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Can the development of electric vehicles reduce the emission of air pollutants and greenhouse gases in developing countries?

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ABSTRACT

Developing the electric vehicle (EV) industry is generally considered to be an effective way of easing the imbalance between the supply and demand of oil, and, in addition, the pressure to reduce environmental pollution. Developed countries and most developing countries including Brazil, Russia, India, and China (so-called 'BRIC' countries) are actively promoting the development of EVs. By studying different types of widely-used gasoline internal combustion engine vehicles (ICEVs) and EVs, we compare the effect on the environment of utilizing EVs in both developed and developing countries. This is achieved by using a 'well-to-wheel' method. The results show that compared to gasoline ICEVs, EVs have a significant effect on CO_2 emission reduction. However, the corresponding air pollution due to SO_2, PM_{10}, NO_x, etc. for a given EV varies substantially in different countries because of the influence of several factors (electrical power structure, line loss rate, and so on). As developing countries use larger proportions of thermal power or present high line loss rates, pollutant emission produced by a certain EV is much higher than that in developed countries. Taking China as a typical developing country as an example, this research dynamically predicts the environmental effects expected in 2020 and 2025 due to a developing EV industry. Predictions are based on a method of Monte Carlo simulation and consider the government's development plan for energy. Finally, according to the results obtained, policies and suggestions for the development of the EV industry in developing countries are proposed.

1. Introduction

It is generally believed that electric vehicles (EVs) have significant advantages compared to alternatives in terms of energy saving, emission reduction, and environmental protection. Therefore, the popularization and application of EVs has great significance for reducing oil demand, ensuring national or regional energy security, and achieving sustainable development of the economy and society (Faria et al., 2014). In the 1970s, developed countries, such as the United States, Japan, and Germany began to research and develop EVs in response to the oil crisis and environmental pollution. Subsequently, a relatively complete technical chain and market system have been formed in these countries. Due to the gradually increasing influence of oil price fluctuations on the economy, and an ever increasing pressure to reduce emission of greenhouse gases (GHGs), popularizing EVs has become a development trend in the global automotive industry and will continue to do so in the future.

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In recent years, many developed countries have made plans for the development of EVs. For example, they have introduced a series of supporting policies (with unprecedented attention) and invested greatly in research and development (R&D). In his 2011 State of the Union address, the president of the United States, Barack Obama, put forward the development goal of putting 1 million EVs into use before 2015 (Whitehouse, 2011). In a development act by the United States Congress for EVs, there is a 20-year long-term development goal to expand the scale of the EV market to 100 million by 2030 (Yang et al., 2011). The Japanese Ministry of Economy, Trade and Industry (METI) published the *Research and Development Strategy for Automobiles of Next Generation* in 2010. The document clarified their strategic steps for the research and development of EVs from six aspects: overall, battery, resource, infrastructure, system, and international standardization. Meanwhile, according to the strategy, the volume of sales of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) is expected to account for 15–20% of new cars by 2020 (METI, 2016).

Some developing countries have also attached great importance to the development of the EV industry. For instance, in 2013 the Indian government issued the *National Electric Mobility Mission Plan 2020* to encourage manufacturers to produce EVs. India's goal is to produce 6–7 million EVs by 2020 (MHIPE, 2013). The Chinese government regards the development of the new energy (mainly for PHEVs and BEVs) automobile industry as an important strategic measure to promote the adjustment of China's economic structure during the period of the 12th Five-year Plan. The aim is to take the lead by making a detailed plan for the application and popularization of EVs in urban bus fleets and vehicles for government use. Furthermore, the government has launched a pilot scheme to provide subsidies for individuals purchasing new energy vehicles (Wang, 2013). In Russia and Brazil, even though EVs are only slowly being popularized, they have also issued development plans for related industries. For example, in 2012 the Russian Ministry of Transport issued the *Plan for Developing and Popularizing Electric Vehicles in Russia* which aims to promote the development of the EV market via policies such as infrastructure construction, tax exemption, etc. (Chen, 2013). The Brazil Electric Vehicle Association has also made a plan related to EV development. The plan requires the number of EVs used to exceed 80,000 by 2020 and expects energy consumption by EVs to account for 3–5% of the national energy consumption by 2030 (Frost and Sullivan, 2013).

In the minds of most people, EVs have various advantages over traditional gasoline ICEV (internal combustion engine vehicles), e.g. diversified fuel sources and low emissions of exhaust gas.[1] Therefore, energy saving, emission reduction, and environmental protection have become powerful forces driving the rapid development of the EV industry. However, one must view the situation from the perspective of the life cycle of the energy used by vehicles and consider the air pollutant emissions and greenhouse gases involved in the process of exploiting, producing, and utilizing the energy. This raises the following questions which need to be answered objectively: Can the utilization of EVs reduce emission of air pollutants and greenhouse gases? Are there significant differences in the environmental effects caused by the development of the EV industry in different countries or regions? If the use of EVs turns out not to be particularly environmentally friendly, then what external supporting measures could be taken to effectively reduce air pollution and greenhouse effect as governments vigorously develop their EV industries? The aim of this study is to attempt to answer these questions.

In recent years, with the commercialized development of EVs, the environmental effects brought by EVs have been given most attention by the academic community. The life cycle method is a comprehensive approach for studying the environmental effects contributed by the utilization of EVs. In this method, pollutant emissions and greenhouse gases caused by consuming energy are assessed over the whole life cycle of the EV. These sources of energy may be primary or secondary, and may be non-renewable or renewable. Based on real driving experiments in Britain, Ma et al. (2012) compared CO_2 emission over the whole life cycle for ICEVs, HEVs (hybrid electric vehicles), and BEVs. The results show that BEVs emit the least amount of CO_2, followed by HEVs; the largest CO_2 emission is found for ICEVs. Pollutant emissions and greenhouse gases from production and recycling are closely related to the production of raw materials, and the evaluation process is complex (Fuchs et al., 2014). Subsequently, more and more scholars are using the 'well-to-wheel' (WTW) approach to assess the environmental effects brought about by the adoption of EVs. Here, pollutant emissions and greenhouse gases are assessed over the whole life cycle of the energy the vehicle uses from production, to utilization, to discharge.

Using the WTW method combined with the GREET model,[2] Huo et al. (2009) evaluated the emission of air pollutants such as volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM) produced by HEVs and BEVs in the United States and Canada. The study found that compared to ICEVs, the use of EVs can significantly reduce the emission of VOCs and CO — however, it increased PM_{10} and $PM_{2.5}$ emission. Also using the WTW method, Álvarez et al. (2015) compared the emission of CO_2 and GHGs brought about by driving BEVs for 1 km in member states of the European Union (EU). The results provide a useful reference for the EU to establish a low-carbon credit policy. On the basis of the WTW method, some scholars have begun to pay attention to external effects resulting from the use of EVs. More specifically, they have attempted to assess the economic loss caused by pollutant emission and greenhouse gases, incorporate the external environmental cost into the total cost of automobile consumption to provide a more unified picture. In this way, the economical efficiency of the use of EVs over ICEVs can be compared to help governments make corresponding development plans and help guide policies aimed at the EV industry. For example, Bickert et al. (2015) explored the external environment costs caused by CO_2 emission from BEVs

[1] In recent years, power to gases (PTG) and power to liquids (PTL) technologies have received increasing attention (Varone and Ferrari, 2015). These technologies can convert electrical power into natural gas, so as to provide fuel for ICEVs. Due to the diversity of raw materials available for power generation, PTG and PTL technologies enable coal, biomass and renewable energy to be power sources for ICEVs. Therefore, the environmental performance of ICEVs equipped with the aforementioned new technologies may be not inferior to EVs.

[2] The **G**reenhouse gases, **R**egulated **E**missions, and **E**nergy use in **T**ransportation model (so-called 'GREET' model).