

Energy and environmental impact of battery electric vehicle range in China



Xinmei Yuan^{a,*}, Lili Li^b, Huadong Gou^a, Tingting Dong^c

^a State Key Lab. of Automotive Simulation and Control, Jilin University, Changchun, Jilin 130025, China

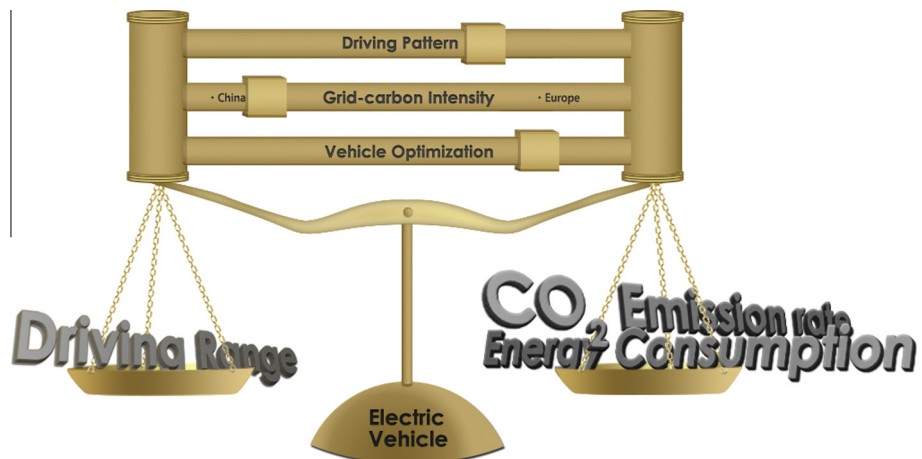
^b State Grid Energy Research Institute, Beijing 102209, China

^c Geely Automobile Institute, Hangzhou, Zhejiang 311228, China

HIGHLIGHTS

- Analysis of the battery electric vehicle (BEV) energy consumption distribution.
- A simplified analytical BEV energy efficiency model to understand the driving pattern impact.
- Parameter variation analysis of rolling coefficient, drag area, battery energy density and grid carbon intensity.
- Evaluation of vehicle design optimization potentials.
- Suggestions of appropriate BEV battery ranges in China.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 20 April 2015

Received in revised form 29 July 2015

Accepted 3 August 2015

Available online 15 August 2015

Keywords:

Electric vehicle
Driving range
Driving pattern
CO₂ emission
Grid-carbon intensity

ABSTRACT

To meet increasingly stringent emission legislation, electric vehicles are expected to offer promising sustainable mobility in the future. However, the driving range of battery electric vehicles (BEVs) is limited as compared with hybrid electric vehicles (HEVs). Additionally, the grid power supply in China is highly dependent on coal-based thermal power generation, which leads to high grid-carbon intensity and increased well-to-tank (WTT) emission for BEVs. Therefore, the tradeoff between electric vehicle driving range and environmental impact has become a critical problem in BEV development in China.

In this study, a BEV model is built and validated. The energy consumption and well-to-wheel (WTW) CO₂ emission rates of different driving ranges and test cycles are simulated. To determine the impact of driving patterns on BEV energy consumption, the distribution of vehicle energy consumption is analyzed and an analytical model is proposed to generalize the energy consumption of BEVs in standardized driving cycles to real-world driving with only two statistical characteristics: the average and the variance of the speeds. It is found that BEVs have a great advantage in terms of energy saving only at driving cycles with low average speeds and frequent stops. While driving at highway speeds, the energy consumption of BEVs can be very high. With an understanding of driving pattern impact, parameter variation analysis of the BEV WTW CO₂ emission rates for different driving ranges is simulated. Simulation results show that the rolling coefficient and battery energy density have a significant impact on driving range, followed by the drag area. However, grid-carbon intensity is more efficient for reducing WTW CO₂ emissions.

* Corresponding author. Tel./fax: +86 043185095425.

E-mail address: yuan@jlu.edu.cn (X. Yuan).

Currently, optimization of the rolling coefficient and drag area is the most viable option for increasing the battery range and decreasing the WTW CO₂ emission rate.

Finally, to reduce the energy and environmental impact of BEVs in China, short driving ranges (<250 km) and low driving speeds (<80 km/h) are suggested for current BEVs, and optimization of the vehicle design and reduction of grid-carbon intensity are considered to be the most critical issues for the future application of BEVs.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

With increasingly stringent car emission legislation worldwide, electric vehicles are expected to offer promising sustainable mobility in the future. The electric vehicle industry has developed rapidly in recent years. Compared with hybrid electric vehicles (HEVs), limited driving range is considered a primary barrier to the adoption of battery electric vehicles (BEVs) [1,2]. Thus, increased battery ranges are expected. However, increased battery ranges lead to increased vehicle mass and decreased energy efficiency. Therefore, both the economic and environmental benefits of electric vehicles could be affected by the increased driving ranges.

Extensive research of electric vehicle energy and environmental impact assessments has been conducted through the methodology of well-to-wheel (WTW) analysis, comprising both the well-to-tank (WTT) and the tank-to-wheel (TTW) energy conversions [3–7]. Globally, the power generation sector is responsible for a large share of present-day greenhouse gas (GHG) emission. WTT analysis for the assessment of power generation is based on mix pathways, including coal, nuclear energy, natural gas, renewable energies, etc. GHG emission from power generation and supply are highly dependent on the generation pathways. Fossil fuel power is still a major contributor to GHG emission; nuclear energy and renewable energies are attractive power generation technologies with much lower GHG emission. Additionally, more efficient conversion of fossil fuels and adoption of carbon capture and storage technologies can also lead to substantial reductions in life-cycle GHG emission [8]. In terms of TTW, BEVs result in zero emission in the transportation sector; therefore, the energy efficiency of BEVs is the primary concern. The impact of driving pattern and vehicle mass is widely discussed. Generally, benefitting from brake regeneration, electric vehicles show greater fuel-saving capabilities under aggressive driving conditions as compared with conventional vehicles [9]. Also, simulation results indicate that significant life cycle energy and GHG emission reductions can be achieved when steel is replaced with lightweight materials [10]. Because of the low battery energy density, the driving range of plug-in hybrid electric vehicles (PHEVs) or BEVs is highly correlated with vehicle mass, and therefore it has a significant impact on energy efficiency [11,12]. Regarding WTW analysis, studies have shown that GHG reduction achievable from electrified transportation is smaller than previously considered [13,14]. This is particularly true in China because of both the increasing demand for mobility and the currently highly carbon-intensive Chinese grid [15]. Previous electric vehicle life-cycle studies have covered a wide range of vehicles [BEVs, HEVs, PHEVs, fuel cell electric vehicles (FCEVs), conventional vehicles (CVs), etc.] and the influence of a variety of factors (grid-carbon intensity, driving pattern, driving range, etc.), but there are several key problems that have not been clearly solved or fully addressed, including the driving pattern effect, the country-specific case in China, and vehicle design optimization potentials.

Generally, the energy consumption of BEVs is estimated from the simulation results of a prototype BEV model in standardized

test cycles [16,15]. Therefore, these results are highly dependent on test cycles. However, real-world driving is complex and can vary substantially from standardized test cycles. Hence, the energy efficiencies estimated from standardized driving cycles are incomplete [17] and difficult to generalize to real-world driving. Many researchers have concentrated their efforts on finding the relationship between energy consumption and driving pattern. Characteristics of test cycles (e.g. average speed, average acceleration, maximum speed, maximum acceleration, stop frequency, time stopped) are used to describe the driving pattern, and statistical analysis of the energy consumption is performed to understand the impact of driving patterns [18]. Because the results are obtained from statistical analysis, they lack analytical explanations and are difficult to generalize. A primary difficulty in driving pattern studies is the nonlinear and nonuniform characteristics of HEV and CV powertrains. Conversely, the characteristics of BEV powertrain are simple and uniform. Therefore, it is possible to derive a physically based analytical model to give a clearer picture of the effect of driving pattern on BEVs.

In 2014, the production of automobiles in China reached 23.7 million, ranking first in the world. Since significantly increased vehicle emission has aroused widespread concern, policies to improve the marketing of electric vehicles are being introduced by the Chinese government [19,20]. In these policies, the driving range of BEVs is an important index related to subsidies, as shown in Table 1. As shown in the table, the subsidies increase with increasing driving range; however, the BEV's energy efficiency decreases because of the increased battery weight. Additionally, considering the environmental impact, the highly carbon-intensive Chinese grid further limits the BEV's driving range. Therefore, a specific case study of the impact of the BEV driving range in China has significance for policy making and BEV development.

Limited by the small production of BEVs, most BEVs in China are modified from conventional models without further optimization. Previous studies have mentioned that using lightweight materials is effective for reducing the WTW emissions of BEVs [10], but other factors (such as rolling coefficient, drag coefficient) in vehicle design are also important. Which factors should be optimized and the improvement potential of the vehicle design optimization are rarely discussed. With a physically based analytical model of BEV energy consumption related to driving pattern, the key factors affecting the energy consumption can be more reasonably chosen and the parametric variation analysis could provide important data for vehicle design optimization.

In this paper, an electric vehicle model is built and validated based on a prototype BEV. In order to understand the influence of driving patterns, a novel analytical energy consumption model

Table 1
Subsidy standard of battery electric passenger car (2013) [19].

Driving range (km)	$80 \leq R \leq 150$	$150 \leq R \leq 250$	$R \geq 250$
Subsidy (RMB)	35,000	50,000	60,000

Download English Version:

<https://daneshyari.com/en/article/6685854>

Download Persian Version:

<https://daneshyari.com/article/6685854>

[Daneshyari.com](https://daneshyari.com)