Hybrid- and battery-electric vehicles offer low-cost climate benefits in China

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ABSTRACT

Car ownership in China is expected to grow dramatically in the coming decades. If growing personal vehicle demand is met with conventional cars, the increase in greenhouse gas emissions will be substantial. One way to mitigate carbon dioxide (CO_2) emissions from passenger travel is to meet growing demand for cars with alternative vehicles such as hybrid- and battery-electric vehicles (HEVs and BEVs). Our study examines the cost-effectiveness of transitioning from conventional cars to HEVs and BEVs, by calculating their marginal abatement cost (MAC) of carbon in the long-run. We find that transitioning from conventional to hybrid and battery electric light-duty, four-wheel vehicles can achieve carbon emissions reductions at a negative cost (i.e. at a net benefit) in China. In 2030, the average MAC is estimated to be about −$140/ton CO_2 for HEVs and −$515/ton CO_2-saved for BEVs, varying by key parameters. The total mitigation potential of each vehicle technology is estimated to be 1.38 million tons for HEVs and 0.75 million tons for BEVs.

1. Introduction

Current carbon emissions from China's transportation sector are relatively low compared to emissions from other carbon-emitting sectors in the country. In 2014, transportation accounted for 9% of total carbon dioxide (CO_2) emissions from fuel combustion in China (IEA, 2016a). Carbon emissions from transportation in China are projected to grow at an increasing rate in the future, faster than emissions from other carbon-producing sectors (Fridley et al., 2012). Much of this growth is expected to be driven by increasing demand for transportation, particularly for personal cars. Although car ownership in China (about 110 per 1000 persons in 2015, varying by region) is still lower than that of other countries such as Japan and the United States (about 600–800 per 1000 persons), it is expected to increase dramatically in the next two decades, to more than 200–300 cars per 1000 persons resulting in more than 300–400 million passenger vehicles (EU SME Centre, 2015; Wu et al., 2014; Wang et al., 2011). China is already the world's largest auto market in terms of annual sales, with 28 million cars sold in 2016 (CAAM, 2017). By 2030, China is expected to rank first in the world in terms of total vehicle stock and will experience the fastest average annual growth rate in vehicle adoption between 2002 and 2030 in the world (Huo and Wang, 2012). Growth in vehicle ownership and use may be slowed if road transportation infrastructure is unable to keep pace with demand, resulting in worsening congestion. However, the strong link between income growth and vehicle ownership has held true in every country thus far (Dargay et al., 2007). If the growing demand for vehicles is met with conventional internal combustion engine vehicles (ICEVs) without any policy intervention, greenhouse gas (GHG) emissions from vehicles in China

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are expected to increase by more than 70% by 2050 (Huo et al., 2012b).[1] Thus, any comprehensive climate mitigation plan for transportation in China must include a strategy for decarbonizing the light-duty vehicle (LDV) fleet.

The country has actually taken several steps toward LDV decarbonization through a focus on progressively stronger fuel economy standards and accelerating the deployment of electric vehicles (EVs). A timetable for increased stringency in fuel economy standards in the form of a Corporate Average Fuel Consumption (CAFC) metric has been proposed until 2020. A CAFC (includes cars and light trucks) compliance level of 6.9 L/100 km went into effect in 2015. The proposed CAFC standard in 2020 is 5.0 L/100 km (ICCT, 2014).[2] Under the National Energy-Saving and New Energy Vehicle Industrial Development Plan for 2012–2020, the country has also launched a series of policies and incentives to deploy electric vehicles (EVs), with focus first on public vehicles in 25 cities (2009–2012) and private vehicle sales in 88 cities (2013–2015). China aims to fully commercialize the EV market after 2025 through continuing policy supports, e.g., targeting deployment of 5 million EVs by 2020 (Gong, 2015; Marquis et al., 2013; He and Tu, 2012). To achieve these goals, the Chinese governments at local and national levels have been attempting to lead consumers toward EVs with a variety of incentives, some of which are described below:

- Generous purchase incentives administered in several forms by several levels of government (e.g. tax credits, discounts or rebates, etc.) (IEA, 2016)
- Exemption of EVs from congestion controls in big cities (e.g., waivers on toll/parking fees, access to restricted traffic zones, etc.) (IEA, 2016; DeMorro, 2015; Edelstein, 2015).
- Large annual quota for EVs under city policies that restrict LDV purchases using a lottery system. Specifically, Beijing only allows half of its annual quota to be filled with conventional cars while the remaining is reserved for EVs. Shanghai has a similar policy but instituted through an auction rather than a lottery (Zeng, 2013).
- Recently, there have been several local government incentives for installation of charging infrastructure which leverage funds from the national level (Gong, 2015).

These policies have been quite successful, making China the leading EV car market in the world.

However, existing literature questions the cost-effectiveness of transitioning to EVs as a CO_2 emissions mitigation strategy. The carbon marginal abatement cost (MAC) curve is a metric commonly used to evaluate the cost-effectiveness of climate change mitigation measures at various scales (e.g., country- and region-specific, global, etc.). Past studies show that, although the magnitude of MAC for hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) varies depending on conditions and scales used in the analysis, the MAC is assessed to be positive, meaning that there is a net cost rather than a net savings associated with EVs as a mitigation measure (savings are indicated by a negative MAC) (Fan et al., 2017; McKinsey & Company, 2009; IEA, 2009). Literature also pointed out that lower battery costs and wider differences between gasoline and electricity prices are important factors that make alternative cars become economical eventually (IEA, 2009; Kammen et al., 2008). This is partly because previous studies overestimated costs of implementing a technology such as HEVs and BEVs over ICEVs.

The objective of this study is to (1) quantify the fuel economy improvements and CO_2 emissions reductions that could result from replacing conventional new vehicle sales with HEVs and BEVs, (2) quantify the capital and operational cost savings associated with this vehicle technology transition, and (3) combine these results to calculate MAC (in terms of $ per CO_2-saved), and generate a MAC curve. We estimate incremental costs for HEVs and BEVs compared to their conventional counterparts for the year 2030, given expected future increases in fuel efficiency standards.

2. Data, methods and assumptions

To achieve the objective of this study, we undertook the following analytical steps:

1. Collected data to generate fuel consumption and CO_2 emissions rates for conventional cars, HEVs,[3] and BEVs,
2. Estimated incremental vehicle costs for HEVs and BEVs in China compared to their conventional counterparts, using component cost information and methods developed by the U.S. National Research Council (NRC, 2013),[4]
3. Calculated operating cost savings for HEVs and BEVs in China compared to their conventional counterparts, using fuel consumption rates determined in step 1.

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[1] For example, Huo et al. (2012b) projected the annual greenhouse gas emissions of Chinese vehicles to be between 1600 and 2000 million metric tons of CO_2e, compared to about 800 million metric tons of CO_2e, with the business-as-usual scenario.

[2] According to the proposed phase-in standard, actual CAFC of a manufacturer between 2016 and 2019 is allowed to exceed the required 2020 CAFC targets by a certain percentage, i.e., 32% in 2016, 24% in 2017, 16% in 2018, and 8% in 2019 (ICCT, 2014).

[3] HEVs in this study are defined as those that combine ICE, electric motor(s), and a battery or ultra-capacitor, such as Toyota Prius. These vehicles cannot be plugged in to charge the battery.

[4] The NRC report assesses the potential for reducing petroleum consumption and GHG emissions by the U.S. LDVs by examining technologies such as highly efficient ICEVs, vehicles operating on biofuels, electricity, hydrogen, and natural gas with comprehensive sets of technical data and scenario analyses. The report used a bottom-up component based methodology for cost estimation of multiple vehicle technologies. The study considered two scenarios, midrange and optimistic, for cost and performance. We used in this analysis midrange goals that are ambitious but plausible.