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# Rethinking impact evaluation and carbon reduction analysis on electric bus vehicles in China

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**Abstract.** New energy bus vehicles (NEBVs) are expanding in China, but they have some problems such as technology, high cost and safety etc., thus NEBVs should be comprehensively evaluated from costs, technologies, environment, and based on the evaluation results, some changes should be improved. This paper firstly analyses the current status of both vehicle development and existing policies, identifies the main characteristics and the main problems in term of the economic, standard, policy, etc., by scenario analysis, forecasts the future growth from now to 2030 and calculates the emission reduction in low level scenario and high level scenario. In 2020 and 2030, 6 million and 24 million ton of CO<sub>2</sub> emission will be reduced respectively. Finally, the paper makes a conclusion of Chinese experiences and gives some measures for the future development.

## 1. Introduction

Nowadays, low carbon development has become the main theme in the development of various industries in China. A key area of carbon emission: transport, keeps growing at a rate of 10% currently [1]. In recent years, New Energy Bus Vehicles (NEBVs) have been an important measure to carry out carbon reduction. Compared with fuel vehicles, NEBVs are characterized by energy saving and emission reduction. Now, NEBVs technology is also gradually advancing to maturity for comprehensive application. From another point of view, the capability of public transport still has a big gap, which must be a golden opportunity for the application of NEBVs in the future. Considering the areas of bus operation are mainly located in the downtowns with convenient supporting facilities, therefore bus become the priority area for NEVs (New energy vehicles) use. So NEBVs, especially BEBVs (Battery Electric Bus vehicles) have become a significant part in the establishment of low carbon transport system in China.

In recent years, many research projects have been conducted on the trends and measures of NEBVs or BEBVs. Taking operating efficiency of NEVs, infrastructure, industrial policy and consumers as the four common influencing factors of the development of NEVs by factor analysis, researchers have built a structural equation model (SEM) of the development of NEVs, then tested the effects from the different influencing factors and their interaction mechanism [2]. The economic, energy and environment benefits of NEVs have been evaluated through establishing life cycle cost model and fuel life cycle analysis, then gives some countermeasures [3]. In the theoretical framework, collects the new energy automobile industry innovation policies from 2001 to 2015 through the database “PKULAW”, using the “Phase-Failure-Incentive” analysis method, then evaluates policy performance to make policy optimization [4]. Analyzes comprehensively the development status, technical progress



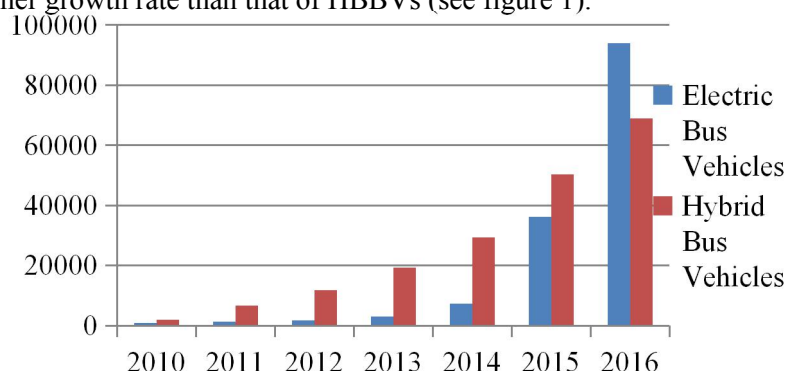
of NEVs industry in China and future development tendency globally, and then makes a series of policy recommendations [5]. Analyzes the subsidy, development target and plan, and then raises the inspiration for fast development of NEVs in China [6]. In conclusion, most of the research projects above are focused on the production and sales of BEBVs or how to develop electric car, while few research projects are focus on the policy and measures, standard, and management of BEBVs in the perspective of bus operation in China.

This paper identifies the main characteristics and the main problems including technology, cost, safety and standard of BEBVs, by scenario analysis using a self-built model, forecasts the CO<sub>2</sub> emission reduction, finally put forward some development measures.

## 2. Development status of NEBVs

### 2.1. Development status

At the national level, by the end of 2016, the volume of Bus vehicles had reached 608,600 among which the volume of NEBVs was 164,600 accounting for 27.1% of the total and covering 31 provinces, areas or municipalities in China. Among them, the ratio for BEBVs and hybrid bus vehicles (HBBVs) is 1 to 1.4, and the annual growth for them are 114.8% and 80.9% respectively between 2010 and 2016, BEBVs has a higher growth rate than that of HBBVs (see figure 1).



**Figure 1.** Development status of NEBVs from 2010 to 2016.

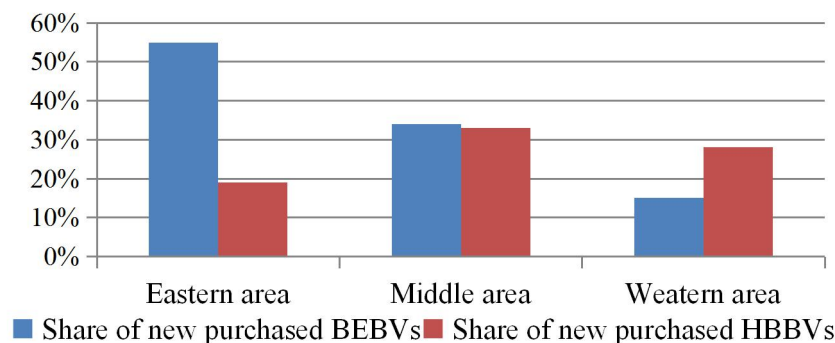
**Data source:** National Report on Urban Passenger Transport Development

At the local level, some provinces and cities develop fast and spend much effort on promotion on NEBVs. By the end of 2016, the ratio of NEBVs use in Henan province is 49.2%, which is the highest one, the ratio of NEBVs growth in Shanxi province is 28.4%, which is the highest one in China. In some cities, Hangzhou has 3451 NEBVs, which is accounting for 39.4% of the total bus vehicles, now all the main urban districts are covered by NEBVs and clean fuel buses. There are 7417 NEBVs (5901 BEBVs and 1516 HBBVs) in Shenzhen now [7].

### 2.2. Main characteristic analysis

1) Regional differences exist in the choice of power type for buses: mainly BEBVs in eastern area, while mainly HBBVs in western area in China

In order to echo the call of the Central Government, different localities are actively promoting NEVs in bus. However, due to differences in industrial policy and economic level and transport condition, the local developments in various regions are significantly different with each other. In those cities of the Eastern area with a high economic level, BEBVs are in a larger volume; in the central area, BEBVs and HBBVs have almost in the same amount; while in those western area, due to a rather low economic level, more HBBVs are adopted (see figure 2) [7].



**Figure 2.** Regional distribution of BEBVs and HBBVs development

**Data source:** National Report on Urban Passenger Transport Development

2) Technical approach is clear, diversified charging patterns of buses, which can meet different consumer' demands

In terms of the technical approaches for the charging of BEBVs, it's given that the technical approaches for current battery charge modes have no obvious good or bad characteristics according to the Central Government in 2003 [8]. So it's more important which modes can meet the different demands well in different areas or for different enterprises. There are normally a variety of modes for buses to charge based on the survey from bus enterprises in China, including slow charging, slow charging with fast replenishment, fast charging and power change. Now different charging modes have been used well during the operation in different areas of China.

3) Battery technology needs to be improved, less travel distance, which leads to low service level of buses

Based on the survey data from bus companies, the lower travel distance or range of BEBVs has seriously affected the service level of these types of bus. Currently, the BEBVs can cover a daily distance of 130 km on average, accounting for about 60% of that by Diesel vehicles. HBBVs can cover a daily distance of 200 km on average, almost the same as Diesel vehicles. In addition, temperature exerts a big impact on the distance and battery life where battery performance is unstable when subjected to the low temperatures experienced in winter in the Northern area. Due to fast battery attenuation, in particular after three years, battery power can attenuate by over 15%.

### 3. Main current policies

#### 3.1. Automotive industrial policies

Since 2010, the BEBVs achieved rapid development, owing to the introduction of many relevant policies, including development planning, guiding opinions, standard system and supporting policies. The development goals, trends, focus, path and safeguard measures have been identified nationwide. For example, *Planning of Industrial Development for NEVs (2012-2020)*, *Guiding Opinions on Accelerating Development of Charging Infrastructure for NEVs* by the State Council and *Notice of Continuing with Application Work on NEVs* jointly by Ministry of Finance (MOF) and Ministry of Science and Technology. By 2020, the new energy automotive industry will have identified its development goals which are to decide on the strategy of NEVs and automotive industrial transformation as battery-driven power and to promote the NEVs with current focus on promoting industrialization of BNEVs and PHVs (Plug in Hybrid vehicles) and penetration of non-PHVs. The development goal of NEVs is that the proportion of NEVs in the new or renewed vehicles where NEVs are promoted and applied should be over 30% [9].

### 3.2. Urban public transport policies

The high importance from Ministry of Transport (MOT) has been attached to the priority development of public transport by some major policies. Rapid development has been achieved in the public transport with service level and capabilities being significantly enhanced, the NEVs are also promoted rapidly in public transport. Major policies promulgated in recent years include *Guiding Opinion on Priority Development of Public Transport* by the State Council, *implementation opinions by MOT concerning the State Council's Guiding Opinion on Priority Development of Public Transport* and *Implementation Opinions of General Office under MOT on Accelerating Application of NEVs*. The development goals of NEVs are proposed: by 2020, the total volume of buses, taxi and urban logistic distribution will have reached 300,000; scale of application is bigger noticeably. Among the new or renewed city buses, taxi and city logistic distribution vehicles for the building of "Transit Metropolis", the share of NEVs will have been no less than 30%; In the Beijing-Tianjin-Hebei area, the share of NEVs will have been no less than 35%. By 2020, the volume of NEVs will have totaled 200,000 [5].

### 3.3. Financial and tax support policies

In order to attain the development goal of NEVs set by the State, the national level financial and tax policies are proposed concerning purchase tax exemption, vehicle tax preference, operation and construction subsidy of supporting facility, mainly including *Notice of Purchase Tax Exemption on Buses and BEVs for Bus*, *Notice of Vehicle Tax Preference on Energy Saving and Using NEVs*. Targets, scope and criteria about subsidy on BEVs by the central budget during the "Thirteenth Five-Year Plan" are identified. The subsidy products include BNEVs, PHVs and fuel cell vehicles (FCVs). The subsidy criteria depends on the effects of energy efficiency in combination of production cost, scale effect and technical advancement. The subsidy criteria in 2017-2018 will lower by 20% based on the figure in 2016 and the subsidy criteria in 2019-2020 will lower by 40% based on that in 2016. In 2016, MoF publicized *Incentive Policies on Charging Infrastructure of NEVs and Notice of Strengthening Application of NEVs*. The central budget allocated subsidy on construction of charging facilities for those eligible provinces [10].

By pushing from the government, guidance of both national and local subsidy and innovation development of the automotive enterprises, BEVs increase quickly and accumulate some valuable experience, and the huge emission reduction has been realized in the meantime.

## 4. Main existing problems

Currently, the BEVs have the following main characteristics: fast volume growth, poor use experience, acute safety problems, poor operation management, underdeveloped supporting facilities and poor in-place standards and regulations.

### 4.1. Frequent safety incidents

At present, serious challenges are encountered considering the uneven level of battery safety on BEVs and safety management of charging facilities. The safety of BEVs application can be reflected in the technical safety of battery, motor and electric control. According to incomplete statistics, over 30 accidents arising from the NEVs catching fire occurred nationwide in recent two years, among which 70% took place on the BEVs. Due to under-production of batteries, approximately 20% unqualified battery with potential hidden safety danger appeared in the market. In 2016, a total of 16 accidents occurred nationwide related to passenger NEVs, among which 13 ones with great social impacts were from BEVs, twice as the figure in 2015. The accident type includes level of fire & smoking as well as level of vehicle burning. Among the accidents, 8 ones were under the condition of manned driving and caused no casualty due to proper emergency response [7]. In terms of accident cause, some accidents were not from the enterprises, but from the possible problems with vehicle assembly, ancillary battery, control system and users.



#### 4.2. *Acute problems in operation*

The BEBVs have acute problems with their operation, which can be presented in the following two aspects: Firstly, affected by less travel distance or range and longer charging time, the daily travel by BEBVs is relatively less on average. Secondly, the technical performance of BEBVs arises as an acute problem in buses. According to survey, the failure rate of BEBVs is much higher than that of diesel/CNG bus vehicles. In addition, in the extreme weather conditions and constrained by the current technical performance, it is quite possible for large-scale BEBVs lay-offs and making it difficult to maintain the regular daily operation of buses.

#### 4.3. *Underdeveloped supporting facilities*

Owing to insufficient planning and tension of urban land use or along with the growing scale of BEBVs into the market, the charging and power changing facilities are underdeveloped and the stations under original planning are unable to meet the launching demands. As the city land use is quite limited, so the charging stations are in shortage and BEBVs power replenishment cannot be guaranteed. Some charging stations are inconveniently located, and the construction of supporting facilities such as dedicated charging stations lacks land to be used and cannot be considered as priority by the policies. This will greatly limit the enhancement on the vehicle use and service.

#### 4.4. *Underdeveloped NEVs standards*

Until now, China has formulated standards on BNEVs, HPVs and FCVs, whose system is enriched. However, we still lag far behind the demands on BEBVs, which may impede the smooth promotion of BEBVs. For example, without standards and regulations on operation, safety and response, I/M, phase-out of BEBVs and charging facility, without technical requirements on endurance travel distance, battery attenuation rate, charging efficiency, safety, operation of BEBVs. Due to absence of good standard system, some low level products or enterprises appear in the market, which will bring important impact for the development of the industry.

### 5. **Development trend and emission reduction of BEBVs**

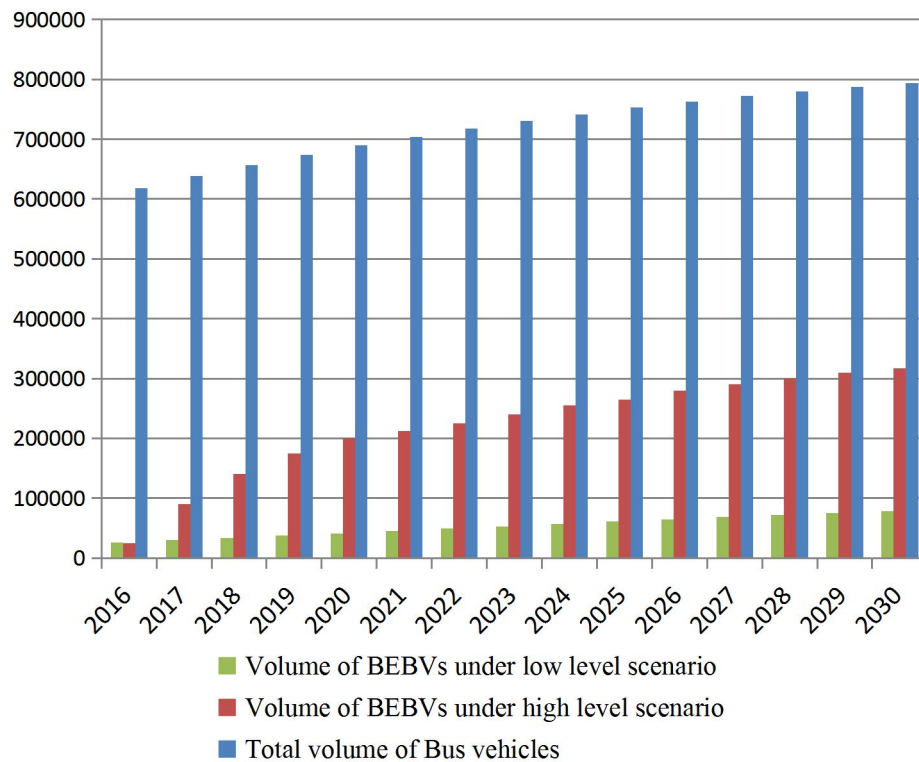
Based on the current status of BEBVs, forecast the possible development trends of China in 2030, Using “ASIF”(Activity–Structure–Intensity–Fuel) methodology and a self-built Excel-based model, and by scenario analysis, the effect of emission reduction of BEBVs development in different scenario is quantified.

In the methodology, the carbon emission can be calculated by the equation (1). In the equation,  $Emi$  is defined by the CO<sub>2</sub> emissions;  $Vehicles$  is defined by the vehicle stock;  $i$  is defined by the vehicle categories;  $VKT$  is defined by the number of vehicle kilometer travelled per year.

$$Emi(i) = Vehicles(i) * VKT(i) * \left( \frac{Emi}{VKT} \right) (i) \quad (1)$$

#### 5.1. *Scenario setting*

According to the different predictions about BEBVs and in the application of linear regression based on GDP and trend extrapolation based on historic data and the national development goals in 2020 and 2030, two development trends about future volume of BEBVs can be obtained and factors like technical advancement, vehicle use and energy intensity of BEBVs in different regions were set. Two scenarios about buses and BEBVs are simulated respectively, i.e. in low level scenario (LLS) and high level scenario (HLS). As of 2020, the share of BEBVs in LLS and HLS will have been 5.9% and 29% respectively; by 2030, the share of it in two scenarios will have been 9.8% and 40%. Among which the LLS refers to the natural growth trend of BEBVs based on the economic and technical development, with existing relevant policies while HLS refers to the development trend of BEBVs against the background of vigorous national effects and more important policies to develop BEBVs. And it can be understood that the BEBVs will share 9.8% and 40% of the total passenger volume with the buses and BEBVs in 2030(see figure 3) [10].



**Figure 3.** Forecast of volume for EBVBs in high and low level scenarios.

Major indicators for consideration include average travel distance, energy intensity, etc. in both LLS and HLS (See table 1).

**Table 1.** Main indicator in both low level scenario and high level scenario.

No.	Main indicators	Low level scenario (LLS)	High level scenario (HLS)	Explanatory notes
1	Average travel distance	45,500 km in 2020; 52,500 km in 2030	52,000 km in 2020; 58,500 km in 2030	Now the travel distance is 39,000 km
2	Energy intensity	7% reduction in 2020; and 10% in 2030	13% reduction in 2020; and 20% in 2030	Now the energy intensity is 100 KWH/100 km
3	Thermal power generation efficiency	40.9% in 2020; 43% in 2030	41.4% in 2020; 45% in 2030	Now the total thermal efficiency is 40%
4	Share of thermal power	69% by 2020; 67% by 2030	68.6% by 2020; 65% by 2030	Now the share of thermal power exceeds 70%

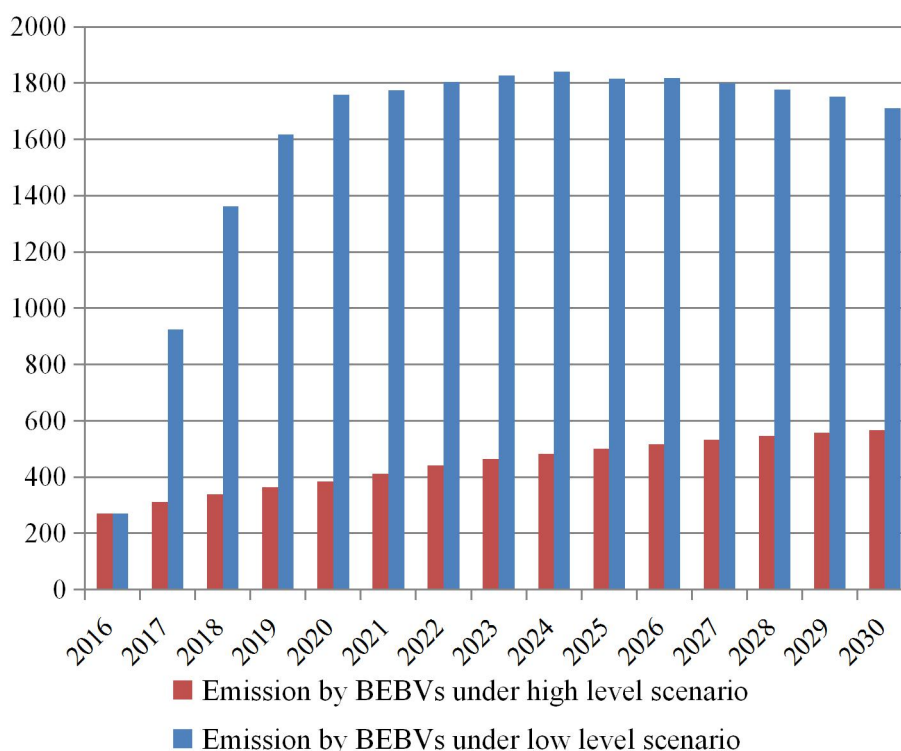
### 5.2. Scenario analysis results

This scenario analysis tries to obtain the level of CO<sub>2</sub> emission reduction on BEBVs in LLS and HLS through the indicators like travel distance, energy intensity and vehicle stock. The consumption of power offered by the power-generating terminals can be obtained by analyzing the source of power

production and its efficiency. In the scenarios, the electric power is calculated based on the life cycle and can be estimated based on the energy efficiency of power plants.

As can be found from figure 4, the development trend of CO<sub>2</sub> emission exhibits both gradual growth ratio in two scenarios, there are more emissions in LLS than that of in HLS, the CO<sub>2</sub> emission keeps low-speed growth in LLS, fast growth first and then low-speed decrease in HLS.

In LLS, the CO<sub>2</sub> emission will be 1758.2 ton in 2020 and 1711.2 ton 2030, while in HLS, they will be 384.8 ton in 2020 and 567.4 ton 2030. In the two scenarios, the battery technology is improved, the vehicle stock and travel distance on BEBVs will rise, while technology, emission intensity and power generation efficiency will be improved and the share of power generation by coal will be on the decline, so the growth ratio of CO<sub>2</sub> emission on BEBVs is reduced. Compared with diesel bus, in 2020 and 2030, 6 million and 24 million ton of CO<sub>2</sub> emission will be reduced respectively. In HLS, the emission intensity of BEBVs will be reduced 3.5%, which can offer 4 times of passenger volume. So the BEBVs have huge potential for emission reduction.



**Figure 4.** CO<sub>2</sub> emissions by BEBVs under LLS and HLS

## 6. Development measures

Considering the main problems on BEBVs currently, some development measures and suggestions are given in perspective of policy, management and supervision, standard [5, 11].

### 6.1. Further optimize policy environment for the promotion of BEBVs

Firstly, a well BEBVs operation subsidy policy needs to be established. Guidance should be offered for those technically well performed and reliable BEBVs to accelerate the application. Secondly, Manufacturers can take the user demand of bus enterprises at the center by further stepping up production R&D and improving technical performance of vehicles to eliminate the concerns and worries of users. Thirdly, the coordinated system of policy makers, industry, universities and research



institutions are to be built to attract domestic institutions for engagement and push forward the relevant policy, R&D.

### 6.2. Strengthen supervision and management of BEBVs operations

Close attention should be given to the BEBVs operation in the transport industry. We need to build up the national and prefecture and city-level information platform on operation supervision of BEBVs, unify the data exchange regulation, strengthen vehicle safety monitoring and control as well as optimize the operation subsidy. By working with relevant associations and scientific research institutions, we have launched regular monitoring and announcement of reports about BEBVs operation in the transport industry. We will take the use of mainstream manufacturers and the announcement of problems with some relevant products for reference when selecting BEBVs.

### 6.3. Improve BEBVs standard systems

The technical standards and regulations including operation management, safety & emergency response, maintenance and I/M as well as phase-out and recycling of BEBVs and charging facilities should be studied. The technical requirements about BEBVs should be studied, including endurance distance, battery attenuation rate, charging efficiency, safety and operation indicators, etc. The threshold for BEBVs should be set up to figure out the boundary of responsibility between transportation industry and vehicle manufacturers. Management of each link should be strengthened to ensure that the BEBVs into the transport industry should conform to the demands for operation scheduling and safe production by the industry.

### 6.4. Facilitate certification on BEBVs

The characteristics about expansion of BEBVs in public transport will be fully taken into account from the perspective of safety, performance, energy efficiency and low carbonized. The certification should to be carried out concerning the terminal products, system and enterprises to support the sound development of the industry as soon as possible, which can promote the establishment of the Top Runner mechanism for BEBVs.

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