Carbon Emissions Change and Key Factors of Promoting New Energy Vehicles in Transit System in Guangdong

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Carbon Emissions Change and Key Factors of Promoting New Energy Vehicles in Transit System in Guangdong

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Abstract. Transportation is a key industry in urban energy consumption, air pollutant emissions and greenhouse gas emissions, which has a significant impact on air quality and climate change. The number of motor vehicles in Guangdong province continues to grow, with more than 18 million at the end of 2017. Under the dual pressure of energy and environmental protection, new energy vehicles, as an important carrier of "low-carbon economy", have become the development direction of cars in Guangdong province. The Guangdong government adopts the B2B model to introduce new energy vehicles from the public transportation. In 2017, Guangdong province had 63,391 buses, of which new energy vehicles accounted for 46.2%. This study takes the implementation of new energy vehicles in the public transport system of Guangdong province as the research object, and the energy consumption of new energy vehicles and traditional vehicles were compared. Based on the CDM methodology, the changes in carbon emissions caused by the introduction of new energy vehicles in the transit system were calculated. Carbon emissions in 2020 were estimated according to the number of public buses in Guangdong province and the new energy bus planning. From 2016 to 2020, EV (electric vehicles) accounted for 63-79% of new energy vehicles in buses of Guangdong province, and HEV (hybrid electric vehicles), mainly natural gas and electric hybrid, accounted for 13-16% of the total buses. The total carbon emission of buses in 2020 was reduced by 44.6% compared with 2016, of which EV contributed the most to the emission reduction. In this study, different scenarios are set up to analyze the influence of power generation energy structure and vehicle fuel type on greenhouse gas emission reduction. It is found that power grid energy structure is a key factor affecting the carbon emission and emission reduction space of electric vehicles. The fuel type of vehicle directly affects the emission coefficient of CO_2 per unit fuel, and plays an important role in carbon emission reduction.

1. Introduction

Transportation, a key industry for urban energy consumption, air pollutant emissions and GHG (Greenhouse Gas) emissions, has important impacts on air quality and climate change. Automobile exhaust emissions are an important source of global GHG emissions [1] and vehicle-related GHG emissions are one of the most important sources of GHG emissions in China. From the signing of the Kyoto Protocol in 1997 to the convening of the Paris Climate Conference in 2015, GHG emission reduction has become an important issue in the international community. Some developed and developing countries have made emission reduction commitments. China's commitment on GHG emission reduction is that China's CO_2 emission per unit of GDP will be reduced by 40% to 45% compared with 2005 by 2020, and it will be incorporated into the medium and long term program of national economic and social development as a binding indicator. Under the dual crisis of energy and environmental protection, new energy vehicles have become the development direction of automobile products in all countries around the world. New energy vehicles mainly include fuel cell electric vehicles (FCEV), hybrid electric vehicles (HEV), hydrogen energy power vehicles, pure electric vehicles (PEV, including solar energy vehicles) and other new energy vehicles (such as high-efficiency accumulator, dimethyl ether). In different countries, new energy vehicles have different connotations in different periods due to different energy endowments or technological advantages. This article focuses on two types of new energy buses: PEV and HEV. As an important part of the new energy strategy and smart grid, PEV will become the focus of the development of China's automobile industry and energy industry in the future. At the same time, from a local perspective, it is an effective way to reduce GHG. However, from the perspective of the whole life cycle, compared with the traditional fuel vehicles, whether the carbon emission of new energy vehicles on the environment is increasing or decreasing has aroused a heated debate [2-3].

Taking the typical model of new energy vehicle Tesla as an example, different ways of obtaining electricity lead to large differences in carbon emissions per kilowatt. For example, the 2,108kg Tesla Model S, which weighs half a ton on its battery alone, consumes about 0.18 kilowatt per kilometer on average. The carbon emissions and their attributes in different countries are shown in table 1. In three different countries, the United States, China and Singapore, due to the different sources of electricity, the energy saving properties of pure electric Tesla vary greatly, and in Singapore, it was even fined $10,880 [4].

Table 1. Tesla's carbon emissions in different countries and their energy-saving attributes

Country	Source of electricity	Carbon emission (g/ km)	Attribute
The United States	Nuclear power	122	Energy-saving and environment-friendly
China	Coal electricity	175	Not energy-saving and environment-friendly
Singapore	Fuel oil generation	222	Severely exceeding the standard, severely fined $10,880

Only large-scale promotion of new energy vehicles is of significance to environmental protection. Scale is one of the important goals of China's new energy vehicles strategic planning. Because of its high frequency of use, wide coverage and centralized procurement mode, bus has become the first choice for the promotion and application of new energy vehicles. [5] Guangdong province is one of the first provinces to promote new energy vehicles in China while the Pearl River delta region has become a demonstration area for the promotion and application of pure electric buses in China. [6] The number of new energy vehicles in Guangdong province is expected to reach 250,000 in 2025. The experience of Guangdong new energy vehicles in the field of public transport has reference significance to other provinces and cities. It is of great practical significance to study the carbon emission reduction effect of the large-scale promotion of new energy bus.

With a total population of 109 million, Guangdong is China's most populous province. [7] With the rapid growth of automobile ownership, urban traffic congestion and environmental protection issues are particularly prominent, so it is imperative to develop a smart public transport system. By 2020, public transport in megacities and large cities will account for more than 60% of motor vehicle trips, the proportion of new energy buses in the whole province will be more than 75%, and the proportion of new energy buses in the Pearl River delta region will be more than 85% [8].

The research on the influencing factors of carbon emissions of new energy vehicles has received great attention since 2013. The typical research achievements include: According to the theory of fuel life cycle, Shi Xiaoqing et al. (2015) analyzed the emission reduction factors affecting electric vehicles. Adopting an improved fuel carbon emission model and combining with the promotion plan of Beijing electric vehicles, they analyzed the influence of six scenario factors on potential emission reduction of electric vehicles, such as power generation structure, vehicle fuel type, vehicle type, urban traffic condition, coal-fired power generation technology and battery type. As a result, they put forward some optimizing measures to reduce traffic energy consumption and carbon emissions,such as improving energy structure, popularizing energy-saving technology, accelerating research and development of power storage battery, popularizing pure electric vehicles and so on [9]. Zhao Lixiang et al. (2018) analyzed the impacts of passenger traffic carbon emission mainly including energy structure, energy efficiency and economic development. The carbon emission reduction accounting model of Beijing passenger traffic was established to analyze the impact of vehicle and fuel improvement technology policy on carbon emission reduction of passenger transport in Beijing is analyzed. The study found that both new and clean energy vehicles and stricter fuel consumption limits could reduce CO2 emissions to some extent. The policy of raising fuel consumption limit standard has a good effect of emission reduction in the short term, but in the long term, the emission reduction effect of updated new energy and clean energy vehicles is more obvious [10]. Zhuang Ying et al. (2017) analyzed the structure of traffic carbon emission and its carbon emission proportion in Guangdong province and the main factors influencing the growth of traffic carbon emission in Guangdong province, proposing measures to reduce traffic carbon emission by using alternative clean energy [11].

There are few studies on the carbon emissions of new energy vehicles in the field of public transport. Existing literatures mainly take Beijing and Tianjin as examples to carry out empirical research: Tang Baojun et al. (2016) carried out quantitative analysis on the energy-saving effect and emission reduction effect of popularizing electric bus in Beijing, which shows that the promotion of electric vehicles, has good effect of energy conservation and emissions reduction, power structure, the influence factors such as vehicle fuel type bigger reduction effects on the electric vehicle [12]. Li Zhipeng (2012) used the method of system dynamics to quantitatively analyze the number of buses, energy consumption and carbon emissions based on the basic data from 2000 to 2010, and predicted the energy consumption and carbon emissions of urban transportation during the 12th Five-Year Plan period. Through scenario analysis, it is considered that residents should be encouraged to use public transport to travel, while improving the operation capacity and efficiency of the public transport system, controlling the rapid growth of private cars, phasing out high-energy cars and encouraging the development of new energy vehicles and hybrid vehicles [13]. Based on the LEAP model, Fu Tan et al. (2017) quantifies the impact of new energy vehicles on energy and urban environment. The research shows that the urban public transport system has a significant influence on the urban air environment. Affected by the adjustment of bus energy consumption structure, electric power and natural gas will replace diesel to a certain extent to become the power energy of buses. Electricity energy demand will grow by nearly 20%, while natural gas energy demand will maintain a growth rate of more than 10% [14].

At present, there are few literatures have to quantify the carbon emission effect of the large-scale promotion of new energy vehicles in the public transportation system of Guangdong province. Based on the statistics of the planning amount of the promotion and application of new energy buses in Guangdong Province during the 13th Five-Year Plan period, this paper studies the carbon emissions and their changes brought about by the large-scale popularization of new energy buses in the public transport system of Guangdong Province, which can be used for reference in the planning and transformation of the future power grid of Guangdong Province, the popularization and application of electric vehicles in public transport system, and the pricing mechanism for electric vehicles, etc.

2. CDM methodology and its application in automotive field

The CDM methodology is a general term for a series of methodologies developed to evaluate the carbon emission reduction of CDM projects. The Kyoto Protocol defines three mechanisms based on market mechanisms: Emissions trading, Clear development mechanism and Joint implementation. Since China signed the Kyoto Protocol, in order to ensure the rapid growth of CDM projects can bring long-term, measurable and effective carbon emissions reductions, it may need to establish a set of effective, open and operational methodology, which referred to as CDM methodology, specific including to establish a baseline determination and additional demonstration, project emissions and leakage estimating, emissions reduction, the calculation and monitoring of emission reduction cost effectiveness, etc. For calculation of emission reduction in transportation, CDM methodologies have corresponding system of methods, including the renewable energy methodology AMS - I. M., AMS - III. T., etc, as well as the energy efficiency methodology AM0031, AM0090, AMS - III. C., etc. [15]. Some scholars calculated the carbon emission reduction of BRT system in this city according to the CDM methodology AM0031 "rapid transit conversion system methodology", and analyzed that the main carbon emission factor of this project is the type of vehicle fuel. It is suggested to consider gas-electric hybrid vehicles and pure electric vehicles more when developing BRT project. Yang Weihua (2014) takes gas-electric hybrid cars as the research object and takes a public transport project in North China as an example, calculating the carbon emission reduction of gas-electric hybrid electric vehicle by using CDM methodology, exploring the influencing factors of carbon emission reduction of gas-electric hybrid electric vehicle, proposing to optimize the energy structure of power generation as well as promote new energy and other low-carbon transportation suggestions [16]. AMS-III.C is a small-scale methodology for reducing emissions through electric and hybrid vehicles, which can be applied to study the carbon emissions and their changes brought about by the large-scale promotion of new energy vehicles in the public transport system of Guangdong Province.

3. Study on carbon emission reduction calculation of new energy vehicles in Guangdong public transport system

The carbon emission reduction of new energy vehicles is calculated mainly according to the CDM methodology, AMS-III.C, a small methodology for emission reduction through hybrid vehicles. Since the implementation of liquefied petroleum gas (LPG) aerodynamic vehicles as buses in Guangdong Province in 2010, this calculation selects an equal number of LPG powered vehicles as the baseline. The bus travels 200km a day and runs for 300 days a year.

3.1. Guangdong bus ownership and new energy bus planning data sources

According to the statistical yearbook of Guangdong province in 2016, the number of public buses and trams in Guangdong province is 61,379, among which 21,806 new energy buses are held, accounting for 35.5% of the total number of buses. The total number of pure electric buses is 13,746, accounting for 63% of the total number of new energy buses and 22.4% of the total number of buses.

According to the plan, from 2016, among the updated or newly added buses, the proportion of pure electric buses is 90%, and the remaining 10% all use new energy vehicles [17]. By 2020, the number of new energy buses in Guangdong province will be about 52,000, and the proportion of new energy buses in Guangdong province will be over 75%, and the proportion of pure electric buses will be over 65% [18]. According to the data in 2015 and 2016, the annual growth rate and update rate of the number of buses are 3.2% and 5% respectively. Calculate the number of pure electric buses in each year based on the planned number of 46,000 by the end of 2020. The data of 2016-2020 public buses, new energy buses and pure electric buses are obtained respectively, as shown in table 2. According to the prediction of this plan, in 2020, the proportion of new energy buses in Guangdong province is 76.3%, the proportion of new energy buses is 52,911, the proportion of pure electric buses is 66.3%, and the proportion of pure electric buses in new energy buses is 86.9%. The estimated results fully meet the targets of the 13th five-year plan, proving the estimation is effective.

Table 2 shows the proportion of new energy vehicles, pure electric vehicles and gas-electric hybrid new energy vehicles in total buses of Guangdong province in 2016-2020. It is worth noting that the proportion of pure electric vehicles in new energy vehicles is 63.0-86.9%. In addition to pure electric vehicles, some of the new energy vehicles in the bus are gas-electric hybrids, which account for 13-16 percent of the total bus fleet, mainly gas-electric hybrids.

Table 2. The number and proportion of various public buses in Guangdong in 2016-2020

year	All bus	New energy bus	Gas-electric hybrid bus	New energy bus among all buses (%)	Pure Electric buses (%)	Pure electric buses among all new energy buses (%)	Gas-electric hybrid bus among all buses (%)	Pure electric buses among all buses (%)
2016	61379	21806	8060	35.5	13746	63.0	13.1	22.4
2017	63391	29300	8825	46.2	20475	69.9	13.9	32.3
2018	65419	37034	9558	56.6	27476	74.2	14.6	42.0
2019	67513	45015	10381	66.7	34634	76.9	15.4	51.3
2020	69333	52911	11163	76.3	46000	86.9	16.1	66.3

3.2. Page Numbers

According to the methodology AMS - Ⅲ. [21] C, calculation formula of the baseline emissions see type (1), (2):

$$BE_y = \sum_i EF_{BL,km,i} \times \mathrm{DD}_{i,y} \times 10^{-6} \tag{1}$$

Formula: BEy is the total baseline emission of y year, tCO2 ; EFBL,km,i are fuel emission factors of benchmark vehicle class i, gCO2/km ; DDi,y is the average annual travel distance of the benchmark vehicle class i in y year, km ; Ni,y is the number of vehicles running the project in category i in y year.

$$EF_{BL,km,i} = SFC_i \times NCV_{BL,i} \times EF_{BL,i} \times IR^t \tag{2}$$

Formula: SFCi is the unit fuel consumption rate of the benchmark vehicle class i, g / km; NCVBL,i is the low calorific value of fossil fuels consumed by the benchmark vehicle class i, J/g; EFBL,iis the emission factor of fossil fuel consumed by the benchmark vehicle class i, g/J; IRt is the vehicle technology improvement factor of the t-year baseline, and the technology improvement rate is applied to each calendar year; t is the number of years of technical improvement (depending on the life data of each vehicle type).

Table 3 shows the baseline carbon emissions of bus, calculated according to formulas (1) and (2). Assuming that all buses use LPG (liquefied petroleum gas) as fuel, it can be seen that the carbon emission of all LPG-fueled buses have an average annual growth rate of 3.2%. New energy buses accounted for 35.5% of the total bus ownership in 2016 to 76.3% in 2020, with an average annual growth rate of 10.2%. The baseline carbon emissions of new energy bus are also given in Table 3, that is, the carbon emissions of all new energy buses are calculated based on the use of LPG.

Table 3. Actual carbon emissions of new energy buses

year	Bus ownership	New energy bus ownership	Emission coefficient of liquefied petroleum gas (kg.km-1)	Baseline carbon emissions of total bus($t.yr^{-1}$)	Baseline carbon emissions of new energy bus($t.yr^{-1}$)
2016	61425	21806	1.163	4286236	1521623
2017	63391	29300	1.163	4423396	2044544
2018	65419	37034	1.163	4564945	2584198
2019	67513	45015	1.163	4711023	3141121
2020	69333	52911	1.163	438057	3692147

3.3. Actual emissions from new energy buses

The formula for carbon emissions of hybrid electric vehicles is shown in (3):

$$PE_y = \sum_i EF_{PJ,km,i,y} \times \mathrm{DD}_{i,y} \times N_{i,y} \tag{3}$$

Formula: PEy refers to emissions in year y, t; EFPJ, km, I, y refers to the emission factor of driving per km for vehicle class i, tCO2/km; Ni, y is the number of vehicles in class i in y year; DDi, y is the annual average travel distance of the benchmark vehicle class i in y year, km.

Vehicle emission factors are determined by formula (4):

$$EF_{PJ,km,i,y} = \sum_i \frac{SEC_{PJ,km,i,y} \times EF_{elect,y}}{\left(1-TDL_y\right)\times 10^{-3}} + \sum_i SFC_{PJ,km,i,y} \times NCV_{PJ,i} \times EF_{P,J,i} \times 10^{-6} \tag{4}$$

Formula: SECPJ,km,I,y is the electricity consumption per kilometer of vehicle class I in y year, kW·h/km; EFelect,y is the carbon dioxide emission factor that consumes electricity for vehicle class i in y year, kgCO2/(kW·h); SFCPJ,km,I,y is the gas consumption per km of vehicle class i in y year, gCO2/km; EFPJ,i is the Carbon dioxide emission factor of natural gas fuel consumed by vehicle type i in y year, g/J; NCVPJ,i is the net calorific value of fossil fuel consumed by vehicle class i in y year, J/g; TDLy represents the average technical transmission and distribution loss of power supply in y year, taking 6.4%.

Table 4 shows the actual carbon emission of new energy bus based on formula (3) (4). It is particularly noteworthy that the carbon emissions of new energy buses account for 11.5-33.7% of the total carbon emissions of buses. Taking the 2020 data as an example, new energy buses accounted f or 76.3% of the total bus and buses with other energy fuels accounted for 23.7% of the total bus, while its carbon emissions accounted for 66.3% of the total emissions. Therefore, the promotion of the use of new energy vehicles on the bus had a significant role in promoting carbon emissions reduction. At present, the new energy vehicles in buses are composed of pure electric buses and gas-electric hybrid buses. Among them, the gas-electric hybrid buses account for 13.1-16.1% of the total buses, accounting for 21.9-36.9% of the total new energy buses, but their carbon emissions account for 72.4-85.2% of the total carbon emissions of new energy buses. 14.8-27.6%, which shows that the promotion of pure electric vehicles in new energy vehicles plays an important role in carbon emission reduction.

Table 4. Actual carbon emission of new energy bus

year	New energy buses among all bus (%)	Pure electric buses among all bus (%)	Gas-electric hybrid buses among all bus (%)	Emission coefficient of natural gas of new energy buses (*kg.km*$^{-1}$)	Power consumption (*kw.h*$^{-1}$. *km*$^{-1}$)	Grid emission factor (*kg.kw*$^{-1}$.*h*$^{-1}$)	Carbon emissions from new energy buses (*t.yr*$^{-1}$)	Carbon emission ratio of pure electric buses to new energy buses (%)	Carbon emission ratio of new energy buses to buses (%)
2016	35.5	22.4	13.1	0.57	0.075	0.804	357729	14.8	11.5
2017	46.2	32.3	13.9	0.57	0.075	0.804	412032	19.1	14.8
2018	56.6	42.0	14.6	0.57	0.075	0.804	468074	22.6	19.1
2019	66.7	51.3	15.4	0.57	0.075	0.804	525908	25.4	25.1
2020	76.3	66.3	16.1	0.57	0.075	0.804	583130	27.6	33.7

3.4. Carbon emission reduction analysis

Carbon emission reduction can be calculated by (5):

$$ER_y = BE_y - PE_y - LE_y \tag{5}$$

Formula: ER is the emission reduction in y year, t/yr; BE is discharge at the y baseline, t/yr; PE is the emission volume of pure electric vehicle in year y, t/yr; LE is the y-year gas-electric hybrid emission, t/yr.

Figure 1 shows the trend of bus carbon emission reduction in 2016-2020 after the use of new energy vehicles. It can be seen that the carbon emission reduction is increasing year by year. The actual carbon emission reduction in 2020 is 2.7 times that in 2016. From analysis in 3.2, PEV is the lowest carbon emissions. If all the new energy vehicles are replaced with PEV, then its carbon emissions is the largest. As can be seen from Figure 1, the maximum emission reductions are also increasing year by year. If all new energy vehicles use pure electric vehicles, they can further reduce carbon emissions by 12-20%.

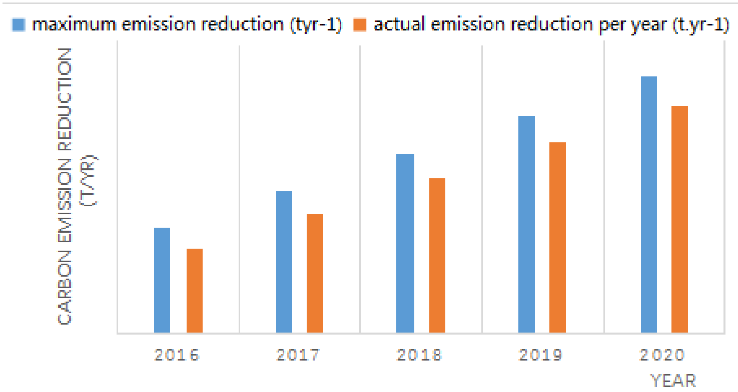

Figure 1. Trend of carbon emission reduction in different years

4. Analysis of the influencing factors of carbon emission reduction

From the above quantitative analysis of carbon emissions, it can be seen that the development of new energy vehicles is conducive to the realization of energy saving and emission reduction goals in China, especially pure electric vehicles, whose energy efficiency is 46% higher than that of traditional fuel vehicles, and has 13% - 68% carbon emission reduction potential, but its emission reduction effect is also affected by many factors [19-21]. In table 4, the grid emission factor and fuel emission factor are given, among which, the grid emission factor is affected by the power generation energy structure, while the fuel emission factor is affected by the vehicle fuel type. Next, the greenhouse gas emission reduction effect is analyzed and discussed respectively on the power generation energy structure and vehicle fuel type.

4.1. Influence of power generation energy structure

The energy structure of power generation determines the CO2 emission coefficient of unit power. At present, most of China's electricity is produced by coal-fired power plants, but the energy structure and proportion of different regions depends on their geographical location and economic development. The power generation energy structure of Guangdong province is composed of coal, natural gas, new energy and renewable energy, hydropower and nuclear power, and some purchased electricity. The emission coefficient can be calculated by formula (6).

$$EF = \sum f_i \times EF_i \tag{6}$$

Formula: i refers to the types of energy such as coal, natural gas, new energy and renewable energy, water and nuclear power; fi is the proportion of corresponding energy in power generation energy structure, %; EFi is the CO2 emission coefficient of corresponding energy, kg/(kW·h). According to the "Twelfth Five-Year Plan" of the State Grid and the "Thirteenth Five-Year Plan" of the State Grid, as well as the development plan and energy structure of the South China Grid, the average CO2 emission factors of the South China region in 2016 and 2020 are calculated to be 0.527 and 0.395 kg/(kW·h) respectively. It can be seen that the average carbon of the power grid is caused by the use of clean energy. Emission factor decreased by 25%.

Figure 2 is a case study of pure electric buses in Guangdong Province in 2016 and 2020. Different emission factors are used to calculate their carbon emissions and compare them with the national average. Compared with the national average emissions, the space for carbon emission reduction in 2016 and 2020 is 35% and 50% respectively, indicating that Guangdong Province is more than the national electricity. Net energy structure is more reasonable and cleaner. It can also be seen that in 2020 pure electric bus ownership is 3.3 times as much as in 2016, and 2020 pure electric bus carbon emissions are 2.2 times as much as in 2016. This indicates that the energy structure of the grid is the key factor affecting the carbon emissions and the emission reduction space of electric vehicles.

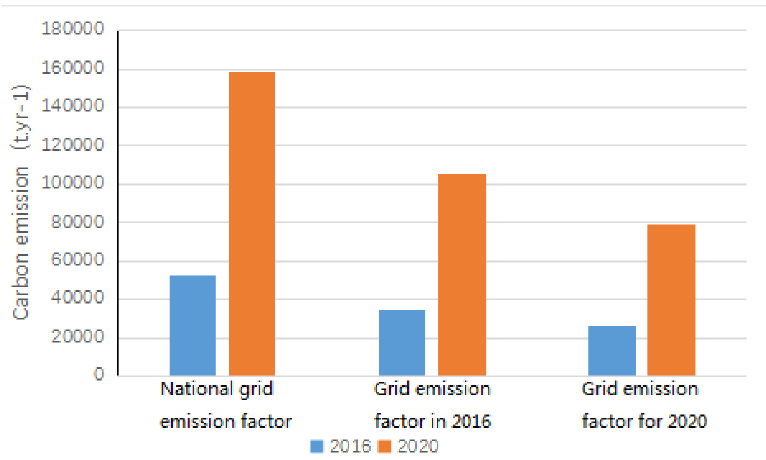

Figure 2. Influence of different grid carbon emission factors on carbon emissions of PEV

4.2. Impacts of vehicle fuel types

Taking 2016 as an example, there were 13,746 pure electric buses in Guangdong province, and the carbon emission and emission reduction potential of the pure electric buses in the energy-consuming driving life cycle phase relative to fuel buses and LPG (liquefied petroleum gas) were estimated when the average annual mileage was the same. Table 5 shows the relevant parameters and carbon emissions of different fuel buses. Compared with fuel bus, LPG bus, gas-electric hybrid bus and pure electric bus reduce their emissions by 29.8%, 63.1% and 70.4% respectively. The type of the vehicle fuel directly affects the emission coefficient of unit fuel CO2, and fuel bus has the largest carbon emission, which is caused by the CO2 emission of diesel life cycle is much higher than that of other fuels. Compared with LPG buses, gas-electric hybrid buses and pure electric buses reduced their carbon emission by 47.5% and 57.9% respectively. It can be seen that vigorously promoting new energy vehicles plays an important role in carbon emission reduction.

Table 5. Relative parameters and carbon emissions of different types of fuel buses

<table>
<tr><th colspan="2">Energy type</th><th>CO_2 emission coefficient (*kg.km*$^{-1}$)</th><th>Power consumption (*kw/h/km*$^{-1}$)</th><th>Grid emission factor (*kg.kw*$^{-1}$*.h*$^{-1}$)</th><th>Carbon emissions (*t.yr*$^{-1}$)</th></tr>
<tr><td colspan="2">Fuel bus</td><td>1.65</td><td>/</td><td>/</td><td>1363240</td></tr>
<tr><td colspan="2">LPG bus</td><td>1.16</td><td>/</td><td>/</td><td>956722</td></tr>
<tr><td rowspan="2">Gas electric hybrid power</td><td>Natural gas</td><td>0.57</td><td>/</td><td>/</td><td rowspan="2">502712</td></tr>
<tr><td>Electric</td><td>/</td><td>0.075</td><td>/</td></tr>
<tr><td colspan="2">Pure electric bus</td><td>/</td><td>0.9</td><td>0.527</td><td>403060</td></tr>
</table>

5. Conclusion

Promoting new energy vehicles in transit system in Guangdong province can lead to carbon emission reduction. The space of carbon emission reduction is affected by power structure and vehicle fuel structure.

5.1. The analysis of the number and proportion of new energy vehicles in the public transport system of Guangdong

Pure electric bus is the mainstream product, while gas-electric hybrid bus is the transition product. According to the base number of public bus in Guangdong province in 2016 and the development plan of new energy vehicle in the public transportation sector, from 2016 to 2020, the proportion of new energy vehicles in public buses increased from 35.5% to 76.3%, and the proportion of pure electric vehicles in the total number of public buses increased to three times, from 22.4% to 66.3%. Gas-electric hybrid new energy vehicles, accounting for 13.1-16.1% of the total number of buses, reduced from 36.9% to 21.1% of the total number of new energy buses.

5.2. The calculation results of carbon emissions from new energy buses show that

Promoting the use of new energy vehicles in the field of public transport has a significant effect on carbon emissions reduction, among which pure electric vehicles have the lowest carbon emissions. The total carbon emissions of buses in 2020 were 44.6% lower than those in 2016; if all new energy vehicles were replaced by pure electric vehicles, the carbon emissions could be further reduced by 12-20%, with the largest reduction.

5.3. Factors affecting carbon emissions of new energy buses

The energy structure of power generation and the fuel type of vehicle respectively affect the CO2 emission coefficient of unit and have significant influence on the carbon emission reduction effect. As a result of the use of clean energy, the average carbon emission factor of Guangdong power grid in 2020 will be 25% lower than that in 2016. According to this estimation, compared with the national average emission value, the carbon emission reduction space of the pure electric bus charging by Guangdong power grid in 2016 and 2020 is 35% and 50% respectively. The calculation of carbon emission reduction by vehicle fuel type shows that gas-electric hybrid buses and pure electric buses reduce carbon emission by 47.5% and 57.9% respectively, compared with LPG buses. All in all, vigorously promoting new energy vehicles plays an important role in carbon emission reduction.

5.4. The deficiency of this study

The specific number of new energy vehicles in the public transport system of Guangdong province in 2017-2020 is estimated according to the quantified value of the promotion plan for new energy vehicles in the pearl river delta region by the government of Guangdong province during the 13th five-year plan period. In addition, the bus update rate and growth of ownership is in accordance with the data calculated from 2015 to 2016, may have some discrepancy with actual situation, for example, the service life of the bus and the mass of the vehicle itself and the relevant policies of the city, taking Shenzhen as an example, the service life of bus generally can be up to 10 years, the reasonable proportion of about 1/10 of the updated annually, however, actual situation of Shenzhen city bus has been updated by 50% in 2016. Therefore, the calculation and actual situation leading to carbon emissions and emissions reduction will also have certain errors. The research results of this paper need further empirical analysis.

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