

Breaking through the Key Challenges to Further Electrification of Public Transport in Beijing

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Abstract: In recent years, with the improvement of people's awareness of environmental protection and the increasingly serious problem of urban traffic congestion, the Beijing Municipal Government has actively promoted the development of green transportation, among which electric buses, as a low-carbon, environmentally friendly and energy-saving mode of transportation, are regarded as an important measure to improve air quality and reduce pollution emissions, which has attracted much attention. As electric buses grow, so do the operational challenges of the promoted electric buses, including high initial investment costs, inadequate charging infrastructure, technical limitations in terms of vehicle range and charging speed, and a lack of more supportive policies and regulations. This paper summarizes and analyzes the current situation of electric buses in Beijing. And proposes to solve the challenges encountered in the operation of electric buses by implementing targeted strategies. For example, optimize government financial subsidy measures and implement diversified financial support; The government supports companies to carry out technological innovation and invest in R&D to enhance electric vehicle technology; further promote the construction of charging infrastructure and improve the level of charging services; Effectively deploy battery recycling; promote the integrated development of intelligent vehicles and networking, and accelerate the construction of intelligent public transportation systems; strengthening international cooperation and resource sharing; and the development of a comprehensive policy to promote and facilitate the electrification of public transport in Beijing. Inject new impetus into Beijing's sustainable urban development.

Keywords: Electric Buses; Development Status; Countermeasure Analysis; Low-carbon Energy Saving; Emission Reduction.

1. Overview

In recent years, with the improvement of people's awareness of environmental protection and the increasingly serious problem of urban traffic congestion, the Beijing Municipal Government has actively promoted the development of green transportation, among which electric buses have become a measure that has attracted much attention. As a low-carbon, environmentally friendly and energy-saving mode of transportation, electric buses are regarded as important measures to improve air quality and reduce pollution emissions. Since 2010, Beijing has been implementing electric bus projects. The Beijing Municipal Government has formulated a series of policies and measures to increase support for electric buses. With the strong support of the government, Beijing's electric buses have gradually developed and expanded.

The development of new energy vehicles is of great positive significance for China to reduce its dependence on oil, reduce carbon emissions, and promote the transformation and upgrading of the automobile industry, and play a significant role in urban haze prevention and control and air quality. At the same time, the public transportation industry has become a breakthrough and frontier in the promotion and application of new energy vehicles with the characteristics of fixed routes and public services. Based on the strategic considerations of the transformation and upgrading of the automobile industry, the adjustment of energy structure, and the alleviation of environmental pressure, the further electrification of public transportation in Beijing is of great significance in terms of environmental protection, economic and social benefits, and promoting regional coordinated development.

Presently, the main challenges and obstacles to further

electrification of public transport in Beijing boil down to four main factors: high initial investment costs, inadequate charging infrastructure, technical limitations in terms of vehicle range and charging speed, and lack of more reasonable supportive policies and regulations. These challenges can be addressed through the implementation of targeted strategies, such as optimizing government financial subsidies and diversifying financial support; The government supports companies to carry out technological innovation and invest in R&D to enhance electric vehicle technology; further promote the construction of charging infrastructure and improve the level of charging services; Effectively deploy battery recycling; promote the integrated development of intelligent vehicles and networking, and accelerate the construction of intelligent public transportation systems; strengthening international cooperation and resource sharing; and the development of a comprehensive policy to promote and facilitate the electrification of public transport in Beijing.

With the continuous support of policies and the continuous progress of technology, the level of electrification of public transportation in Beijing will continue to improve, injecting new impetus into the sustainable development of the city.

2. Research Question

What are the key challenges and barriers to further electrifying public transport in Beijing, and how can these be addressed?

3. Research Methods

The development of electric buses varies from city to city in China. Taking Beijing as the main research city, this paper analyzes the promotion and operation status of electric buses from an objective perspective based on the big data of new

energy electric bus operation provided in the public data of the Internet. Using big data, this paper tries to understand the current situation of the promoted electric vehicle operation and discusses the current situation and problems of the promotion and operation of electric buses on the basis of quantitative and qualitative analysis.

3.1. Quantitative Methods

Data Analysis of Existing Databases: I will utilize various existing databases that contain information on public transport electrification, electric bus price, air quality, and greenhouse gas emissions in Beijing. I will conduct descriptive statistics, correlation analysis, and possibly regression analysis to identify patterns and relationships between public transport electrification and its impacts on air quality and greenhouse gas emissions.

Literature Review: I will conduct a thorough literature review of existing research articles, reports, and policies related to public transport electrification, urban air quality, and greenhouse gas emissions. This will help me identify key trends, gaps in research, and potential theoretical frameworks to guide my analysis.

3.2. Qualitative Methods

Content Analysis: I will analyze the content of relevant articles, policies, and reports to understand the context, motivations, and challenges associated with public transport electrification in Beijing. This will provide me with insights into the social, economic, and environmental factors that influence the implementation and impact of this policy.

Case Studies: I will select a few case studies of successful or challenging implementations of public transport electrification in Beijing or similar cities. By analyzing these cases in depth, I can identify factors that contribute to success or failure and derive lessons that may be applicable to Beijing.

3.3. Limitations of the Method

Availability of Data: The availability and quality of existing data may be limited, especially for specific metrics or time periods due to China's policies. This could affect the accuracy and comprehensiveness of my analysis.

Lack of Primary Data: Since I will not conduct field visits, I will not have access to primary data that could provide more nuanced insights into the perspectives and experiences of stakeholders.

4. Challenges and Obstacles

Although new energy buses have many advantages such as environmental protection, energy saving, and low carbon, they also face many challenges and obstacles in the process of their development. At present, the main challenges and obstacles to further electrification of public transport in Beijing are mainly attributed to the following factors:

4.1. High Initial Investment Cost

From the perspective of the purchase cost of a single vehicle, the price of an electric bus is 2~3 times that of a traditional fuel bus; If a fuel bus is replaced with an electric bus in a ratio of 1:2, the purchase cost of the electric bus alone is 4~6 times that of the fuel bus (excluding subsidies).

Although the substitution of electric vehicles for fuel vehicles is not simply the replacement of two automobile products, it also includes the energy cycle process of automobile fuel production and use, as well as the entire life cycle of the vehicle. Due to the production and use of fuels used in fuel vehicles, a large amount of greenhouse gases and air pollutant emissions are generated. Replacing gasoline-powered vehicles with electric vehicles has a positive impact on climate and health, as well as the potential for energy savings. Table 1 illustrates our basic understanding of the environmental friendliness of electric vehicles as an alternative to conventional fuel vehicles [1].

Table 1. benefits for a FV-to-EV substitution

	Climate Effects	Health Effects	Energy Effects
Fuel Vehicle	Greenhouse gas (GHGs) emissions from crude oil extraction, transportation, refining and other links. Greenhouse gas (GHGs) emissions from fuel vehicle	Premature death and illness caused by the emission of air pollutants in crude oil extraction, transportation, refining and other links. Premature death and illness caused by the marginal increase in long-term population exposure concentrations of PM _{2.5} and O ₃ caused by air pollutant emissions from gasoline vehicles. Other health terminals caused by pollution emissions from gasoline vehicles	Gasoline costs
Electric Vehicle	Greenhouse gas (GHGs) emissions from power plant	Premature death and illness caused by emissions of air pollutants from power plants leading to marginal increases in PM _{2.5} , long-term population exposure concentrations;	The cost of electricity
FV-to-EV cost deference	The difference between the social cost of carbon emissions from a single gasoline vehicle and a single pure electric vehicle	The difference between the cost of health damage from primary PM _{2.5} , NO _x and VOCs emissions from a single gasoline vehicle and primary PM _{2.5} , NO _x and SO ₂ emissions from a single pure electric vehicle	The difference between the cost of electricity for a single battery electric vehicle and the cost of gasoline for a single gasoline vehicle

As shown in Figure 1[2], electric buses have a more significant control effect on air pollutants than traditional fuel

buses compared with greenhouse gas emission reduction. The total pollutant emission limit for heavy-duty diesel vehicles is 2.04 g/kWh, and the total pollutant emissions for electric buses are 0.83 g/kWh and 1.6 g/kWh respectively under the condition of 100% and 77% thermal power [3]. If non-exhaust emissions (such as power generation emissions, tire friction emissions, etc.) are not calculated, the pollutant emissions of electric buses are basically zero. As shown in Figure 2[4], at

the current national average of 71% of thermal power generation, the emission of pure electric buses is the lowest among all models, 31%-38% less than traditional diesel buses, 0%-45% less than natural gas buses, and lower than all types of hybrid vehicles [3]. It can be seen that pure electric buses are an effective measure to control urban air pollution and greenhouse gas emissions.

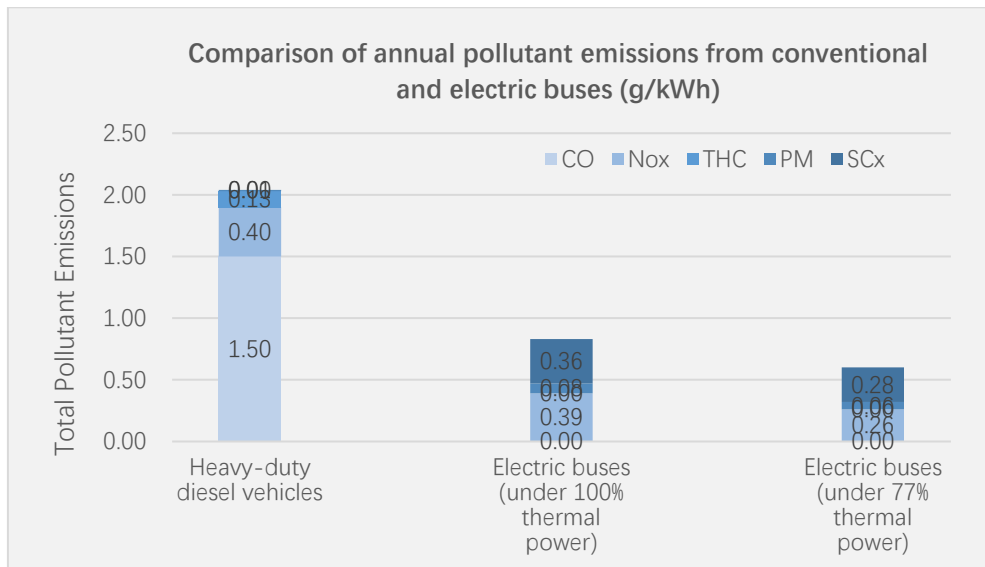


Figure 1. Comparison of annual pollutant emissions from conventional and electric buses

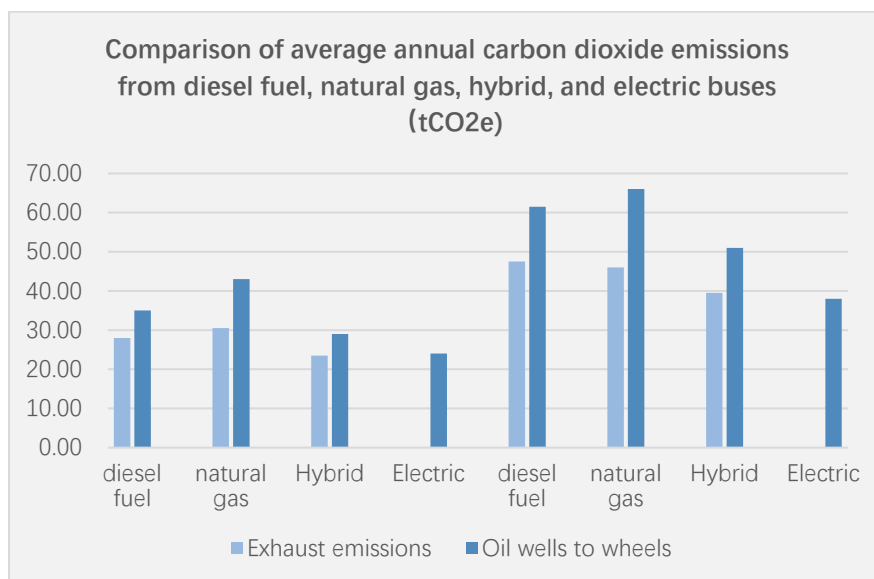


Figure 2. Comparison of average annual carbon dioxide emissions from diesel fuel, natural gas, hybrid, and electric buses (tCO₂e)

However, even if the use of electric vehicles instead of traditional combustion vehicles can achieve carbon reduction of about \$45.6/ (vehicle ·year), reduce health damage by about \$49.5/vehicle ·year, and save energy by about \$607.49/ (vehicle ·year), The huge difference in manufacturing and infrastructure costs between the two is about \$2,240.84 per vehicle· year [1] (as shown in Figures 3 and 4) and is too much to ignore. At this stage, the complete elimination of traditional fuel vehicles with electric vehicles cannot achieve overall social welfare improvement, and the high initial investment cost is still an important obstacle to further electrification of public transportation.

Based on the strategic considerations of the transformation and upgrading of the automobile industry, the adjustment of

the energy structure and the alleviation of environmental pressures, the Chinese government has introduced a number of policies in recent years to overcome the obstacles of high initial investment costs and promote the promotion of public transport electrification.

4.2. Insufficient Charging Infrastructure

As the capital city, Beijing has a huge scale of public transportation trips, super travel intensity, and a very concentrated spatial and temporal distribution. The suburban trunk line mainly serves long-distance commuting, shopping, tourism and other travel between the far suburbs and the central urban area, and the line length is very long. Figure 5 shows that during working days, the number of bus trips in

the city was about 6.1 million per day, accounting for 30% of the city's permanent population. About 4.4 million people per
day on weekends, and 72% of weekend trips on weekdays.[5].

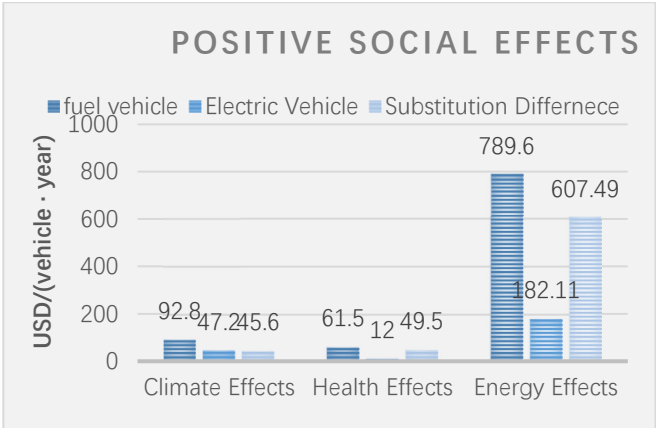


Figure 3. Climate, health and energy impacts for a fuel vehicle-to-electric vehicle substitution

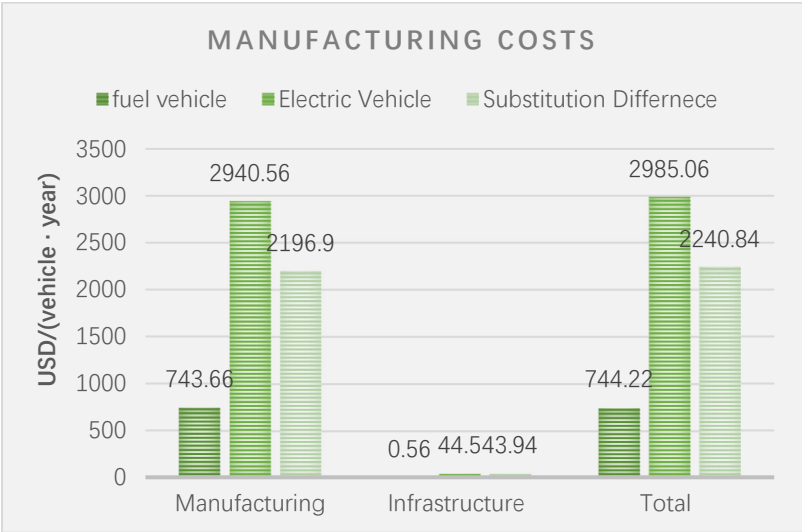


Figure 4. Manufacturing costs for a fuel vehicle-to-electric vehicle substitution



Figure 5. The number of people who travel on public transportation in Beijing on daily basis.

Among the daily bus passengers in Beijing, 50% of the passengers only take the ground bus, 30% of the passengers only take the rail transit, and 20% of the passengers take the ground bus and the rail transit together. Among the 6.1 million people who traveled by public transport on weekdays, about 3.03 million (49.7%) only took ground buses; about 1.82 million people only took the subway, accounting for 29.8%; There were about 1.25 million passengers in bus-subway rides, accounting for 20.5%. On weekdays, the average bus rider takes 65 minutes per day (excluding waiting time). As shown in Figure 6, more than 80% of passengers make 1-2 bus trips per day. Passengers who make one trip per day

account for 30.7% on weekdays and 36.8% on weekends. Passengers who made two trips accounted for 55.8% on weekdays and 48.5% on weekends. Passengers who made

three or more trips accounted for 13.5% on weekdays and 14.7% on weekends [5].

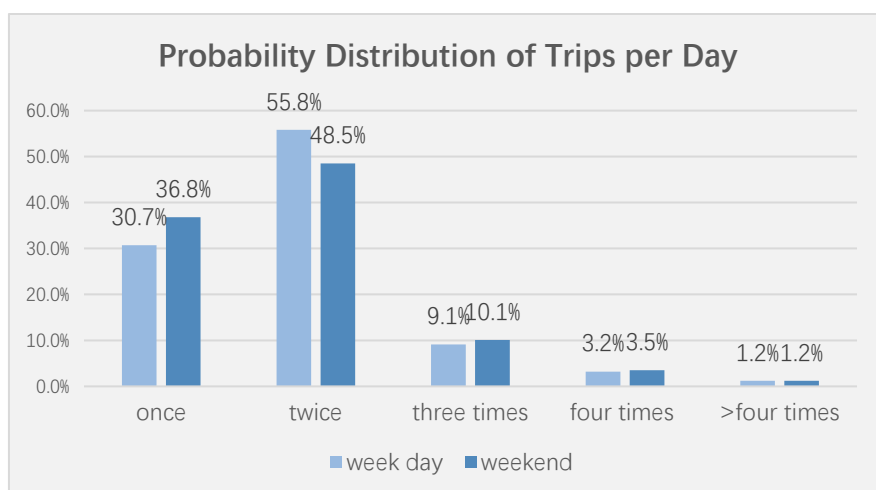


Figure 6. Probability distribution of trips per day

The scale and intensity of travel in Beijing's public transport system, and the lack of charging infrastructure to further electrify its public transport, will be a huge obstacle. The lack of charging infrastructure renders several implications for the electric bus industry. First of all, the poor consumer experience with charging hinders the popularity of new energy vehicles. If there is no sufficient number and stability of charging equipment, the needs of users will not be satisfied, which will affect their experience and evaluation of electric buses. Second, battery life anxiety will limit users' willingness to buy. Before the range problem of existing electric vehicles are completely resolved, users have general concerns when purchasing. If charging infrastructure is missing, it will be difficult for users to find reliable and convenient charging facilities, further exacerbating their range anxiety and discouraging more people. At present, the charging infrastructure problems mainly focus on the Insufficient coverage of charging stations, varying quality of charging equipment, and inconsistent charging interface standards.

According to the "Beijing Electric Vehicle Charging Station Layout Planning Research", by the end of 2019, the number of new energy vehicles in Beijing reached 312,000, of which electric vehicles accounted for 10.3%. At the same time, the total number of charging facilities in Beijing is 30,444, including 1,849 charging stations, and the number of charging piles accounts for 94.2%. However, there are still problems such as low density of charging piles and single type of charging pile construction. The construction of foreign charging stations is mainly based on fast charging centers, taking into account ordinary charging stations, which can meet the needs of users who urgently need charging. However, the construction of domestic charging stations is mainly based on ordinary charging stations, and the number of fast charging centers is small and sparsely distributed, so it is difficult to meet the ordinary electricity demand of electric vehicles while meeting the users who are in urgent need of charging.[6]

In addition, the planning of electric bus charging piles should be implemented simultaneously with the purchase of vehicles. When the capacity of the distribution network in the old city of the city is insufficient, or the bus admission rate is low and the proportion of roadside parking is high, the urban

traffic management department and the public transport company can adjust the vehicle technology selection, charging technology and purchase plan in advance according to the pile construction conditions. However, in reality, many bus companies choose to start considering the problem of charging piles after purchasing vehicles. The construction of charging piles is a complex project, which not only involves multiple departments, but also involves traditional construction problems such as land and capital, which are difficult to solve in the short term. It usually takes about a year from planning to implementation, which gives rise to many problems of "having a car but not a pile" [3].

4.3. Technical Limitations on Vehicle Range and Charging Speed

One of the challenges that electric buses have been facing is the problem of short range and slow charging speed, and battery technology and battery life are key factors in the problem, which directly affect the range, operating costs and reliability of electric buses. In 2018, the average daily travel time of pure electric buses was only 8.36 hours [7], which was far from meeting the needs of Beijing's public transport companies.

Battery technology for pure electric buses refers to the type of battery used and the battery management system.

Currently, the main types of batteries include lithium-ion batteries and sodium-sulfur batteries. Lithium-ion batteries are currently the most widely used battery type, with high energy density and cycle life, which can meet the needs of long-term operation of buses. Sodium-sulfur batteries are a new type of battery technology with higher energy density, but they still face challenges such as short cycle life and low safety. While battery technology continues to advance, energy density still needs to be improved, which limits the driving range on a single charge.

The battery will gradually decay during long-term use, affecting the endurance. For lithium-ion batteries, each charge-discharge cycle results in a small loss of battery capacity, and long-term accumulation leads to a decrease in battery capacity. The charging temperature and charging speed can also affect the life of the battery.

With the increase of service life, the performance of vehicle

batteries has decreased. Taking a brand of pure electric buses as an example, we selected several buses that were newly launched in December 2016 in different regions and had operating data for the whole year of 2017 and 2018 as typical vehicles to analyze the degradation of battery performance. As shown in Figure 7, the actual mileage of selected four pure electric buses in 2017 has been attenuated to a certain extent

compared with the nominal mileage of the vehicle, where in the attenuation rate of vehicle1 is the lowest, only 3.67%, and the attenuation rate of vehicle2 is the highest, reached 18.13%. In 2018, the second year of online operation, the battery performance of four vehicles was further attenuated, of which the attenuation rate of vehicle1 battery was 26.88%, and the attenuation rate of vehicle2 battery had reached 28.57%. [7]

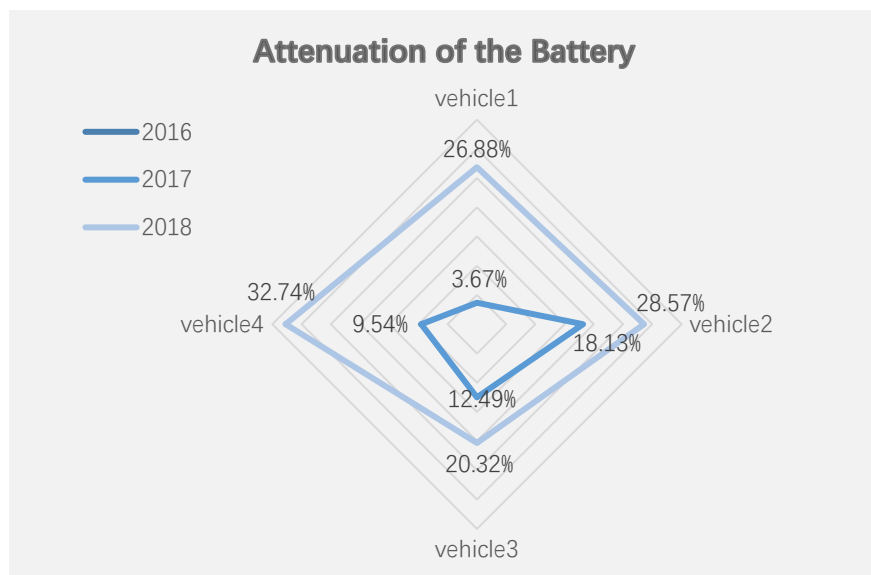


Figure 7. Comparison of the attenuation rate of typical pure electric buses in Heilongjiang in 2017 and 2018

In addition, the impact of climate on the attenuation of batteries cannot be ignored. The battery attenuation rate in the southern region is lower than that in the northern region like Beijing. As can be seen from Figure 8, in 2018, the battery attenuation rate of typical vehicles in Heilongjiang Province was as high as 27.13%, while the vehicle attenuation rate in

Guangdong was low, at 15.66%. The reason for the analysis may be that compared with the northern region, the temperature in the southern region is higher and the temperature difference is smaller, and the operating environment of the battery is not as harsh as in the north, so the performance of the battery is more stable. [7]

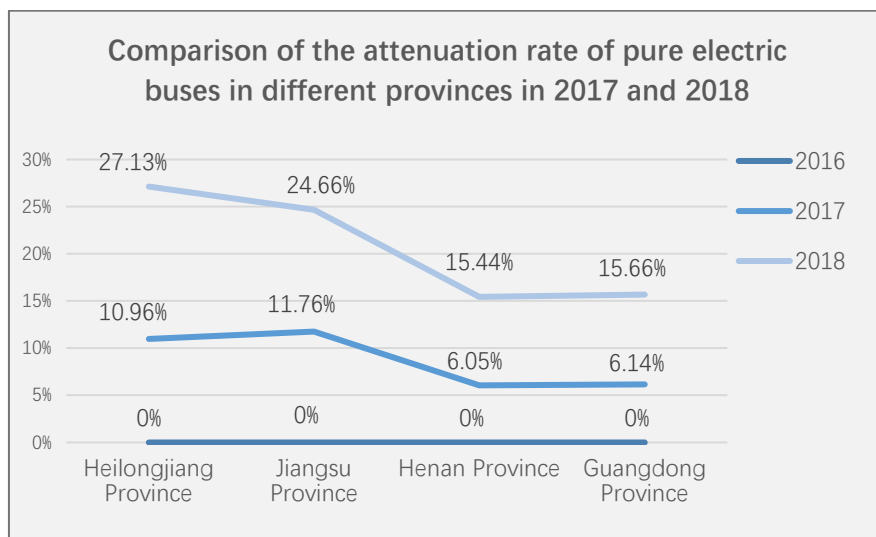


Figure 8. Comparison of the attenuation rate of pure electric buses in different provinces in 2017 and 2018

The battery management system is a system designed to extend battery life and ensure battery performance, which can monitor the temperature, voltage, current and other parameters of the battery to ensure that the battery is in the best working condition. Through the rational design and application of advanced battery management system, the battery life of pure electric buses can be effectively improved. At the same time, in practical applications, balance the relationship between charging speed and battery life,

formulate a reasonable charging and discharging strategy, optimize charging speed, improve charging efficiency, and avoid damage to the battery caused by overcharging and frequent charging.

The problem of short cruising range and slow charging speed of electric buses will bring a lot of anxiety to users in actual operation, which in turn affects users' willingness to buy.

First of all, the problem of short cruising range can lead to

bus route limitations. Vehicles can only travel short distances, and on long-distance routes, vehicles need to return frequently to the charging station to recharge, which not only increases operating costs, but also affects the travel efficiency of passengers, which in turn leads to passenger dissatisfaction with the service of electric buses.

In addition, in emergency situations such as special weather or traffic congestion, the range of electric buses may be further shortened. If the vehicle runs out of battery while on the road, it will have to be urgently charged or towed back to the charging station, which not only causes inconvenience to passengers, but can also cause traffic jams and safety issues. This uncertainty makes users doubt the reliability of electric buses. This psychological anxiety can reduce their satisfaction and trust in electric buses.

Slow charging also leads directly to the compression of electric bus operating time. For example, if an electric bus takes hours to fully charge, then it will not be able to carry out the next round of operation in a short period of time, which will affect the operational efficiency of the entire bus system. At the same time, passengers may experience reduced shifts or longer wait times due to long charging times, affecting their travel plans. These situations can cause passengers to be dissatisfied with the service of the electric bus and greatly reduce the user experience of the electric bus.

According to reports, on December 14, 2023, the moderate snow in Beijing cooled down, and the bus queue waiting for charging was particularly long. The No. 1 bus line has a total of 29 stops from the starting point to the end point, with a total length of 26 kilometers. Due to the short battery life, slightly longer lines, coupled with traffic jams, the problem is more serious. Especially in the winter when the weather is cool, the heater in the car must be turned on all the time, so it will consume more power than usual. The Beijing No. 1 pure electric bus is equipped with lithium titanate batteries, with a total storage capacity of 168.912kWh and a maximum range of 130 kilometers. The battery power is also difficult to support daily line operation. Drivers take 15 minutes to charge the bus every time they arrive at the end/start of the line. In extremely cold climates, the battery life of pure electric buses is even more serious. In order to ensure the normal operation of the line, the use of warm air had to be restricted. In the case of cooler weather, complaints from passengers have become "commonplace" [8].

4.4. Lack of Supportive Policies and Regulations

Safety issues remain a focal point of public concern and a top priority in the design, production, and operation of vehicles.

Security risks remain. Beijing followed the national charging pile standards include GB/T 20234.1 "Electric Vehicle Conductive Charging Connection Devices Part 1: General Requirements", GB/T 20234.3 "Electric Vehicle Conductive Charging Connection Devices Part 3: DC Charging Interface", GB/T 28569-2012 "Electric Vehicle AC Charging Pile Power Metering", GB/T 18487.1-2015 "Electric Vehicle Conductive Charging System Part 1: General Requirements" and other national standards. However, there are obvious loopholes, in terms of clarifying the requirements for ultra-high temperature alarm and fire alarm system, resulting in the general charging pile is not included in the scope of fire safety supervision, and the focus of supervision is still on the supervision of electric bicycles,

at the same time, the charging interface, charging time, billing requirements, fire protection requirements and other inconsistencies of charging piles on the market have led to the mixing of charging pile markets and the savage growth of various brands; The "remote control" and "remote" business models of charging pile manufacturers and operators lead to difficulties in the later maintenance of charging piles; The safety management of some charging stations is not standardized, and there are certain potential safety hazards in the absence of emergency lanes, overload protection devices, and the establishment of regular inspection mechanisms and measures[9].

In addition, with the continuous improvement of the coverage rate of pure electric buses, the problem of battery retirement and replacement has also become prominent. There are still problems with the current recycling and reprocessing mechanism of retired batteries. As we all know, lithium iron phosphate batteries are safer, so pure electric buses generally use lithium iron phosphate batteries. However, lithium iron phosphate batteries also have the shortcomings of low energy density and poor low temperature. In addition, buses need to be charged and discharged frequently, which also accelerates battery degradation to a certain extent. When the power battery cannot meet the daily operation of the bus, replacing the battery becomes one of the solutions, but the high price will make the operating company in a dilemma, resulting in the dilemma of pure electric bus outage.

In 2022, the bidding announcement for the procurement of pure electric buses and the battery replacement project of old vehicles announced that the battery replacement cost of old vehicles is 180,000 yuan per vehicle. Since the end of 2016, the purchase subsidy for electric buses has been declining year by year, and by the end of 2022, the purchase subsidy for new energy vehicles has been completely abolished, and the high cost of battery replacement has increased the burden on bus companies [10].

5. Current Situation and Policy Support

5.1. Current Subsidies Policy Support

Under the severe challenge of global climate change, green and low-carbon development has become a global consensus. In response to the call of the state, the Beijing Municipal Government has formulated and implemented a series of policies and measures to promote the green transformation of urban transport. As an important part of green transportation, electric buses have been highly valued by the government. In recent years, the Beijing municipal government has formulated a series of preferential policies for electric buses. Subsidies will be given to enterprises that purchase electric buses to reduce the cost of purchasing vehicles; Preferential fares are offered to electric bus users to attract more passengers to choose electric buses. In addition, the government also provides free charging facilities to solve the problem of inconvenient charging of electric bus vehicles. The introduction of these policies has greatly stimulated the enthusiasm of enterprises and individuals to purchase and use electric buses.

In January 2009, the "Ten Cities and Thousand Vehicles" project was launched. It is a demonstration and promotion project of energy-saving and new energy vehicles jointly launched by the Ministry of Science and Technology, the Ministry of Finance, the National Development and Reform

Commission, and the Ministry of Industry and Information Technology. Its main content is to provide financial subsidies, and it is planned to develop 10 cities every year for about 3 years. Each city will launch 1,000 new energy vehicles for demonstration operation, involving these large and medium-sized cities in the fields of public transportation, leasing, government, municipal, postal and other fields, and strive to make the new energy vehicle operation scale account for 10% of the automobile market share by 2012[11].

Since 2010, electric buses, as a low-carbon, environmentally friendly and energy-efficient mode of transportation, have been regarded as an important measure to improve air quality and reduce pollution emissions. The Beijing government is strongly supporting the electric bus project.

As shown in Table 2, according to the "Ten Cities, Thousand Vehicles" Project in 2009, the subsidy for pure

electric vehicles is \$8.5K per vehicle, and the subsidy for pure electric city buses with a length of more than 10 meters is \$70K. The local finances of the 13 cities (including Beijing) participating in the demonstration should also arrange matching funds to give appropriate subsidies to the purchase of new energy buses, the construction and maintenance of supporting facilities, and other related expenditures[12].

In 2013, the government continued to provide high purchase subsidies to consumers and businesses that purchase electric buses. The subsidy standard for pure electric buses is divided according to the length of the body: \$42K for 6-8 meters vehicles, \$56K for 8-10 meters vehicles, and up to \$70K for vehicles above 10 meters[13]. These subsidies have greatly reduced the purchase cost of electric buses and enhanced the procurement power of new energy buses in the field of public transportation.

Table 2. The subsidy standard from 2013 to 2024

Years	Subsidy Standards (dollar/vehicle)					
	Pure Electric Vehicles			Pure Electric Buses		
	$6 \leq L < 8\text{m}$	$8 \leq L < 10\text{m}$	$L \geq 10\text{m}$	$6 \leq L < 8\text{m}$	$8 \leq L < 10\text{m}$	$L \geq 10\text{m}$
2010	8.5K	8.5K	8.5K	42K	56K	70K
2011	-	-	-	42K	56K	70K
2012	-	-	-	42K	56K	70K
2013	42K	56K	70K	42K	56K	70K
2014	27K	36K	45K	42K	56K	70K
2015-2019	24K	32K	40K	42K	56K	70K
2022	6K	6K	6K	42K	56K	70K

In 2014 and 2015, the subsidy standards for pure electric passenger vehicles, pure electric special vehicles, and fuel cell vehicles decreased by 10% and 20% respectively on the basis of the 2013 standards; The standard for pure electric buses remains unchanged[14]. Meantime, the local subsidy was increased to 50% of the national subsidy. Although the subsidy in 2015 has declined, but the new energy bus from the initial purchase cost advantage to the whole life cycle advantage, the industry to maintain a reasonable profit level, the growth factor is more reasonable and sustainable, the growth of new energy buses into a stable period[15].

Since 2018, the local purchase subsidy funds for new energy vehicles have been gradually transferred to support the construction and operation of charging infrastructure, the use and operation of new energy vehicles, and other links [16]. In 2022, national policies indicate that in the future development of new energy vehicles in China, public transportation electric vehicles will still be the main focus. Central government subsidies are directly allocated to production enterprises, reducing intermediate links. The financial subsidy standard is an average of \$6K per pure electric vehicle, and \$70K per pure electric bus with a length of more than 10 meters. This policy greatly promotes the promotion speed of new energy buses[17].

In 2024, the Notice of the Ministry of Transport and the Ministry of Finance "The Implementation Rules for the Renewal Subsidy of New Energy City Buses and Power Batteries" clarified: A fixed subsidy will be given to urban public transport enterprises for updating new energy city buses and replacing power batteries. For the renewal of new energy city buses, the average subsidy per vehicle is 11K dollar; For the replacement of power batteries, the subsidy is

\$6K per vehicle[18].

As the capital, the Beijing Municipal Government has implemented multi-level subsidy policies in promoting electric buses. For pure electric buses, the Beijing Municipal Science and Technology Commission has issued a subsidy method that specifies a 1:1 ratio between subsidy standards and national standards. The government provides financial support for purchased buses to ensure that the total subsidy amount from local and central governments does not exceed 60% of the vehicle's sales price [19]. This policy not only reduces the purchasing cost of public transportation enterprises, but also accelerates the promotion and application of electric buses in Beijing.

In the past few years, electric buses have been expensive, but the Chinese state and the local government in Beijing have provided various types of high subsidies to accelerate their adoption. Taking 2016, the annual sales volume of electric buses is the largest, as an example, if the local purchase subsidy is calculated at 50% of the national purchase subsidy, the total national and local purchase subsidy can be as high as 600,000 yuan, close to 40% ~ 50% of the vehicle price; Some pure electric buses are even comparable to fuel buses after subsidies. These national and local subsidy measures have greatly eased the pressure on bus companies to purchase cars and stimulated the rapid growth of the number of pure electric buses. However, since 2017, with the rapid decline of state subsidies and the return of pure electric buses to market competition, vehicle performance has continued to improve, and the demand for car purchases has become more rational. Although indicators such as the operational efficiency of electric buses (e.g. daily mileage) have improved, the increase is still small compared to the increase in the number of electric

buses[3].

5.2. Current Investment and Policy Support for Electric Bus Technology Research and Development

The government focuses on the research and development of electric bus technology and equipment, continuously improving the performance and quality of electric buses. By introducing various advanced battery technologies and drive systems, the range and operational efficiency of electric buses are continuously improved. At the same time, the government also encourages the innovation and promotion of green transportation technology and promotes the development of electric buses in terms of intelligence and networking. These efforts have laid the technical foundation for the rapid development of electric buses.

Since the beginning of this year, the Beijing Municipal Bureau of Finance has implemented comprehensive policies from the supply side, the demand side and the service side to help the promotion and application of new energy vehicles in the city. On the supply side, we will coordinate scientific and technological research and development funds, support the research and development of new energy vehicles, and help improve the competitiveness of new energy vehicle products; Make good use of government investment funds such as high-tech funds and science and technology innovation funds, guide social capital investment, and jointly promote the development of the new energy vehicle industry; Promote the demonstration application of hydrogen fuel cell vehicles in "medium and long-range, medium and heavy-duty" scenarios, and promote the upgrading of industrial and supply chains in the Beijing-Tianjin-Hebei region[20].

Recently, the Beijing Municipal Party Committee said that new energy vehicles and autonomous driving are important driving forces for intelligent transportation, and Beijing should "base itself on the strategic positioning of the capital city and strive to create a new situation of high-quality development"[21].

5.3. Current Situation and Policy Support of Charging Facilities

To ensure the normal use of electric buses, the government also provides free charging facilities to solve the problem of inconvenient charging for electric buses. State Grid Beijing Electric Power Company has built over 15000 charging facilities, covering various types of vehicle usage scenarios such as residential communities, enterprises and institutions, and rural areas. At present, Beijing has taken the lead in achieving full coverage of charging stations in every county and township in China, providing a solid infrastructure guarantee for the widespread application of electric buses.

5.3.1. Charging Piles

According to the "Electric Vehicle Charging Infrastructure Construction Plan" and the "Guiding Opinions on the Construction of Charging Infrastructure", by 2020, the number of domestic charging and swapping stations will reach 12,000, and the number of charging piles will reach 4.5 million[22].

According to the "Report on the Implementation of Beijing's 2023 National Economic and Social Development Plan and the 2024 National Economic and Social Development Plan", by 2023, Beijing has built about 315,500 new energy vehicle charging piles[23]. There are 16,832 new

energy buses, 251 bus charging stations and 1,727 charging piles[24].

5.3.2. Charging Cabinets

Electric bus charging cabinets, as one of the key infrastructures in the field of electric vehicles, have attracted much attention from the government. The Beijing Municipal Government has comprehensively considered the operational needs of buses, traffic flow, land resources and other factors, and scientifically planned the construction location of the charging cabinet. Especially in key areas such as transportation hubs, bus stations, and gas stations, priority should be given to promoting the construction of charging cabinets to form a charging network with wide coverage and reasonable layout.

Up to now, Beijing has made remarkable progress in the construction of electric bus charging cabinets. On the one hand, the government has increased investment in the construction of charging facilities and encouraged social capital to participate in the construction of charging facilities through financial subsidies and tax incentives. On the other hand, bus companies have also actively responded to the government's call to actively invest in the construction of charging cabinets to meet the charging needs of electric buses.

According to relevant data, in recent years, the number of electric bus charging cabinets that have been built and put into use in Beijing has continued to grow, providing a strong guarantee for the normal operation of electric buses. At the same time, with the continuous progress of technology and the gradual reduction of costs, the charging efficiency and service quality of charging cabinets are also improving.

With the continuous progress of science and technology, charging cabinet manufacturers will provide more intelligent services. For example, transparent charging data, more intelligent management systems, predictive maintenance, and convenient payment functions. At the same time, it will also explore the direction of charging cabinet energy Internet, multi-energy linkage, and smart energy[25].

5.3.3. Super Charging Stations and Policy Support

In August this year, in order to accelerate the construction of a high-level charging infrastructure network system and strongly support the promotion and application of new energy vehicles, the Beijing Municipal Development and Reform Commission promulgated the "Implementation Plan for Accelerating the Construction of New Energy Vehicle Super Charging Stations in the City". It is planned to build super charging stations to improve the speed of energy replenishment and improve the convenience of new energy vehicles. The plan is to build 1,000 supercharging stations in Beijing by the end of 2025, and it will form a comprehensive, efficient and intelligent supercharging network. This initiative is based on the technology promotion of power battery and vehicle enterprises and the gradual improvement of the charging infrastructure base, aiming to cope with the rapidly growing demand for new energy vehicles. The plan adopts the strategy of "ultra-fast combination and moderate advancement", giving priority to the layout of urban core areas and transportation hotspots, with a medium-term target of 500 in 2024 and 1,000 by the end of 2025. At the same time, the plan encourages the use of diversified space, including bus stations, gas stations and space under bridges, and promotes the construction of overcharging stations in expressway service areas, so as to promote the coordinated coverage of the Beijing-Tianjin-Hebei region. All overcharging stations will implement a unified standard, emphasizing the openness

and sharing of public facilities and the full safety management[26].

Meantime, the Beijing Municipal Development and Reform Commission researched and formulated the "Several Measures to Give Play to the Amplification Effect of Government Investment to Accelerate the Cultivation and Development of New Kinetic Energy", to support the implementation rules of advanced charging facilities demonstration projects, and will give 30% of the municipal government's fixed asset investment support for the construction of high-power charging facilities and the construction of vehicle-network interactive charging facilities[27].

5.4. Promotes Green Electricity Trading.

Since January 2024, more than 8,000 electric buses in Beijing have started to use green electricity, marking the first time that Beijing has achieved green charging of electric buses.

Capital Electric Power Trading Center Co., Ltd. actively serves the green and low-carbon transformation of Beijing energy, relying on the Beijing power trading platform to match inter-provincial green power transactions, and purchasing 370 million kWh of wind power and photovoltaic power from XilingolLeague and Ulanqab City of Inner Mongolia Autonomous Region across provinces. This year, this green power will provide a steady stream of green kinetic energy for more than 8,000 electric buses in Beijing through about 1,200 charging piles at electric bus stations. This not only reduces the operating costs of the buses, but also significantly reduces carbon emissions. It is estimated that this green power transaction is expected to reduce carbon dioxide emissions by about 295,100 tons throughout the year. For many citizens who travel by public transport, this means that their low-carbon travel will be upgraded to a "zero-carbon" travel mode[28].

5.5. Alternative Action for Public Transport Electrification

To further enhance the electrification level of urban public transportation systems, on March 13, 2024, the State Council issued the "Action Plan for Promoting Large scale Equipment Renewal and Consumer Goods Trade in". The plan clearly proposes to "continuously promote the electrification of urban buses and support the upgrading of old new energy buses and power batteries". This policy provides strong policy support for the electrification replacement of buses in Beijing, which helps accelerate the upgrading of old vehicles and improve the overall performance of the public transportation system.

According to the "Electric Vehicle Charging Infrastructure Construction Plan" and the "Guiding Opinions on the Construction of Charging Infrastructure", the number of domestic charging and swapping stations will reach 12,000 and the number of charging piles will reach 4.5 million by 2020.[22]

5.6. Government Assessment Policy

In 2015, in order to further accelerate the promotion and application of new energy vehicles in the field of public transportation, the Ministry of Transport, the Ministry of Finance, and the Ministry of Industry and Information Technology of China jointly issued the "Assessment Measures for the Promotion and Application of New Energy Buses (Trial)", referred to as the "Assessment Measures".

According to the "Assessment Measures", from 2016 to 2020, the promotion and application of new energy buses will be assessed once a year according to the procedures, mainly to assess the proportion of new energy buses in the new and replaced buses in each natural year in each province. Among them, Beijing and Shanghai and other key provinces and cities for air pollution remediation have relatively high requirements for new and replacement proportions, which should reach 40%, 50%, 60%, 70%, and 80% respectively from 2015 to 2019 [29]. As shown in Table 3 [30]

Table 3. The proportion of new energy buses in the new and replaced buses.

Proportion of Electric Buses in the New and Replaced Buses					
	2015	2016	2017	2018	2019
Key areas and key provinces and cities for air pollution control (including Beijing, Shanghai, Tianjin, Hebei, Shanxi, Jiangsu, Zhejiang, Shandong, Guangdong, Hainan)	40%	50%	60%	70%	80%
Central provinces (including Anhui, Jiangxi, Henan, Hubei, Hunan) and Fujian provinces	25%	35%	45%	55%	65%
Other provinces, municipalities and districts	10%	15%	20%	25%	30%

5.7. The Number and Proportion of New Energy Buses

In recent years, the proportion of bus electrification has increased year by year. According to public data, as of 2012, the number of buses in China was 440,000, and the number of new energy buses was 11,000, accounting for 2.5%[31]. From 2014 to 2022, the total number of new energy buses in China increased from 37,000 to 540,000, accounting for 6.9% to 77.1%, a cumulative increase of 14 times in eight years[32]. In 2015, the number of buses will reach 600,000, while the number of new energy buses will increase to 83,000,

accounting for 13.8% [31]; By the end of 2016, the total number of new energy buses in the country had exceeded 160,000[33]. According to the total number of buses 625,000,accounting for 25.6%; In 2017, the number of buses in the country was 650,000 [34], and the number of new energy buses accounted for 35.9%[35]; As of the end of 2018, China had 673,400 buses and trams, of which 22.2% were diesel vehicles, 24.5% were natural gas vehicles, 37.8% were pure electric vehicles, and 12.9% were hybrid vehicles[36], so the proportion of new energy buses was 50.7%; In 2019, the proportion of new energy buses in the total number of buses increased significantly, and the number of new energy

buses exceeded 410,000, accounting for 59% of the total number of buses in the country[37]. By 2020, there were 466,000 new energy buses, accounting for 66.2% of the total number of urban buses[38]. By the end of 2023, the number

of buses in China will reach 682,500, of which 554,400 will be new energy buses, accounting for 81.2%[39] (As shown in Figure 9 and Figure 10).

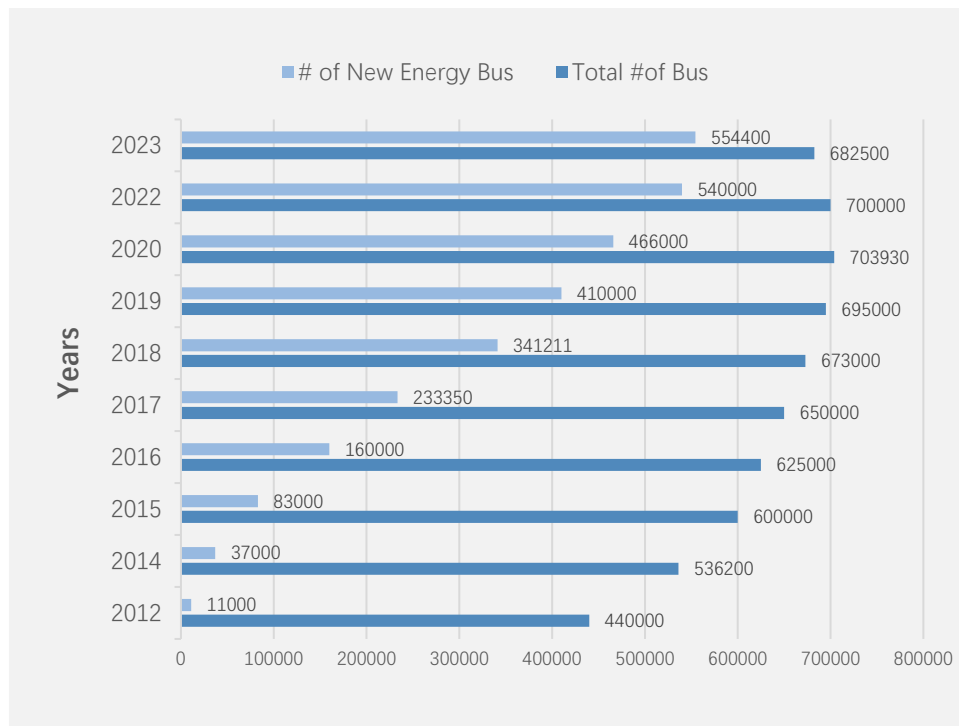


Figure 9. The Total Number of Buses and that of The New Energy Buses

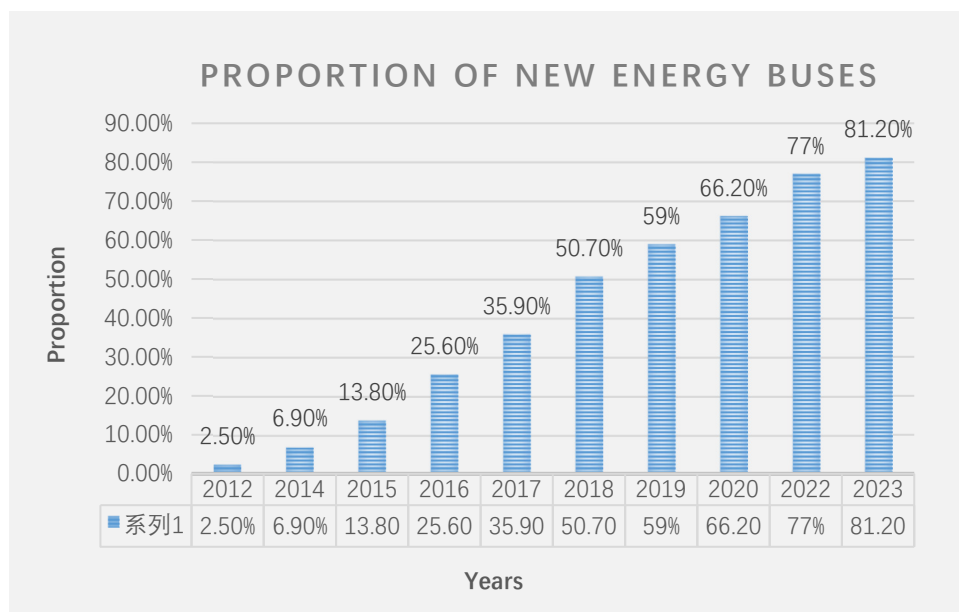


Figure 10. Proportion of New Energy Buses

5.8. Pricing Trend of Electric Buses (Using the BYD-K9 Model as an Example)

As an important pure electric bus product of BYD, BYD-K9 began to achieve the world's first batch of large-scale commercial operation in 2011. As shown in Figure 3, the price of the BYD-K9 has been declining since 2012[40].

As BYD's representative work in the field of new energy buses, BYD-K9's battery technology has been continuously updated with the improvement of BYD's overall technical strength. BYD-K9 originally adopted lithium iron phosphate battery technology, which has high safety, long life, and good

environmental adaptability, which provides a strong guarantee for the reliable operation of K9. With BYD's continuous R&D and innovation in battery technology, the battery system of the K9 has also been optimized many times. These optimizations include upgrades to the battery management system, improvements to the battery pack structure, and optimization of the battery thermal management system, with the aim of improving the energy density, cycle life, and safety of the battery. Advances in battery technology have significantly increased the range of the K9. In addition to continuously optimizing lithium iron phosphate battery technology, BYD is also actively exploring

other new battery technologies, such as solid-state batteries and semi-solid-state batteries. These new battery technologies offer higher energy density, faster charging, and better safety. With the continuous breakthrough and innovation of key technologies, the cruising range, charging convenience, and

operation stability of BYD-K9 will be further improved. These technological advances will reduce the cost of using BYD-K9 and improve its market competitiveness, which may indirectly reduce the market price (as shown in Figure 11).



Figure 11. The prices trend of BYD-K9 from 2012 to 2024

Secondly, the government's various support policies have also played an important role in the decline of the unit price of BYD-K9. The car purchase subsidy provided by the government can directly reduce the purchase cost of consumers and encourage more customers to choose electric buses; The tax reduction and exemption policy for electric buses effectively reduces the operating costs of enterprises, improves the profitability of enterprises, stimulates the production enthusiasm of enterprises, and promotes the expansion of the scale of the electric bus market. At the same time, with the improvement of environmental awareness and the popularization of green travel concepts, more and more consumers and institutions have begun to choose electric buses as a means of travel, and the market demand is growing. These national support policies, as well as the country's vigorous promotion of green energy, have effectively promoted the rapid progress and large-scale production of electric bus technology, thereby reducing the cost of a single vehicle.

To sum up, the BYD K9 electric bus has gone through multiple stages from R&D, commercial operation to market expansion and technological innovation since its launch. With the continuous support of the state for the new energy vehicle industry, including the implementation of policy measures such as car purchase subsidies, tax exemptions, R&D capital investment, and active publicity and calls, the production cost of BYD K9 has gradually decreased.

5.9. Emission Reduction Effect of Electrification of Public Transport

In recent years, Beijing Public Transport Group has made many achievements in energy conservation and emission reduction. It not only reduces CO₂ emissions and energy consumption, but also improves air quality and provides citizens with a greener and more environmentally friendly way to travel.

According to the "Beijing 2013-2017 Clean Air Action

Plan", Beijing Public Transport Group updated 700 electric vehicles and 1,950 natural gas vehicles in 2014, 450 electric vehicles and 1,000 natural gas vehicles in 2015, 600 electric vehicles and 1,000 natural gas vehicles in 2016, and 600 electric vehicles and 1,000 natural gas vehicles in 2017, so that the total number of new energy and clean energy vehicles accounted for about 65% of public transport vehicles. Pollutant emissions reduced by 50% [41].

Compared with 2016, the annual energy consumption of the Beijing Public Transport Group has decreased by 340,000 tons of standard coal, carbon dioxide emissions by 580,000 tons, and diesel consumption from 250,000 tons to less than 50,000 tons in 2022[42].

The electrification of public transportation in Beijing has promoted the optimization of the energy structure and reduced the dependence on traditional fossil energy sources such as oil. According to statistics, compared with 2016, the energy consumption of Beijing Public Transport Group in 2021 has decreased by 200,000 tons of standard coal, and the consumption of diesel has dropped from 250,000 tons to less than 100,000 tons[43]. This marks an increase in energy efficiency and a decrease in total energy consumption. In addition, electric buses can save significantly more energy than gasoline buses while driving the same mileage. At the same time, electrification of buses not only reduces carbon dioxide emissions, but also reduces emissions of pollutants such as nitrogen oxides, carbon monoxide, hydrocarbons, and particulate matter, thereby improving urban air quality and effectively reducing PM_{2.5} levels in the air.

6. Strategies to Address the Challenges

In order to promote the rapid and sustainable development of electric buses, government subsidies and incentives should comprehensively consider the challenges in the whole life cycle of new energy buses, and promote the healthy and sustainable development of the new energy bus industry from multiple aspects such as charging infrastructure construction,

technology research and development and upgrading, operation and maintenance and support, marketing and public education, and policy and financial support.

6.1. Further Optimize Government Financial Subsidy Measures and Implement Diversified Financial Support

In addition to directly issuing subsidies for car purchases to reduce initial costs, the government's financial subsidy measures should also fully consider the challenges that will be faced in the whole life cycle of new energy buses and implement diversified financial support. For example, subsidies will be given to enterprises that build charging stations and battery swap stations, and encourage them to deploy charging facilities in places such as public transportation hubs and along major roads; Preferential electricity prices will be given to the charging of new energy buses, so as to reduce the operating costs of bus enterprises; The implementation of subsidies is linked to technical indicators and promotion ratios to achieve simultaneous improvement of technology and scale; Actively attract social capital to invest in the new energy bus industry through government guidance funds and social capital cooperation; We will continue to explore new financing models to support the development of new energy buses.

6.2. The Government Supports Enterprises to Carry out Technological Innovation and Invest in Research and Development

The government should continue to improve the requirements for the technical indicators of electric buses, improve their endurance and charging efficiency, and promote the research and development of new charging and swapping technologies and equipment such as high power density, high conversion efficiency, high applicability, wireless charging, and mobile charging to promote the technological progress of enterprises. At the same time, we will set up special scientific and technological projects, integrate technical forces to focus on tackling key problems, increase scientific research strength and capital investment, and actively provide financial support and development platforms for new energy vehicle technology research and industrial innovation, including new energy buses, and vigorously support enterprise technological innovation.

6.2.1. Application of Wireless Charging Technology

First of all, wireless charging technology solves the problem of insufficient charging facilities for electric buses. Wireless charging technology is not limited by charging facilities, and by establishing strong electromagnetic induction, electric buses can be charged anytime, anywhere. This means that the electric bus does not need to be parked at a specific charging facility during the driving process, and can be charged at any time, which greatly reduces the charging stay time, prolongs the mileage of the electric bus, and effectively alleviates the contradiction between the charging demand and the lack of charging facilities. This is of great significance for the development of long-distance routes and the expansion of the coverage area of electric buses, as well as to improve the occupancy rate and operational efficiency of electric buses. In addition, with the spread of electric buses, the pressure on urban power grids has increased. Wireless charging technology, on the other hand, does not require a wire connection and can charge electric buses through an

electrical energy transmission system buried in the ground or under a road, thereby reducing the load on the city's power grid.

However, there are also some challenges and limitations to wireless charging technology in electric bus operations. The first is the issue of technology. Wireless charging technology is still in the early stage of development and needs to be further refined and standardized. Issues such as charging efficiency, transmission distance, and safety still need to be addressed. The second is the issue of cost. Wireless charging technology requires a large amount of R&D and implementation investment, and the cost of building charging facilities is high. Rolling out wireless charging technology can be an economic challenge [44].

6.2.2. Application of AC Charging Technology.

AC charging technology has one outstanding advantage: low manufacturing and installation costs for charging equipment. However, due to the low charging power provided by AC charging technology, and the equipment of AC charging technology usually has a certain energy conversion loss, AC charging technology has the disadvantages of long charging time and large energy loss. In view of these weaknesses, we can actively promote the development and application of fast AC charging technology, and at the same time, through the introduction of intelligent control and management technology, we can achieve accurate control of battery charging status, current and voltage, etc., and improve charging efficiency and safety. Considering the characteristics of DC charging and AC charging technology, the appropriate charging method is selected according to the specific operation needs[45].

6.2.3. Hydrogen Fuel Cell Technology Application

A hydrogen fuel cell is a power generation device that directly converts the chemical energy of hydrogen and oxygen into electrical energy, and its basic principle is the reverse reaction of electrolysis of water. Hydrogen fuel cells have the advantages of no pollution, no noise, high efficiency, renewable, and flexible application. Hydrogen fuel cell vehicles use hydrogen as energy and produce water through hydroxide chemical reaction, truly achieving zero pollution. Hydrogen fuel cells operate quietly and can generate more than 50% of the electricity efficiently. In addition, hydrogen fuel comes from renewable energy sources, such as photovoltaic panels, wind power generation, etc., which is more sustainable.

Despite the many advantages and wide application prospects of hydrogen fuel cells, their development still faces some challenges: First, the production of hydrogen fuel requires advanced technology and equipment, resulting in high fuel costs. At the same time, storing hydrogen also requires special containers, which adds additional costs. Second, due to the low density of hydrogen and the need for specific storage equipment and conditions, the widespread use of hydrogen fuel cells faces certain difficulties. Third, the promotion of hydrogen fuel cells requires the construction of corresponding hydrogen refueling stations and other infrastructure, which puts forward new requirements for the existing transportation infrastructure. Therefore, the dedicated support of national policies will help to further promote hydrogen fuel cell vehicles.

6.2.4. Energy Storage Technology Applications

The new energy storage technology also has a variety of functions, such as peak shaving, valley filling, frequency

modulation, phase modulation, accident backup and black start. This means that in the event of a grid failure or disruption, new energy storage technologies can respond quickly, providing emergency power and ensuring the proper operation of critical equipment and services.

Promote the application of new energy storage technology to the construction of charging stations for electric buses, equipped with efficient energy storage equipment, which can store electricity during the night trough hours and provide charging services for electric buses during the peak hours during the day. This not only reduces charging costs, but also relieves the pressure on the power grid and improves the reliability of the charging station.

6.2.5. Autonomous Driving Technology Applications

Autonomous driving technology can significantly improve the operational efficiency and safety of public transportation, optimize the transportation network, alleviate traffic pressure, and improve passenger convenience, and its popularization and application require strengthened technology research and development, policy support and public publicity. With the continuous technological innovation and the increasing awareness of autonomous driving technology, autonomous driving will play an increasingly central role in the field of public transportation, and the application of this technology will not only have a profound impact on the public transportation industry[46], but also promote the modernization of the entire transportation system. The creation of a pilot project for autonomous buses is of great significance to promote the rapid and sustainable development of electric buses.

6.3. Promote the Construction of Charging Infrastructure and Improve the Level of Charging Services

Improving the operational efficiency of electric buses and promoting the promotion of electric buses is a complex and systematic task, which requires the joint efforts of relevant national ministries and commissions, industry associations, local industry management departments, public transport enterprises and vehicle manufacturers. The government should play a promoting role in the construction of charging facilities, increase the supply of charging facilities from many aspects such as institutional guarantees, coordination mechanisms and technological innovation, strengthen management and planning, improve the reliability of charging stations, and improve the level of charging services. Enterprises should increase R&D investment, improve product quality, deepen cooperation to reduce costs, and promote technological innovation.

In response to the problem of insufficient charging infrastructure, the government should further formulate policies to build charging facilities in the public service sector. For electric buses, according to the needs of line operation, priority should be given to the construction of charging facilities in parking lots and stations, the reasonable construction of independent fast charging stations and battery swap stations along the way, the establishment of road traffic sign systems for charging infrastructure should be accelerated, and the route layout should be continuously optimized, and the overall planning and scientific layout should be carried out. Promote the efficient operation of new energy buses by strengthening the construction of charging facilities and strengthening vehicle operation management. At the same

time, establish a mechanism for performance testing, scoring, spot checks and announcements of electric buses to provide a refined basis for decision-making. Supervise and encourage public transport enterprises to advance the planning and construction of charging piles to the purchase of cars to avoid the emergence of the problem of "cars without piles".

In addition, government affairs should promote a unified charging interface standard. Accelerate the revision and introduction of charging interface and communication protocol standards, and actively promote the testing and certification of charging facilities; develop and revise data exchange standards between charging service platforms; Clearly define security management requirements; Establish a safety management system for charging infrastructure, improve safety standards, and set up safety technical measures such as fire protection in charging sites; Improve the standards for charging and battery swapping equipment and electric vehicle batteries, and clarify fire safety requirements. Strengthen daily fire safety inspection and management and eliminate potential safety hazards in a timely manner.

At the same time, improve the management standards of charging infrastructure metering, billing, settlement and other operational services, cultivate more internationally competitive charging service enterprises, and adopt a combination of online and offline methods to provide value-added services such as intelligent charging and discharging, e-commerce, advertising, etc., so as to enhance the sustainable development ability of charging service enterprises.

Supporting business model and financial service innovation in vehicle procurement and charging station construction. Encourage enterprises to create new charging service business models and innovate business cooperation models to build charging infrastructure through cooperation with automobile manufacturers and crowdfunding. Expand diversified financing channels, effectively integrate all kinds of public resources, and create conditions for social capital to participate in the construction and operation of charging infrastructure; Encourage financial institutions to innovate financial products and insurance products, comprehensively use risk compensation policies, and improve the financial service system under the principle of commercial sustainability; Promote pledge financing methods such as equity, project income rights, and franchise rights. Actively promote the establishment of financing guarantee funds and broaden the financing channels for charging infrastructure investment and operation enterprises and equipment manufacturers; Encourage the use of social capital to set up a special fund for the development of charging infrastructure, issue corporate bonds for charging infrastructure, and explore the use of basic pension insurance funds to invest in supporting the construction of charging infrastructure.

6.4. Effectively Lay out Battery Recycling

In view of the problems such as the life of new energy buses and power batteries is not synchronized, the power batteries cannot be replaced in time, and the retired power batteries cannot be fully utilized, the challenges that will be faced in the whole life cycle of new energy buses are comprehensively considered, policies and standards for power battery recycling are formulated, and a channel for dismantling waste batteries after recycling is built to minimize their impact on the environment. Through policies

such as the standard conditions of the new energy vehicle battery industry and the requirements for battery recycling, we will maintain the order of the new energy vehicle market and ensure product quality [47].

6.5. The Integrated Development of Intelligent Vehicles and Networking Will Accelerate the Construction of Intelligent Public Transportation Systems

Promote the effective combination of transportation network and energy Internet and promote the integrated development of electrification and intelligence.

Improve the intelligent level of charging infrastructure and accelerate the construction of intelligent public transportation systems. Including the real-time information query system of public transportation, the pilot operation of self-driving buses, and the improvement of intelligent dispatching center. By leveraging big data analytics and cloud computing technologies, we aim to improve the efficiency of public transport operations, reduce passenger wait times, and enhance the travel experience.

Build a charging intelligent service platform. Vigorously promote the "Internet plus charging infrastructure", improve the intelligent level of charging services, improve operational efficiency and user experience, and promote the two-way interaction between electric buses and smart grids to achieve energy and information. Encourage users to use mobile Internet, Internet of Things, big data and other technologies to provide users with services such as fee navigation, status inquiry, fee appointment, fee settlement, etc., and expand the platform's value-added business.

6.6. Strengthen International Cooperation and Resource Sharing.

International cooperation and resource sharing are the keys to promoting the sustainable development of electric buses. In the process of promoting and applying new energy buses, we pay attention to exchanges and cooperation, and actively build a communication platform.

7. Conclusion

To summarize, the development of electric vehicles and charging infrastructure in Beijing still faces numerous challenges and obstacles. However, with the concerted efforts and collaboration of the government, enterprises, and the public, it is anticipated that in the near future, quick progress will be made in promoting and popularizing electric vehicles. Such efforts will contribute meaningfully to environmental protection and the advancement of sustainable development. In addition, to achieve the popularization and promotion of electric vehicles, it is also necessary to strengthen the recycling of batteries to reduce environmental pollution and waste of resources. The government and enterprises can encourage and support the development of battery recycling enterprises, improve the efficiency and technical level of recycling, and strengthen the supervision and regulation of the field of battery recycling. In addition, with the development of intelligent technology, electric vehicles and charging stations should also develop in the direction of intelligence and automation. For example, smart charging networks can be developed to enable more granular charging management, charging efficiency and user experience. At the same time, the development of autonomous electric vehicles

can be explored, their operational efficiency and safety can be improved, and the development of electric vehicles can be further promoted. Finally, there is also a need to strengthen international cooperation, learn from the experience and practices of other countries and regions, and accelerate the development of electric vehicles and charging facilities. At the same time, through international cooperation, promote the advanced technology and products of China's electric vehicles and charging facilities, improve international competitiveness, and contribute to global environmental protection and sustainable development.

In short, the popularization and promotion of electric vehicles is the common responsibility of the whole society, which requires the joint efforts of the government, enterprises and the people. It is necessary to strengthen the recycling of batteries, promote the intelligent and automated development of electric vehicles and charging stations, strengthen international cooperation and resource sharing, and promote sustainable and environmentally friendly transportation solutions.

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