Research on Carbon Emissions of Electric Vehicles by Constructing Mathematical Model Based on Big Data

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Abstract—After the “3060” carbon peak and neutrality strategic goal was put forward, various industries actively responded to find new ways for energy conservation and emission reduction. In the field of automobile manufacturing, the transition from traditional fuel vehicles to electric vehicles is an inevitable trend. This paper builds a mathematical model that uses the three major indicators of carbon emissions per 100 kilometers, energy-saving emission reduction coefficients, and annual carbon emissions as parameters to measure carbon emissions benefits, and combines survey data to conduct empirical analysis to explore the advantages of electric vehicles in energy saving and emission reduction compared with traditional fuel vehicles under different power supply structures. At the same time, based on the existing data and conclusions, the research is extended to the analysis of carbon emissions prospects in decades, and the possible contribution of future electric vehicles in energy utilization and environmental protection is predicted, to explore its role in promoting the achievement of the double-carbon goal, and put forward corresponding recommendations based on the research results.

1. Introduction

Energy is an important material basis for the stable development of the national economy and the long-term stability of the people's livelihood. The world today is undergoing major changes unseen in a century. It is necessary to study and plan mid- and long-term strategic tasks and strategic layouts to ensure national security and ensure overall social and political stability. [1] On September 22, 2020, President Xi Jinping announced in his important speech at the general debate of the 75th United Nations General Assembly: "China will increase its nationally determined contributions and adopt more effective policies and measures. Emissions strive to reach a peak before 2030, and strive to achieve carbon neutrality by 2060."

Statistics show that the average annual growth rate of carbon emissions in China's transportation sector has remained above 5%, which has become the fastest-growing field of greenhouse gas emissions. The transportation sector's carbon emissions account for about 15% of the country's terminal carbon emissions. While the transportation sector is a “larger” of carbon emissions, it also has great potential for energy conservation and carbon reduction. [2] Therefore, electric vehicles are not only an integral part of the energy revolution and energy transition but also an important starting point for achieving carbon peak and carbon neutral goals.
The automobile and transportation sectors will assume the main role of large-scale consumption of new energy to replace oil consumption. The large-scale "replacement of oil with electricity" in the automotive and transportation sectors will reduce the proportion of oil consumption and reduce environmental pollution and carbon emissions. Similarly, automobile traffic powered by new energy sources plays an important "regulator" and "stabilizer" role for the safe and stable operation of the power system [3].

As the carrier of transportation, the pace of transformation of automobiles determines the speed of transportation carbon reduction to a certain extent. The automobile, transportation, and energy sectors form a very close and complete carbon chain, and they need to work together to promote the realization of the goal of “carbon peak and carbon neutrality”. Therefore, the transportation sector in the development of carbon reduction path strategy, must be integrated with the process of vehicle electrification. Statistics show that the number of new energy vehicles in my country has exceeded 5.5 million, and its production and sales have ranked first in the world for six consecutive years. my country’s new energy vehicles have been in the forefront of the world. More and more auto companies have transformed and developed electric vehicles. Many new forces have also emerged, forming a complete set of power batteries, charging infrastructure, mobile power exchange, and travel platforms. Green ecology, which is a reconstruction of the urban transportation system, is of great significance to economic, social and environmental benefits.[5]

2. Research Approach
The combustion of fuel in the machinery of traditional fuel vehicles during the driving process will produce a large amount of carbon dioxide emissions, which will cause serious pollution to the environment and air quality. Electric vehicles rely on an on-board power supply, so they will not bring a lot of carbon emissions during driving, but may emit carbon dioxide during the process of producing electric energy, and different ways of producing electric energy will bring about differences in carbon emissions. This article aims to compare and explore traditional fuel vehicles by formulating three major indicators for evaluating the carbon emission benefits of electric vehicles, establishing the calculation and analysis of the three major mathematical models of carbon emission levels per 100 kilometers, annual carbon emissions, and emission reduction coefficients, and empirical analysis of survey collected data. Pure thermal power charging, hybrid (69.6%, 50%, 25% thermal power charging) charging, 100% new energy charging electric vehicle carbon emission benefits, quantitative analysis of the advantages of electric vehicles in terms of energy saving and emission reduction; and based on the existing Policies and data make predictions on the future development of electric vehicles, extend the research to the analysis of their carbon emissions prospects, and explore their role in boosting the 2030 carbon peak and 2060 carbon neutral goals.
3. Analysis Process

3.1. Data preprocessing
This article selects the full-day 96-point load data of various charging piles in Hangzhou from January 1 to June 6, 2020. It is difficult to directly count the electricity consumption data of electric vehicles for end users, and electric vehicles mainly rely on charging piles. Charging, so this article approximates the electricity consumption of electric vehicles by calculating the load data of the charging pile. After data preprocessing, the effective data of 94 days in the first half of the year in Hangzhou was obtained.

The charging pile load data table in Hangzhou collected by the survey uses a 15-minute period to record the load of the charging pile in kilowatts. Calculating the preprocessed valid data according to the following formula, the total load of 94 days in the first half of 2020 can be obtained. The formula is as follows:

$$ P = \sum_{00:00 \leq i \leq 23:45} a(i,j) $$

Where, $P$ is a total load of all charging piles in Hangzhou for 94 days in 2020; $i$ is the row of the data table, representing a total of 94 days of valid data; $j$ is the column of the data table, representing the data obtained from monitoring every 15 minutes from 0:00 to 23:45 a day; $a(i,j)$ is the element representing the specified position in the table.

$$ W = \int \frac{P}{94 \times 4} \, dt $$

Fig.1 Flow chart for the research process
Where, \( W \) is the total electric energy consumption of electric vehicles throughout the year, and the load is integrated over time to get \( W=6963942.127 \text{kWh} \).

3.2. Calculation of carbon emission level per 100 kilometers

(1) Fuel vehicles

The carbon emissions of fuel vehicles mainly come from the carbon dioxide produced when gasoline is burned. This article selects "fuel consumption per 100 kilometers" as a parameter to measure the unit fuel consumption of a car. Factors such as driving habits are related. Taking the above factors into consideration, based on literature review and research, this paper proposes that 10L is the average fuel consumption per 100 kilometers of a fuel vehicle in g.

Gasoline is divided into different models due to the different proportions of a certain component, and its density is also slightly different. The data shows that the density of No. 93 gasoline is 0.725g/ml, and the density of No. 97 gasoline is 0.737g/ml. At present, electric vehicles are mainly for household use, while petrol-fueled private cars mainly use No. 93 and No. 97 gasoline. In this project, the two types of gasoline each account for 50%, and the average density \( \rho \) of gasoline is calculated to be 0.731g/ml.

The carbon emission factor refers to the mass of carbon dioxide produced when a unit of energy is burned or used. Different energy sources have different carbon emission coefficients. According to the official data of the China Energy Contract Management website, the gasoline carbon emission coefficient \( e_{oil} \) is 2.9251kgCO2/kg.

The formula for calculating carbon emissions per hundred kilometers is:

\[
E = g \rho e_{oil} \tag{3}
\]

Where, \( E \) is the carbon emission level of fuel vehicles per 100 kilometers; \( g \) is fuel consumption per hundred kilometers; \( \rho \) is the density of gasoline; \( e_{oil} \) is the gasoline carbon emission factor. Calculate \( E=23.382481 \text{kgCO}_2 \).

(2) Electric vehicle

This project investigates the performance parameters of different types of electric vehicles on the market:

| Automotive businesses | motorcycle type | Top speed per hour/(km/h) | driving range/km | Power consumption of one hundred kilometers/kWh | Vehicle quality/kg |
|-----------------------|-----------------|---------------------------|------------------|-----------------------------------------------|-------------------|
| Chery                 | Q6 electric car | 80                        | 150              | 10                                            | 590               |
| Volkswagen            | Lavida electric car | 130                      | 150              | 14                                            | 1498              |
| Roewe                 | Roewe 350 electric car | 150                      | 200              | 13                                            | 1500              |
| Guangsheng            | Electric passenger car | 60                        | 160              | 15                                            | 780               |
| Tongyue               | Electric passenger car | 95                        | 150              | 15                                            | 1200              |
| Zotye                 | 2008EV car       | 110                       | 200              | 12                                            | 1200              |

Calculate the average power consumption per 100 kilometers of electric vehicles \( h=13.17 \text{kWh} \).

The carbon emissions in the power generation process mainly come from thermal power generation. According to China's current power structure, approximately 69.6% of the electricity source is thermal power generation. (As shown in the figure), between 100% thermal power and 100% clean energy power generation, the ratio of thermal power to 69.6% is selected as a category for calculation.
One of the most important methods of thermal power generation is coal-fired power generation. For every kilowatt-hour of electricity generated, approximately 0.4kg of coal is consumed. This consumption is called the coal consumption rate $f$.

$$e_f = e_c f$$

$e_f$ is the carbon emission coefficient of thermal power, which reflects the relationship between the electricity generated by thermal power and carbon emissions. $e_c$ is the coal emission coefficient, which can be obtained by looking up the table. The coal carbon emission coefficient is 1.9003kgCO$_2$/kg.

Therefore, calculate the thermal power carbon emission coefficient $e_f=0.76012$kgCO$_2$/kWh.

According to the different proportions of power supply structure, the carbon emission level of 100 kilometers of new energy vehicles can be calculated:

$$F = \beta h e_f$$

Power consumption per hundred kilometers $h=13.17$kWh;

Thermal power carbon emission coefficient $e_f=0.76$kgCO$_2$/kWh

Where, $\beta$ is the ratio of thermal power to the total power generation;

When $\beta=1$, the electricity provided to electric vehicles is all derived from thermal power generation, and the carbon emission level per hundred kilometers is $F=10.0107804$kgCO$_2$; when $\beta=0$, it means all electricity is new energy, and the carbon emission level per hundred kilometers is $F=0$kgCO$_2$;

When $\beta=69.6\%$, $F=6.967503158$kgCO$_2$.
When $\beta=50\%$, $F=5.0053902$kgCO$_2$.
When $\beta=25\%$, $F=2.5026951$kgCO$_2$.

The chart is as follows:

Fig. 2 Power generation ratio

Fig. 3.Carbon emission levels of electric vehicles for 100 km under different power structure proportions(kg)
3.3. Emission reduction factor

The emission reduction factor is the reduction rate of carbon emissions brought about by electric vehicles compared to traditional fuel vehicles. The formula is:

$$\mu = \frac{E - F}{E} \times 100\%$$  \(6\)

The calculation results of emission reduction coefficients for different power structures are as follows:

| Power Structure          | Carbon emission level for 100 kilometers (kg CO₂) | Emission reduction factor μ |
|-------------------------|-------------------------------------------------|-----------------------------|
| Fuel-oil vehicle        | 21.38                                           | 0                           |
| 100% thermal power      | 10.01                                           | 53.18%                      |
| 69.6% thermal power     | 6.97                                            | 67.41%                      |
| 50% thermal power       | 5.01                                            | 76.59%                      |
| 25% thermal power       | 2.50                                            | 88.30%                      |
| 100% new energy electricity | 0.00                                      | 100.00%                     |

3.4. Calculation of annual carbon emissions

The carbon emission level in 2.2 is calculated based on 100 kilometers. Therefore, to calculate the different types of annual carbon emissions, it is necessary to calculate the number of 100 kilometers traveled by electric vehicles in Hangzhou in 2020. According to the electricity consumption per 100 kilometers and the electricity consumption of electric vehicles in Hangzhou in 2020, the number of electric vehicles in Hangzhou in 2020 can be calculated.

$$n = \frac{W}{h}$$  \(7\)

Calculated \(n=535687.8599\)

From this, the calculation formula for annual carbon emissions is:

$$Y = ng\dot{k}$$  \(8\)

$$Y = nh\dot{F}$$  \(9\)

Formula (8) is used for calculation of fuel vehicles, and Formula (9) is used for calculation of electric vehicles. Because the members of this project team want to analyze and explore the advantages of electric vehicles in reducing carbon emissions compared with traditional fuel vehicles, and the gap in total carbon emissions between 100% thermal power, hybrid power structure, and 100% new energy power. Therefore, after calculating the annual carbon emissions of Hangzhou in 2020 under the normal power structure ratio (69.6% thermal power), we converted 69.6% of the total annual mileage of thermal electric vehicles into fuel vehicles, 100% thermal power, 69.6% thermal power, 50% thermal power, 25% thermal power, 100% new energy vehicle mileage. In this case, six sets of data are calculated. The calculation results are shown in the table:
3.5. Prospect analysis

Assuming that the number of existing electric vehicles is A, the average annual growth rate of electric vehicles in the country is α, and the average annual driving distance of each electric vehicle is B.

Then carbon emissions in 2020 (Q1) = ABF (F is the level of carbon emissions per 100 kilometers), carbon emissions in 2021 (Q2) = A (1 + α) BF

Annual carbon emission growth rate = \( \frac{1 + \alpha - 1}{\alpha} = \alpha \)

Therefore, the annual carbon emission rate of electric vehicles is α. The following models are all based on the 2020 Hangzhou data as an example.

Annual carbon emissions Y

\[
\begin{align*}
Y(\tau) &= (1 + \alpha)^\tau Y_0 \\
\tau &\text{ represents the number of years that have elapsed after 2020, and represents the carbon emissions of electric vehicles with different power supply structures in 2020.}
\end{align*}
\]

The difference in carbon emissions between coal-fired vehicles and electric vehicles

\[
\begin{align*}
\Delta Y(\tau) &= (1 + \alpha)^\tau (Y_0^d - Y_0) \\
\Delta Y &\text{ represents the carbon emissions of fuel vehicles in 2020.}
\end{align*}
\]

Under the condition of \( \alpha=10\% \), the members of this group predicted the carbon emissions of fuel vehicles and electric vehicles (the ratio of thermal power plants were 100%/69.6%/50%/25%) in the next 60 years. The results are as follows:

Fig. 5. The carbon emissions of fuel vehicles and electric vehicles
4. Conclusion
Compared with traditional fuel vehicles, electric vehicles have advantages in energy saving and emission reduction.

Even when the power structure is composed of 100% thermal power, the carbon emissions of electric vehicles are less than that of fuel vehicles, and the emission reduction coefficients are greater than zero.

With the optimization of the power supply structure, electric vehicles can reduce carbon emissions more effectively. With the continuous optimization of the power supply structure, the carbon emission level of electric vehicles per 100 kilometers has been continuously reduced, and their energy-saving and emission-reduction benefits have gradually increased. This also provides ideas and directions for technological improvement for achieving carbon neutrality in 2060: the country should increase major investment and development of clean energy such as pumped storage power stations, photovoltaic power generation, and wind power generation. At the same time, attention is paid to the research and utilization of emerging renewable energy such as hydrogen energy, tidal energy, and geothermal energy, so as to increase the proportion of renewable energy in all energy sources and optimize the country’s power supply structure continuously.[6]

The large-scale promotion of electric vehicles can contribute to the realization of the country’s "3060" strategic goal. As the sales of electric vehicles increase, the carbon emissions of electric vehicles will be significantly reduced by 2030 and 2060 when the power structure is 100% thermal power. Therefore, in order to realize China’s carbon neutral goal by 2060, the promotion of electric vehicles will play a vital role in the field of green transportation. [7]

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