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Research on Carbon Emissions of Electric Vehicles throughout the Life Cycle Assessment Taking into Vehicle Weight and Grid Mix Composition

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Abstract: To study the impact of the promotion of electric vehicles on carbon emissions in China, the full life carbon emissions of electric vehicles are studied on the basis of considering such factors as vehicle weight and grid mix composition, and fuel vehicles are added for comparison. In this paper, we collect data for 34 domestic electric vehicles, and linear regression analysis is used to model the relationship between vehicle weight and energy consumption. Then, a Hybrid Life Cycle Assessment method is used to establish the life cycle carbon emission calculation model for electric vehicles and fuel vehicles. Finally, the life cycle carbon emissions of electric vehicles and fuel vehicles under different electrical energy structures are discussed using scenario analysis. The results show that under the current grid mix composition in China, the carbon emissions of electric vehicles of the same vehicle weight class are 24% to 31% higher than that of fuel vehicles. As the proportion of clean energy in the grid mix composition increases, the advantages of electric vehicles to reduce carbon emissions will gradually emerge.

Keywords: vehicle weight; grid mix composition; electric vehicle; life cycle assessment; carbon emissions

1. Introduction

Due to the reduction of exhaust emissions during driving, electric vehicles are used by more and more countries to promote low-carbon development and traffic emission reduction. Major developed countries in the world have successively put forward the development strategies for electric vehicles [1]. To comply with the global trend of electric vehicle development, reduce automobile carbon dioxide emissions, improve air quality and reduce dependence on international oil, China has taken the development of electric vehicles as one of its national strategies [2]. According to The Global Electric Vehicle Vision 2018 [3] released by the International Energy Agency, the global electric vehicles reached 3109.05 thousand in 2017, and is expected to reach 13 million in 2020 and nearly 130–228 million in 2030. By the end of 2018, China's electric vehicles reached 2.61 million, accounting for 1.09% of the total number of vehicles. In 2030, China's electric vehicle market share will reach 26–40% [3].

For the research on the whole life cycle carbon emission assessment of electric vehicles, foreign countries have put forward relevant methods which are being constantly improved [4]. At present, the mature LCA models in other countries include GREET and e-balance; in the automobile field, it also includes models built with GaBi 6 software, EIO-LCA model of university of Toronto, DfE model of Mercedes-Benzes, etc. [5].

In China, the research on the application of full Life Cycle Assessment in the field of automobile started in the early 21st century [6,7]. Around 2010, with the start and development of electric vehicles in China, Ou Xunmin et al. [8,9] used the Life Cycle Assessment theory to compare the carbon emission and environmental impact of coal-electric vehicles with traditional fuel vehicles, proposed the China Tsinghua-CA3EM model, and found that electric cars can save more than 35% energy and reduce emissions by about 20% compared with fuel cars. Shi Xiaoqing [10,11] et al. believed that according to different power supply scenarios, all-electric vehicles can achieve emissions reductions of 57% to 81.2%.

However, some experts and scholars think that the emission reduction effect of electric vehicles is not obvious, and they may even increase the greenhouse gas emission under the influence of the current high-carbon electricity. For example, Song Yonghua et al. [12] thought that the development of electric vehicles is high carbon in terms of the national average carbon emissions from power terminals. Zhang Lei et al. [13] believed that the full life cycle comprehensive environmental impact of electric vehicle power system was 60.15% higher than that of internal combustion engine vehicle power system. Feng Chao et al. [14] thought that in the current grid mix composition and technical conditions, although electric cars had high energy efficiency and good oil substitution, their higher lifetime coal consumption would result in higher greenhouse gas emissions than conventional gasoline vehicles, in this case, large-scale development of the electric car is not good for greenhouse gas emissions.

In summary, domestic and foreign experts and scholars have carried out research on the full life cycle carbon emission of electric vehicles, but there is still a dispute on whether it is beneficial to reduce carbon emissions. Domestic scholars pay more attention to the research of whole-life cycle carbon emission model, but ignore the fact that China, as a big producer and seller of electric vehicles, produces electric vehicles with different vehicle weights, battery capacities and ranges, and different carbon emissions over the whole life cycle [15,16]. Therefore, it is of great significance to study the effects of vehicle weight, battery capacity and cruising range on carbon emission and environment. Meanwhile, the grid mix composition is also an important factor affecting the carbon emission of electric vehicles [17]. Therefore, it is also necessary to perform a comparative analysis of the influence of grid mix composition on the carbon emission of electric vehicles [18].

To study the impact of the promotion of electric vehicles on carbon emissions, this paper studies the full life cycle carbon emissions of electric vehicles, and makes a comparison with the full life cycle carbon emissions of fuel vehicles [19]. In this paper, we use a hybrid life cycle assessment method to calculate the carbon emissions of vehicles. The Hybrid Life Cycle Assessment (HLCA) combines the advantages of the Process-based Life Cycle Assessment (PLCA) with the Economic Input-Output Life Cycle Assessment (EIO LCA), which made the boundary more complete and the results more accurate. In addition to this, it can significantly reduce the truncation error. To conduct a more accurate study on the emission reduction effect of electric vehicles, this paper intends to use the HLCA method to calculate the energy consumption and greenhouse gas emissions of electric vehicles.

The primary objective of this paper is to study the impact of vehicle weight and gird mix composition changes on the life cycle carbon emissions of electric vehicles in China. For this purpose, we compare the life cycle carbon emissions of the same class electric vehicles and fuel vehicles. A second objective is to find out whether the development of electric vehicles in China can help reduce emissions under the current conditions. The final objective is to explore the carbon emission proportion for each phase of the life cycle of electric vehicles and fuel vehicles, which may help to develop an emission reduction policy for vehicles.

2. Research Methods

At first, this paper uses the linear regression analysis to verify the relationship between vehicle weight and energy consumption of 100 km, and then the Hybrid Life Cycle Assessment method is used to calculate energy consumption and greenhouse gas emissions through Tinghua-CA3EM [8] model built by Ou Xunmin et al. and with the same grade of fuel car for comparative analysis. Finally, the scenario analysis of the full life cycle carbon emissions of electric vehicles and fuel vehicles under the grid mix composition in 2020, 2030 and 2050 is conducted.

2.1. Linear Regression Analysis

First of all, the functional relationship between the vehicle weight and energy consumption of 100 km is established through the existing data of electric vehicles, and relevant parameters are obtained accordingly. Furthermore, four electric vehicle models are obtained by modeling electric vehicles. To understand the general situation of electric vehicles in China and determine the vehicle models to be evaluated, this paper collected data of 34 popular all-electric vehicles in the Chinese market(The parameters of the 34 electric vehicles are shown in Table A1), such as models, power types, vehicle weight, power consumption of 100 km, battery capacity and range. For conventional vehicles, the whole vehicle weight and energy consumption are strongly coupled [20], so the functional relationship between the whole vehicle weight of these 34 models and the power consumption of 100 km is obtained (as shown in Figure 1). Although energy consumption is affected by many technical characteristics other than vehicle quality [21], we can assume a linear regression curve. Through linear regression analysis and testing, it is verified that there is a linear relationship between the energy consumption of 100 km and the vehicle weight: y = 0.0051x + 6.0576, and the determination coefficient R^2 = 0.951, which proves that the model fits well. From the slope of the linear regression curve, it can be known that every 100 kg increase in the vehicle weight will increase the energy demand of electric vehicle by 0.0051 kWh/km.

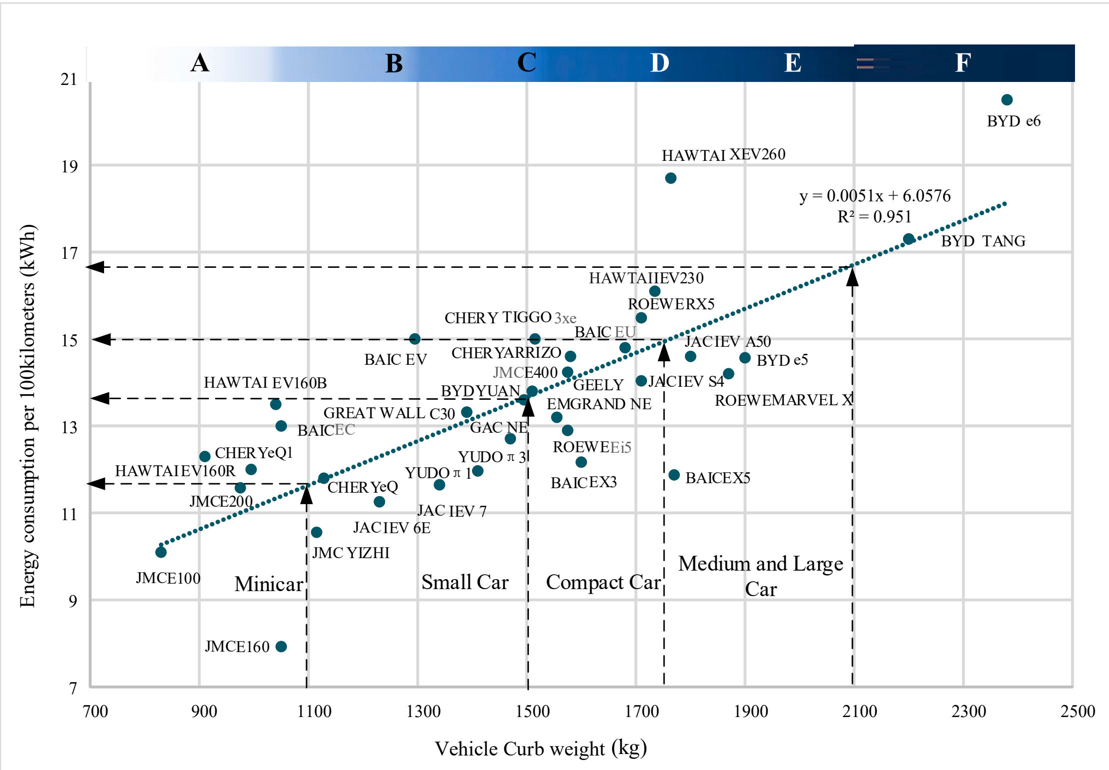


Figure 1. The relationship between electric vehicle energy consumption and vehicle weight.

Because China has no electric vehicle classification standard at present, in this paper, with reference to the classification standards in European and American countries and based on the electric car manufacturers of electric vehicles from the classification (classification data from the Pacific automotive network), four types of electric vehicles are modeled: mini car (segment A), small car (segment C), compact car (segment D), medium and large car (segment F). According to the regression equation, once the vehicle weight is determined, the 100-km energy consumption demand of the electric vehicle can be determined, and the appropriate battery capacity and range can be determined [9]. To calculate the total energy demand of electric vehicles, we assume that the charging efficiency of electric vehicles is 96% and the battery efficiency is 95% [15]. Related parameters of this model are shown in Table 1. After modeling and determining parameters, relevant data can be collected and life-cycle carbon emission calculation can be carried out.

Table 1. Basic parameters of different levels of electric vehicles.

Classification	The Vehicle Weight (kg)	Battery Capacity (kWh)	Range (km)	Energy Consumption per 100 km (kWh/100 km)
Segment A—mini car	1100	17.7	151	11.67
Segment C—small car	1500	24.4	177	13.71
Segment D—compact car	1750	42.1	281	14.98
Segment F—medium and large car	2100	59.9	357	16.77

2.2. Hybrid Life Cycle Assessment

According to different system boundaries and principles, Life Cycle Assessment methods can be divided into process-based Life Cycle Assessment (PLCA), input-output Life Cycle Assessment (EIO LCA) and Hybrid Life Cycle Assessment (HLCA).Hybrid Life Cycle Assessment is a method combining PLCA and EIO-LCA, which cannot only eliminate the truncation error of PLCA, but also overcome the weakness of weak pertinence of EIO LCA, and also bring the use and scrapping stage of products into the evaluation scope [22]. HLCA is mainly divided into three forms: hierarchical, split input-output sectors and integrated mixed analysis, according to the data availability and accuracy, this paper adopts hierarchical HLCA. The direct emission of each stage is calculated by PLCA method, while the indirect emission is calculated by EIO-LCA. Greenhouse gas emissions in the whole life cycle are the sum of direct and indirect emissions in each sub-phase [23].

According to the usage conditions and scenarios of PLCA and EIO LCA [22,24,25], the boundary between PLCA and EIO LCA in the HLCA model of the full Life Cycle Assessment of electric vehicles is divided: in the research of the full life cycle of the fuel of electric vehicles, the PLCA method is directly adopted; in the study of the whole life cycle of electric vehicles, the production process of vehicles is decomposed. EIO LCA method is adopted in the upstream process from raw material mining to parts production, and PLCA method is adopted in the stage of vehicle assembly, production, transportation and final scrapping.

2.3. Evaluation Objectives and System Boundaries

In the past, the boundary of vehicle Life Cycle Assessment system was mainly defined as fuel cycle material cycle [5], fuel cycle and vehicle cycle [26], with reference to the selection of whole life cycle of the past boundary, the evaluation boundary in this paper includes fuel cycle and vehicle cycle, and the life cycle process covers the production stage, use stage and scrap stage of the whole life cycle (Figure 2).

1. Fuel cycle: The analysis is based on the full grid mix, which includes coal-fired power generation and other power generation forms. The system boundary includes the production and transportation of electricity. For example, the coal-fired power generation include the processes from coal mining and transportation to power plants, power generation processes and power transmission processes to charging piles and the consumption process of vehicles. Because our country electric grid mix composition including other power generation methods except coal, water power, wind power, solar power, nuclear power, etc. They generate electricity with different carbon emissions and environmental impacts; therefore, this article will fully consider these power generation methods, according to the proportion of 2017 years of Chinese electric grid mix composition energy (source: China statistical yearbook, 2018). In contrast, the fuel cycle of a fuel truck includes the extraction, transportation to a chemical plant, refining, transportation to a gas station and consumption of fuel truck.

2. Vehicle cycle: vehicle cycle includes the mining of raw materials, production and assembly of parts, use and scrap of electric vehicles. As there are many similar processes in the process of production, maintenance in the process of use, parts replacement and final scrapping, the vehicle maintenance parts with small energy consumption and emission are ignored in this paper for the whole life cycle.

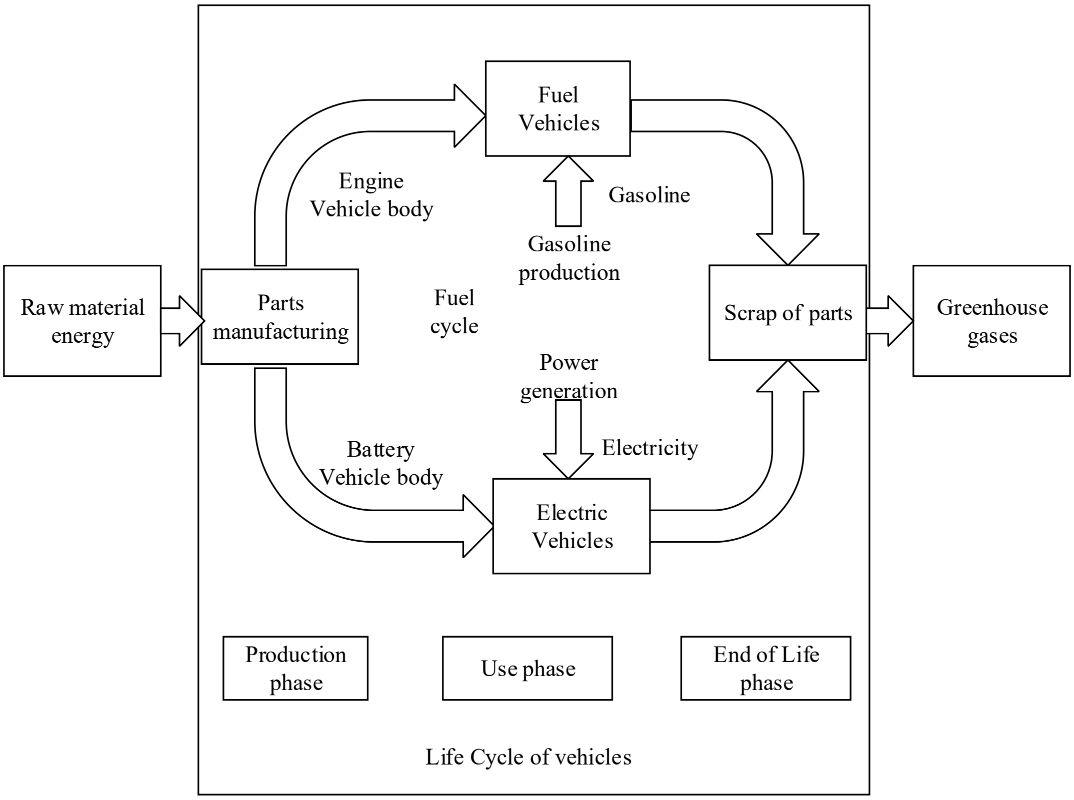


Figure 2. System boundary of Life Cycle Assessment for electric vehicles and fuel vehicles.

2.4. Greenhouse Gas Emission Calculation Model

When selecting the calculation model of greenhouse gas emissions, taking into account the characteristics of China, this paper selects the Tinghua-CA3EM model proposed by Ou Xunmin [9] and others for calculation.

The model first calculates the emissions of CO_2, CH_4 and N_2O in each process, and finally converts them into CO_2 equivalent according to the Global Warming Potential (GWP). According to the results of the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the GWP of CH_4 and N_2O are 34 and 298, respectively [27].

The total equivalent of greenhouse gas emission of the *j*th type of energies is denoted as G_j (j = 1, . . . , 7), CO_2, CH_4 and N_2O emissions of the *j*th type of energies are denoted as $CO_{2,j}$, $CH_{4,j}$, N_2O_j, then:

$$G_j = CO_{2,j} + 34 \times CH_{4,j} + 298 \times N_2O_j. \quad (1)$$

The lifecycle emissions of each particular type of greenhouse gas can be calculated by adding the direct emission intensity of upstream emissions and the process fuels (electricity, diesel, gasoline, etc.) used throughout the process. Take CO_2 emissions generated by coal power generation in power plants as an example:

$$CO_{2,\mathrm{coal}} = EN_{\mathrm{coal}}\left(CO_{2,\mathrm{upstream\ coal}} + CO_{2,\mathrm{direct}}\right), \quad (2)$$

$$CO_{2,\mathrm{direct}} = \frac{44}{12} CC_{\mathrm{coal}} FOR_{\mathrm{coal}} CO_{2,\mathrm{coal}}. \quad (3)$$

$CO_{2,upstream\ coal}$ is the upstream CO_2 coal emission factor (g/MJ), $CO_{2,direct}$ is the direct CO_2 emission factor (g/MJ) of coal as fuel, CC_{coal} is the carbon content (g/MJ) of coal, FOR_{coal} is the carbon oxygen content rate of coal.

Among them,

$$EN_{coal} = \frac{SH_{coal}}{\eta_{power\ plant}}, \tag{4}$$

where EN_{coal} is the amount of coal used in the factory for each MJ of final power generation, SH_{coal} is the proportion of coal in the total power generation; $\eta_{power\ plant}$ is the energy efficiency of coal-fired power plants. Similarly, CH_4 and N_2O emissions are calculated accordingly.

Taking into account the production time and location of PV modules and wind turbines, Dr. Wilfried van Sark [28] calculated and found that the carbon emissions per kWh of photovoltaic and wind power generation is only 1/10 to 1/20 of fossil energy in 2015. There is an overwhelming advantage for renewable power generation in reducing carbon emissions. Overall, whenever the installed capacity of clean energy doubles, the energy consumption of PV modules and wind turbines will drop by about 12%, and carbon emissions will fall by 17–24% [28]. As the proportion of clean energy increases and production technology advances, carbon emissions from renewable energy generation will be greatly reduced. Therefore, in the calculation of carbon emissions, carbon emissions from renewable power generation could be negligible.

3. Data Collection

The calculation process of carbon emission in the whole life cycle of automobiles involves the collection of a large number of basic data. With reference to the existing literature, the data collected in this paper and their approaches are shown in Table 2.

Table 2. Data sources.

Data Name	Source
Green House Gas (GHG) emission factor	IPCC [29], Guidelines for Compiling Provincial GHG Inventory [30]
Total energy consumption coefficient	China statistical yearbook 2018 [31]
Automobile production process data	Comparative analysis of dynamic system life cycle environmental impact of electric and fuel vehicles [32]
Fuel upstream raw material mining, fuel processing, transportation	Statistical data, professional internal reports, literature and expert consultation of national bureau of statistics, transportation, coal, petroleum and petrochemical, electric power and other departments [33–38]
Data related to the driving process of the car	Pacific automotive network [39]

According to the "Introduction to the Operation of Renewable Energy Grid-Connected in 2018" [40], the "2018 National Electric Power Process Statistics Express List" [41], and the "National People's Republic of China 2018 National Economic and Social Development Gazette" [42] and Grid mix composition estimates based on national energy and power development strategy goals, the grid mix composition of China in 2020, 2030 and 2050 is shown in Figure 3 (The grid mix composition data of China is shown in Table A2).

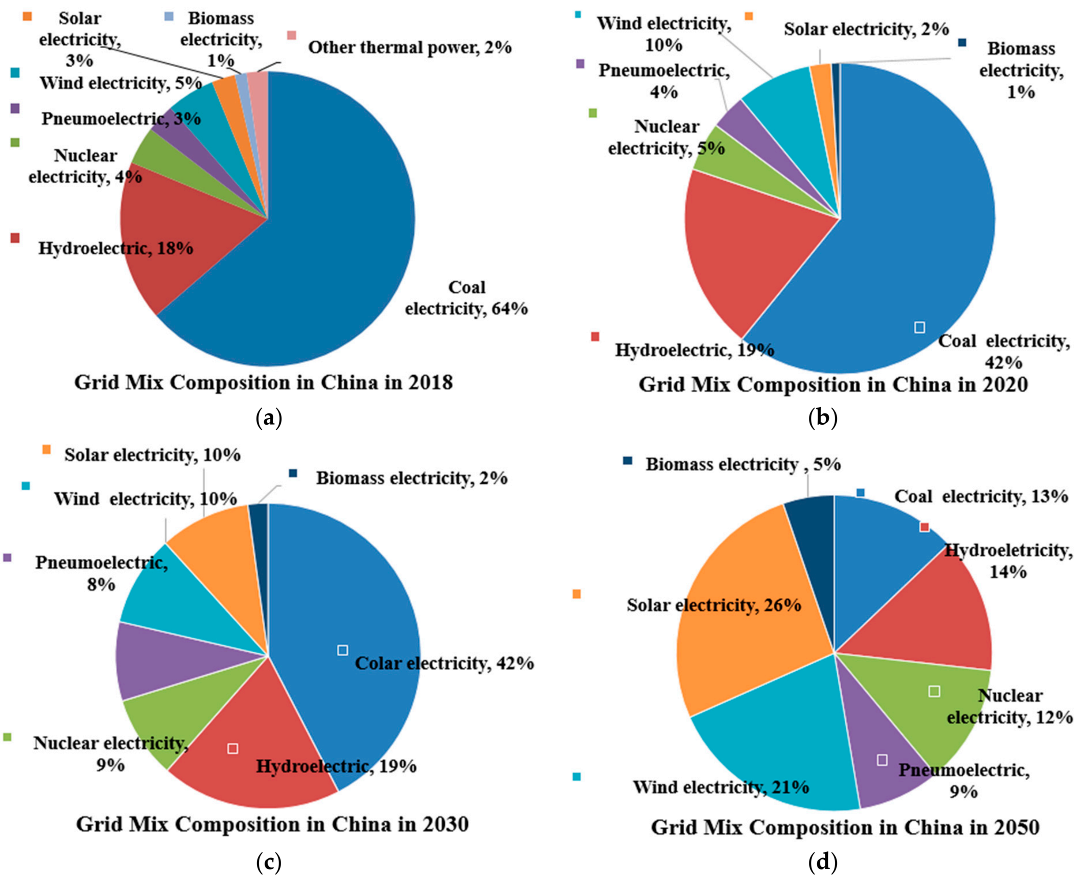


Figure 3. (**a**) China's grid mix composition and ratio in 2018; (**b**) China's grid mix composition and ratio forecast for 2020; (**c**) China's grid mix composition and ratio forecast for 2030; (**d**) China's grid mix composition and ratio forecast for 2050.

4. Research Results

4.1. Carbon Emission Comparison between Electric Vehicles and Fuel Vehicles under the Current Electric Energy Structure

Based on China's grid mix composition and ratio forecast for 2018, 2020, 2030 and 2050 and the model we built, the carbon emission of electric vehicles and fuel vehicles under the current Grid mix composition in China is shown in Figure 4. The unit "CO_2-eq" of carbon emissions in the figure means carbon dioxide equivalent. Figure 4 compares the greenhouse gas emissions of different vehicles over their whole life cycle. The solid line on the left of Figure 4 represents the carbon emission of electric vehicles, while the dotted line represents the carbon emission of fuel vehicles. The histogram shows the carbon emission of electric vehicles at all stages of their life cycle, which shows the impact in the production stage, use stage and treatment stage in a cumulative manner.

As can be seen from Figure 4, the carbon emission of the two kinds of cars is quite different in different life cycle stages. No matter how electric vehicles are configured, their carbon emission performance at the present stage is not as good as that of conventional fuel vehicles. In the production stage, electric cars are not as environmentally friendly as traditional fuel cars, because the production of battery system in the production stage produces more carbon emissions than the engine [43]. In the use phase, electric vehicles do not offset the carbon emissions in the production phase by reducing the carbon emissions in the use phase.

At the scrapping stage, the carbon emissions of electric cars are similar to those of electric cars. Throughout its life cycle, electric cars have higher carbon emissions than conventional fuel cars.

In addition, the bigger the electric car, the more carbon it produces. Whether it is a traditional fuel car or an electric car, whether it is directly through fuel combustion or indirectly through electricity production, the carbon emission in the use stage is the main carbon emission in the whole life cycle. For the model adopted in this paper, the carbon emission of electric vehicles of any level is higher than that of conventional fuel vehicles. Among them, the carbon emission of A-class electric vehicles, C-class electric vehicles, D-class electric vehicles and F-class electric vehicles is 1.24 times, 1.26 times, 1.28 times and 1.31 times that of the fuel vehicles of the same grade. For the same model, the carbon emission of F-class electric vehicles is 1.25 times that of A-class electric vehicles, C-class electric vehicles and D-class electric vehicles are 1.16 times and 1.08 times, respectively. The carbon emission of A-class electric vehicles in the production, use and scrapping stages accounts for 8.5%, 90.8% and 0.5% of the whole life cycle, respectively. The carbon emission in the production, use and scrapping stages of C-class electric vehicles accounts for 9.5%, 89.9% and 0.6% of the whole life cycle, respectively.

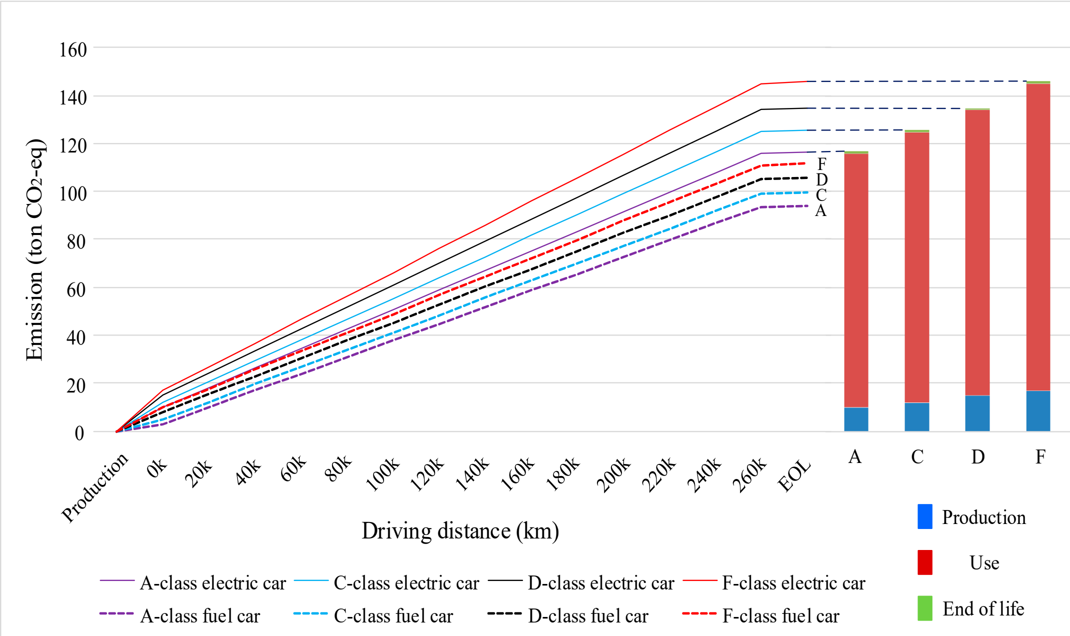
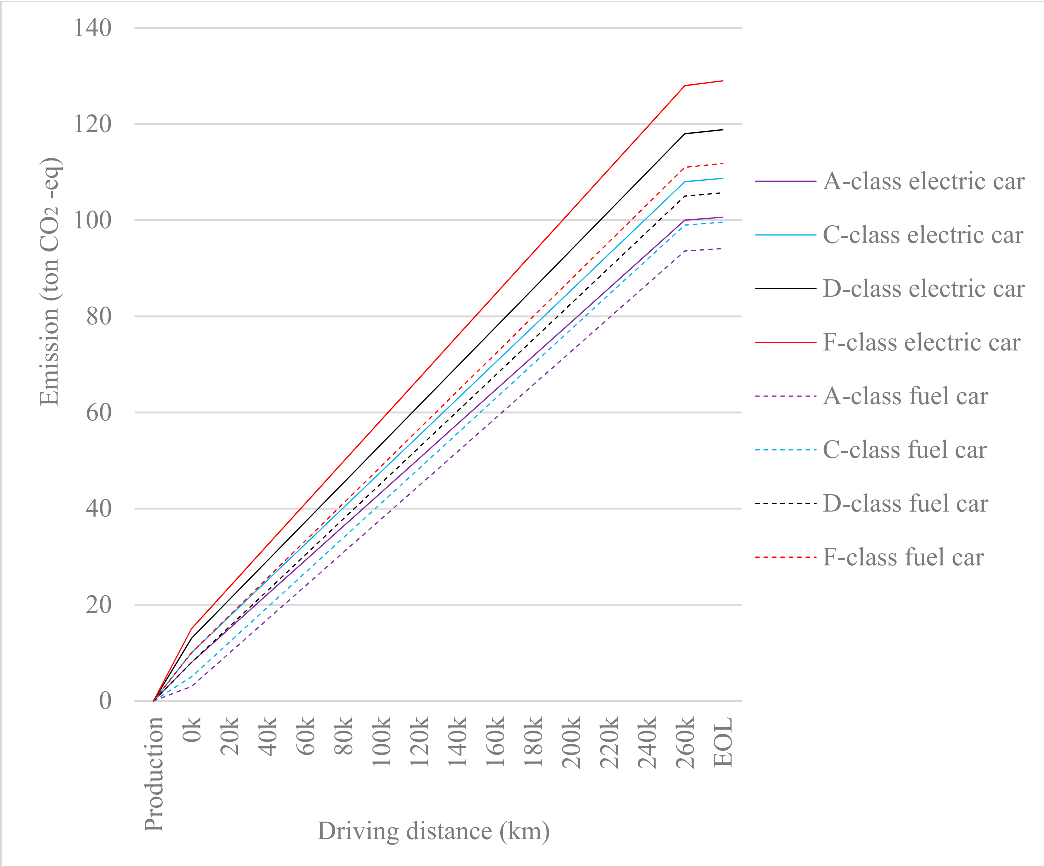


Figure 4. Comparison of life cycle carbon emissions between electric vehicles and fuel vehicles under the current grid mix composition.

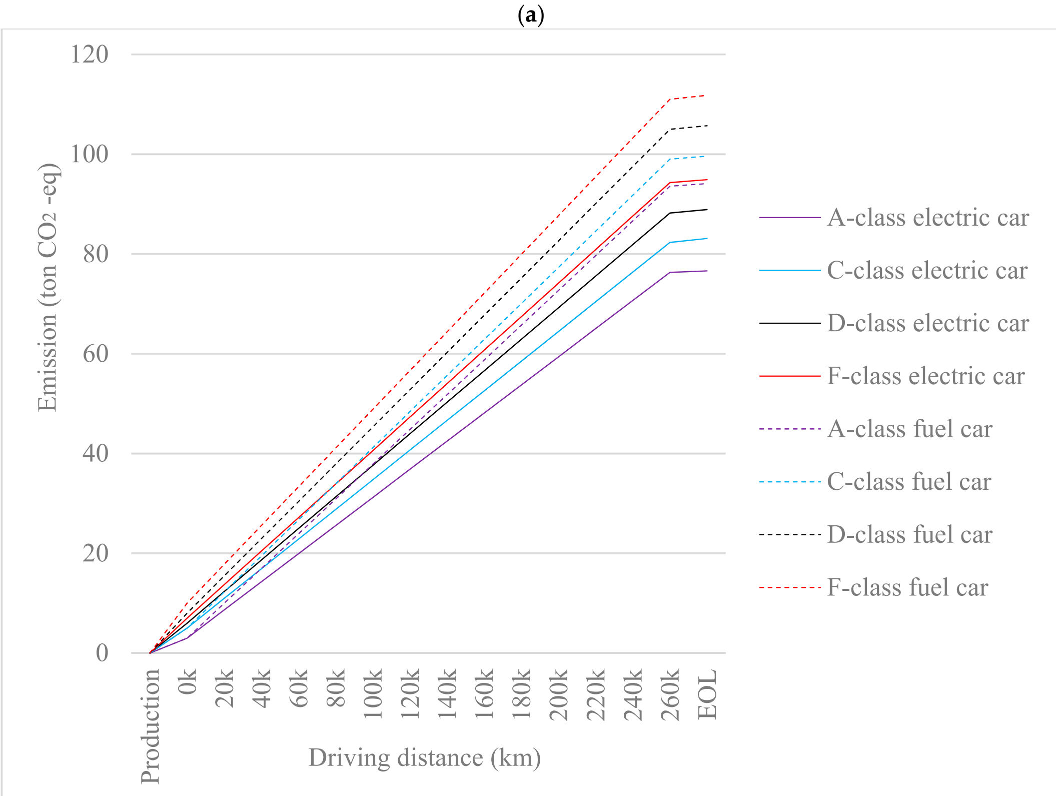
4.2. Carbon Emission Comparison between Electric Vehicles and Fuel Vehicles under Different Grid Mix Compositions

Based on China's 2020, 2030 and 2050 electricity generation and its structure forecast, this paper makes a comparative analysis of the carbon emissions of electric vehicles and fuel vehicles.

With the development of clean energy, more and more coal power will be replaced by clean energy in the future. With the reduction of the proportion of coal power in the grid mix composition and the increase of the proportion of clean energy, the carbon emission intensity generated by electricity generation will be reduced, and the carbon emission caused by electricity generation will be reduced in the electric energy consumed by electric vehicles in the use stage [44–50]. Carbon emissions of electric vehicles and gasoline vehicles in the full life cycle under the predicted grid mix composition in 2020, 2030 and 2050. Results show that in 2020, under the grid mix composition of the electric car the whole life cycle of carbon emissions is still higher than fuel vehicles; in 2030, under the grid mix composition of the lifecycle carbon emissions of electric cars will be lower than for fuel vehicles; in 2050, under the grid mix composition of the lifecycle carbon emissions of electric cars will be much lower than fuel vehicle emissions. In these three cases, the full life cycle carbon emission of electric vehicles and gasoline vehicles of four levels is shown in Figure 5a–c.

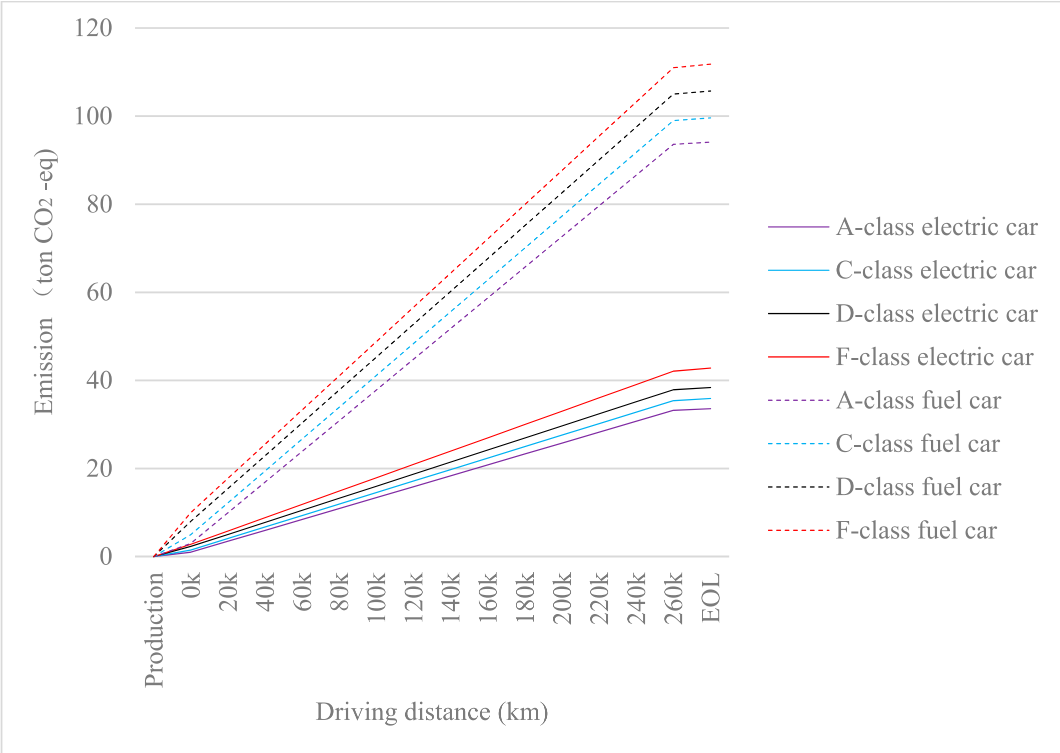


(**a**)



(**b**)

Figure 5. *Cont.*



(**c**)

Figure 5. (**a**) Comparison of carbon emissions of two types of vehicles under the grid mix composition in 2020; (**b**) Comparison of carbon emissions of two types of vehicles under the grid mix composition in 2030; (**c**) Comparison of carbon emissions of two types of vehicles under the grid mix composition in 2050.

From Figure 5a–c, it can be concluded that under the power structure of 2020, 2030 and 2050, the carbon emission ratios of Electric Vehicles and fuel vehicles at various phases of the life cycle are shown in Table 3.

Table 3. Values of share for production phase, use phase and end of life phase of different vehicles.

Year	2020			2030			2050		
Phase / Vehicle Type	PP (%)	UP (%)	EOLP (%)	PP (%)	UP (%)	EOLP (%)	PP (%)	UP (%)	EOLP (%)
A segment EV	7.95	92.05	0.62	3.92	96.08	0.39	2.98	97.02	1.19
C segment EV	9.20	90.80	0.66	6.02	93.98	0.96	4.18	95.82	1.39
D segment EV	10.94	89.06	0.69	6.75	93.25	0.79	5.99	94.01	1.30
F segment EV	11.63	88.37	0.78	7.38	92.62	0.63	6.54	93.46	1.64
A segment ICEV	3.19	96.81	0.54	3.19	96.81	0.54	3.19	96.81	0.54
C segment ICEV	5.02	94.98	0.60	5.02	94.98	0.60	5.02	94.98	0.60
D segment ICEV	7.57	92.43	0.66	7.57	92.43	0.66	7.57	92.43	0.66
F segment ICEV	8.94	91.06	0.72	8.94	91.06	0.72	8.94	91.06	0.72

Note: PP means Production Phase, UP means Use Phase, EOLP means End of Life Phase.

According to the results, the carbon emissions of Electric Vehicles and fuel vehicles are mainly concentrated in the use phase. The use phase accounts for more than 90% of the life cycle carbon emissions for all types of vehicles.

5. Conclusions

This paper collected the highest sales on the Chinese market by electric vehicle weight and hundreds of km of energy consumption data, and then modeling the relationship between the two variables, four levels of the electric car model, and based on vehicle weight to find the corresponding level of gasoline vehicles, and then the full Life Cycle Assessment model based on the analysis of the four different levels of the electric vehicle and fuel vehicle emissions, and based on the simulation analysis of the full life cycle carbon emission of electric vehicles and fuel vehicles in the electric grid mix composition in 2020, 2030 and 2050. The following conclusions are drawn:

1. Through the data collection and analysis of 34 electric models in China, it is found that there is a linear relationship between the whole weight of electric vehicles and the energy consumption of 100 km. The larger the vehicle weight, the greater the energy consumption for 100 km, and the greater the corresponding battery capacity and range. In the same life cycle, electric vehicles with large vehicle weight will consume more electricity and generate more carbon emissions than electric vehicles with small vehicle weight. The comparison of the carbon emission of electric vehicles and fuel vehicles shows that the full life cycle carbon emission of electric vehicles of any level is higher than that of fuel vehicles of the same level under the current energy structure. In addition, the lifetime carbon emissions of electric vehicles increase with the increase of vehicle weight.
2. It can be seen from the calculations that the energy consumption and pollutant emissions of the whole life cycle of the automobile mainly come from the use stage. Due to China's current grid mix composition still being dominated by coal, the electricity consumed during the electric vehicle use phase contains a large amount of carbon emissions, so the electric car relative to the fuel vehicle emission reduction effect is not obvious, and may even result in lifecycle carbon emissions that are more than those of fuel vehicles, which is consistent with the conclusions of Feng Chao [14] and Global Electric Vehicle Prospect 2018 [3]. There is some difference between the research results and those of Ou Xunmin et al. [9], who believe that the carbon emission of electric vehicles is less than that of fuel vehicles in their whole life cycle. The main reason is that the PLCA method selected by Ou Xunmin et al. may have truncation errors when selecting system boundaries.
3. Under the current grid mix composition, the carbon emissions of electric vehicles of the same level are higher than those of fuel vehicles over the whole life cycle. As clean energy increasingly replaces coal power, the relative carbon intensity of electric vehicles will be reduced. In the predicted electricity structure of 2020, the carbon emission of electric vehicles of the same level is higher than that of fuel cars, while in the electricity structure of 2030 and 2050, the carbon emission of electric vehicles of the same level is lower than that of fuel cars. This is mainly due to the lower production carbon emissions of the electricity consumed during the use of electric vehicles.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The parameters of the 34 electric vehicles.

Vehicle \ Parameter	Energy Consumption (kWh/100km)	Vehicle Weight (kg)	Drive Type	Vehicle Model
Beiqi EC	13	1050	Pure electric	Mini car
Beiqi EX3	12.17	1600	Pure electric	SUV
Beiqi EX5	11.88	1770	Pure electric	SUV
Beiqi EV	15	1295	Pure electric	Small car
Beiqi EU	14.8	1680	Pure electric	Compact car
BYD Yuan	13.6	1495	Pure electric	SUV
BYD Tang	17.3	2200	Pure electric	SUV
BYD e5	14.57	1900	Pure electric	Compact car
BYD e6	20.5	2380	Pure electric	MPV
Jianghuai IEV 6E	11.26	1230	Pure electric	Mini car
Jianghuai IEV 7	11.65	1340	Pure electric	Small car
Jianghuai IEV S4	14.04	1710	Pure electric	SUV
Jianghuai IEV A50	14.6	1800	Pure electric	Compact car
Jiangling E100	10.1	830	Pure electric	Mini car
Jiangling E200	11.58	975	Pure electric	Mini car
Jiangling E160	7.93	1050	Pure electric	Small car
Jiangling E400	13.8	1510	Pure electric	SUV
Jiangling Yizhi	10.56	1115	Pure electric	Small car
Chery Ayers5e	14.6	1580	Pure electric	Compact car
Chery eQ	11.8	1128	Pure electric	Mini car
Chery eQ1	12	995	Pure electric	Mini car
Chery Tiggo3xe	15	1515	Pure electric	SUV
Roewe Ei5	13.2	1555	Pure electric	Compact car
Roewe RX5	15.49	1710	Pure electric	SUV
Roewe MARVEL X	14.2	1870	Pure electric	SUV
Huatai EV160B	13.5	1040	Pure electric	Mini car
Huatai EV160R	12.3	910	Pure electric	Mini car
Huatai XEV260	18.7	1764	Pure electric	SUV
Huatai IEV230	16.1	1735	Pure electric	Compact car
Geely New Energy	14.24	1575	Pure electric	Compact car
Changcheng C30	13.32	1390	Pure electric	Compact car
Guangqi New energy	12.9	1575	Pure electric	Compact car
Yundu π3	12.71	1470	Pure electric	SUV
Yundu π1	11.97	1410	Pure electric	SUV

Data Source: Pacific Auto Network.

Table A2. China's power structure data in 2018, 2020, 2030, and 2050.

Power Generation Type \ Year	2018	2020	2030	2050
Coal power (trillion kWh)	4.45	4.506	3.789	1.59
Hydropower (trillion kWh)	1.23	1.428	1.71	1.71
Nuclear power (trillion kWh)	0.29	0.377	0.78	1.5
Gas power generation (trillion kWh)	0.22	0.275	0.749	1.04
Wind power (trillion kWh)	0.37	0.581	0.86	2.589
Solar power (trillion kWh)	0.18	0.166	0.86	3.256
Biomass power (trillion kWh)	0.0906	0.068	0.191	0.647
Other thermal power (trillion kWh)	0.16	-	-	-
Total (trillion kWh)	6.994	7.401	8.939	12.332

Data Source: National Energy Administration "Introduction to the Operation of Renewable Energy Grid-Connected in 2018", "2018 National Electric Power Process Statistics Express List" issued by China Electricity Council, "National Economic and Social Development of the People's Republic of China 2018" issued by the National Bureau of Statistics Development Bulletin and Power Structure Estimation Based on National Energy and Power Development Strategic Objectives.

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