. For example, about 78,000 tons of pollutant emissions were eliminated during the 2009–2010 traffic control in Beijing and the air quality has improved significantly[4]. However, with China's rapid urbanization, the accelerated dense population and the city sprawl, more and more cities in China are experiencing an increasing vehicle stock, confronted with the identical energy and environment issues. Therefore, this paper focuses on the city level problem in China in order to provide more reasonable and effective policies for the energy conservation and emissions reduction.

Tianjin, as one of the four centrally administered municipalities, has experienced a rapid increase in its private vehicle population from 114,100 in 1999 to 1.13 million in 2010.[5] The refined oil consumption in Tianjin's transport sector accounts for about 42% of the total refined oil use in 2010.[6] Moreover, Tianjin is one of the 10 worst air quality cities in China during the first three quarters of 2013,[7] which poses a serious threat to people's health. Reducing energy consumption and emissions in the transport sector in Tianjin is therefore a pressing concern, with little existing direct evidence on the Tianjin context. This paper correspondingly takes Tianjin city as an example and tries to evaluate different reduction scenarios.

As a bottom-up modeling tool, LEAP model has been widely used in transport energy consumption and emissions analysis especially in developing countries and regions [1,12,17–22]. Compared to other energy modeling approaches, LEAP's initial data requirements are relatively simple. The concepts of sector, sub-sector, end-use and the characterization of technological components embodied in LEAP make it both practical and convenient for researchers who model energy systems to analyze each stage from primary energy through to final use [22]. Therefore, based on LEAP model, this paper extrapolates energy consumption, GHG emissions and pollutants emissions of Tianjin's urban passenger transport sector between 2010 and 2040 under four scenarios in order to analyze the reduction potential of various policy measures, and obtain some policy implications. The rest of this paper is organized as follows. In Section 2, we set up an urban passenger transport LEAP model and describe the data sources. In Section 3, we introduce the scenario design and quantification. Results are discussed in Section 4 and policy implications are subsequently made in Section 5. In Section 6, some conclusions are given.

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