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Development of electric vehicles use in China: A study from the perspective of life-cycle energy consumption and greenhouse gas emissions

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HIGHLIGHTS

- There was a marked difference in energy saving and GHG emission reduction for EVs powered by regional grids in China.
- Energy saving and GHG emission reduction from EVs development will be more obvious in China in future.
- EVs development will benefit the strategy of oil/ petroleum substitute in China.

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ABSTRACT

China has promoted the use of electric vehicles vigorously since 2009; the program is still in its pilot phase. This study investigates the development of electric vehicle use in China from the perspectives of energy consumption and greenhouse-gas (GHG) emissions. Energy consumption and GHG emissions of plug-in hybrid electric vehicles (PHEVs) and pure battery electric vehicles (BEVs) are examined on the level of the regional power grid in 2009 through comparison with the energy consumption and GHG emissions of conventional gasoline internal combustion engine vehicles. The life-cycle analysis module in Tsinghua-LCAM, which is based on the GREET platform, is adopted and adapted to the life-cycle analysis of automotive energy pathways in China. Moreover, medium term (2015) and long term (2020) energy consumption and greenhouse-gas emissions of PHEVs and BEVs are projected, in accordance with the expected development target in the Energy Efficient and Alternative Energy Vehicles Industry Development Plan (2012–2020) for China. Finally, policy recommendations are provided for the proper development of electric vehicle use in China.

1. Introduction

1.1. *Energy consumption and greenhouse gas (GHG) emissions in the transport sector*

China is one of the world's fastest growing economies; however, its economic growth has coincided with significant environmental challenges. With an average economic growth rate of 11.2% in the 11th Five-Year Plan period of 2006–2010, economic development is both consuming vast amounts of energy and releasing large quantities of greenhouse gases and noxious chemicals. China is the number one producer of CO_2 emissions and the third-largest producer of SO_2 emissions in the world (Hu and Lee, 2008). China accounted for 23.7% of the world's 28,999 million ton (Mt) CO_2 emissions in 2009, compared with 5.7% of 15,624 million ton CO_2 emissions in 1973 (IEA (International Energy Agency), 2011). China has entered the 12th Five-Year Plan period of 2011–2015, and the central government has laid out objectives to build an energy-efficient, environment-friendly society, in part by saving energy and reducing emissions. Before the 2009 United Nations conference on climate change in Copenhagen, China announced that its target CO_2 emissions reduction per unit gross domestic product in 2020 was 40%–45% relative to the 2005 level (Qiu, 2009).

Emissions from transport vehicles comprise CO_2, CO, HC, NO_x, and particulate matter. The transport sector, as one of the three high-energy-consumption sectors in China (the others being industry and building) and a high GHG emissions sector, faces a serious resource and environmental challenge.

Wang (2011) reported that the consumption of oil products in the Chinese transport sector was 223.2 million ton of oil equivalent

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(Mtoe) in 2010. Gasoline consumption totaled 67.60 million ton and was almost entirely due to road transport demand. The transport sector accounted for 40% and 48% of oil product consumption in China in 2000 and 2009, respectively (CAERC (China Automotive Energy Research Center, Tsinghua University), 2012), and this proportion is expected to rise to more than half of the total oil demand in 2030, in line with global patterns (IEA, 2008). Although the relevant GHG emissions data has not been officially published, the IEA (2003, 2010b) estimated that the transport sector accounted for 6% of China's total CO_2 emissions in 2000 and 7% in 2008. However, as the transport energy demand rapidly increases in China, this share is expected to increase. Cai (2008) projected the share to be 12%–15% by 2020, while the IEA (2008) projected it to be 11.0% by 2030; however, these levels are still lower than the 2008 levels of 20% and 30% for Japan and the United States, respectively (IEA, 2010b).

1.2. Initiatives of electric vehicles (EVs) development in China

China is a developing country, with a huge population and scarce resources. It is important to this country to moderate the relationship among transportation development, resource conservation, and environmental protection, and realize the sustainable development of transportation, energy and the environment.

Zhou et al. (2010) provided a detailed overview of energy efficiency policies in China in past years, and listed a series of policies for the transport sector. In the transport sector, China has launched a series of policies from energy saving and environmental protection perspectives; e.g., China adopted fuel economy standards from 2004, and its fuel economy standards are now more stringent than those of the United States, Canada, and Australia, but less stringent than those of the European Union and Japan. China also implemented the National Phase III vehicle emission standards (equivalent to Euro III standards) in 2007. Additionally, China prioritized urban public transport and promoted efficient public transport systems. Furthermore, vehicle purchase restrictions and traffic restrictions (such as only permitting the use of cars with even/odd license plate numbers on certain days) and parking charges are implemented in some key cities in China.

China has promoted the use of energy-efficient and alternative-energy vehicles. Zheng et al. (2012) provided a detailed review of the relevant policies of EVs development in China. In 2012, China enacted the Energy-efficient and Alternative-energy Vehicle Industry Development Plan (2012–2020) (hereinafter referred to as the “Plan”) (State Council, 2012). The Plan highlights that energy-efficient and alternative-energy vehicles mainly include plug-in hybrid electric vehicles (PHEVs), pure battery electric vehicles (BEVs), fuel-cell vehicles (FCVs), and alternative-fuel vehicles (AFVs) (such as natural-gas and biofuel vehicles).

The Plan gives priority to the development of PHEVs and BEVs, and the speeding up of the transformation of the automotive industry. At the same time, China will continue to develop a unified plan with due consideration to all concerned. Great efforts will be made to develop energy-efficient vehicles and to continue to investigate FCV technology and develop AFVs in accordance with local conditions.

The development strategy of the Chinese industry of energy-efficient and alternative-energy vehicles is to develop BEVs and PHEVs in a coordinated manner, then gradually shift away from PHEVs and toward BEVs, and ultimately develop FCVs. The target accumulated production and sales numbers of BEVs and PHEVs in the Plan are 0.5 million to 2015 and 5 million to 2020.

1.3. Research on EVs energy consumption and GHG emissions in China

Recent researches have examined the GHG emissions related to the use of EVs in China. Ou et al. (2010a) examined GHG emissions of coal-fired-based EVs and conventional coal-to-liquid vehicles making key assumptions for the year 2015. Their result shows that the use of coal-fired-based EVs can reduce life-cycle GHG emissions whereas the use of conventional coal-to-liquid vehicles will increase life-cycle GHG emissions relative to the use of petroleum-based gasoline vehicles in the near future. Ou et al. (2010b) examined the energy consumption and GHG emissions of AFVs using real-world data for 2009 and found that the use of an EV bus can reduce GHG emissions slightly when compared with the use of a gasoline/diesel bus, and they suggested the promotion of EVs development in China. Huo et al. (2010) examined CO_2 and other emissions of EVs in both current (2008) and future (2030) periods, and compared them with the emissions of conventional gasoline internal combustion engine vehicles (ICEVs) and PHEVs. Their results show that the use of EVs does not reduce CO_2 emissions currently, but greater CO_2 reduction could be expected in the future if coal combustion technologies improve or the share of coal-fired electricity decreases in China in future. Doucette and McCulloch (2011) simulated CO_2 emissions of the BEVs which are modeled to determine their energy consumption, by combining with data on the CO_2 intensity of the power generation mix in different countries including China, and compared with data for four ICEVs counterparts to reveal the emissions resulting from BEVs operation. Their results show that for China, India, and other countries with a similarly high CO_2 intensity, unless power generation becomes dramatically less CO_2 intensive, BEVs will not be able to deliver a meaningful decrease in CO_2 emissions, and an increase in the penetration of BEVs could actually lead to higher CO_2 emissions. Wu et al. (2012) analyzed the GHG advantage of EVs at a regional level in China by taking a group of cities undergoing special economic development. There are two main aspects to the different conclusions of whether the use of EVs can reduce GHG emissions compared with the use of conventional ICEVs in the above mentioned studies: the range of the energy efficiency advantage of the EVs over the ICEVs and the carbon intensity of electricity used to charge an EV. In China, the electric power supply structure depends on the region. Each power grid has a different energy structure and each city within a regional power grid receives most of its electricity from the grid in which it is located, and there is little transfer of electricity among regional grids currently. It is thus necessary to examine the EVs energy consumption and CO_2 emissions for different regional power grids (Zhu et al., 2005; Cherry et al., 2009; Huo et al., 2010; Wu et al., 2012).

1.4. About this study

This study examines energy consumption and GHG emissions of PHEVs and BEVs through life-cycle analysis (LCA), and includes a comparison study with conventional gasoline ICEVs. Energy consumption and GHG emissions performance in EVs pilot cities within regional grids, which have seldom been considered in former studies, are analyzed. Energy consumption and GHG emissions are projected in the medium term (2015) and long term (2020) in accordance with the targets announced in the Energy-efficient and Alternative-energy Vehicle Industry Development Plan (2012–2020) for China.

From the perspective of reducing energy (petroleum in particular) use and GHG emissions, the objectives of this study are as follows:

(i) Confirm the rationale of EVs development policies, such as the benefits of energy savings, GHG emissions reduction, and oil/petroleum substitution.