Analysis of carbon emission reduction contribution during usage phase of new energy vehicles based on big data: a case study of Tianjin

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Abstract: Countries around the world are paying increasing attention to greenhouse gas emissions reduction. Under the guidance of "dual carbon" strategy in China, the development of the new energy vehicle industry as an important means of carbon emission reduction in the transportation sector has become a trend. At the same time, the Tianjin New Energy Vehicle Monitoring Platform has recorded real-time big data on the operation of new energy vehicles since 2017, covering vehicle ownership and mileage data, which can support the calculation of carbon emission reduction contributions during usage stage of new energy vehicles. Based on the big data of the platform, this article calculates the carbon emission reduction contribution of new energy vehicles in Tianjin during usage stage, and analyzes the carbon emission reduction contributions under different technology types, vehicle types, vehicle classes, and usage scenarios. Moreover, an analysis was conducted on the top ten enterprises in Tianjin that contribute to carbon emission reduction. The reasons for the carbon emission reduction contributions of different enterprises are slightly different, mainly due to high ownership or actual driving mileage.

1. Introduction

With the increasing attention paid by countries around the world to environmental protection, the Chinese government has also proposed a "dual carbon" strategy based on China's national conditions. Currently, the "dual carbon" goal has become a consensus in the development of various industries. As the country with the world's largest total carbon emissions, China's transportation sector accounts for about 11% of the country's carbon emissions[1,2], while road transportation accounts for about 86% of the total carbon emissions. Therefore, carbon reduction in the automotive industry has become an important component of China's transportation sector to achieve the dual carbon goals[3]. Accelerating the process of low-carbon and decarbonization throughout the entire industry chain and achieving full lifecycle carbon reduction is imperative. New energy vehicles(NEV) are driven by electricity and emit almost no exhaust gases or greenhouse gases, resulting in significant energy-saving and emission reduction effects. Therefore, developing the new energy vehicle industry has become an important means of carbon reduction in China's transportation sector[4].

In order to implement the requirements of the Ministry of Industry and Information Technology's "Notice on Further Improving the Safety Supervision of the Promotion and Application of NEV" on monitoring and managing the safety status of key systems such as the vehicle and power battery, Tianjin Industry and Information Technology Institute has built the Tianjin NEV safety monitoring platform. This platform implements functions such as basic data collection for NEV, real-time monitoring of vehicle geographic location and operational status. This platform records actual driving data of NEV, which can be used to calculate the carbon emission reduction contribution of NEV during usage phase.

Based on the big data of NEV monitoring in Tianjin, we calculated the carbon emission reduction contribution of NEV during usage phase in Tianjin, and analyzed the impact of ownership structure and usage characteristics on carbon emission reduction contribution.
electricity, we have included the carbon emissions from the power grid in the carbon emission considerations for NEV during usage phase[12].

Therefore, the carbon emission reduction contribution of NEV during usage phase over a period of time can be expressed as

\[ \text{ER} = \text{BE} - \text{PE} \tag{1} \]

where \( \text{ER} \) is the carbon emission reduction contribution of NEV during usage phase, \( \text{BE} \) is the baseline emission representing the carbon emissions of ICEV, and \( \text{PE} \) is the project emission representing the carbon emissions of NEV.

2.1. Baseline emission

The baseline emission is related to the fuel consumption, vehicle miles traveled (VMT), and fuel type used by ICEV, which can be expressed as

\[ \text{BE} = \sum_i \sum_j FC_i \times VMT_{i,j} \times \text{EC}_{\text{gasoline}} \tag{2} \]

where \( i \) is serial number of ICEV model, \( j \) is serial number of vehicle, \( FC_i \) is the fuel consumption of the \( i^{th} \) ICEV model, \( VMT_{i,j} \) is vehicle miles traveled of the \( j^{th} \) ICEV in the \( i^{th} \) ICEV model, \( \text{EC}_{\text{gasoline}} \) is the carbon dioxide emission coefficient of gasoline.

2.2. Project emission

The project emission is related to the electricity consumption and vehicle miles traveled (VMT) of NEV, and the grid emission factor, which can be expressed as

\[ \text{PE} = \sum_i \sum_j EC_i \times VMT_{i,j} \times \text{EF}_{\text{grid}} \tag{3} \]

where \( i \) is serial number of NEV model, \( j \) is serial number of project vehicle, \( EC_i \) is the electricity consumption of the \( i^{th} \) NEV model, \( VMT_{i,j} \) is vehicle miles traveled of the \( j^{th} \) NEV in the \( i^{th} \) NEV model, \( \text{EF}_{\text{grid}} \) is the grid emission factor.

3. Analysis and results

Based on the NEV monitoring big data in Tianjin in 2022, we calculated the carbon emission reduction contribution of NEV during usage phase. According to the CATARC vehicle ownership database, as the end of 2022, the number of new energy passenger vehicles (NEPV) in Tianjin was 324000, including 234200 battery electric vehicles (BEV), accounting for 72.3%, and 89800 plug-in hybrid vehicles (PHEV), accounting for 27.7%. Due to the lack of access to Tianjin NEV safety monitoring platform for vehicles produced and sold before 2017, as well as some companies closing down and no longer uploading data, Tianjin had a total of 237900 active NEPV in 2022, covering 73.4% of NEPV. Among them, there are 166200 BEV, accounting for 69.9%, and 71700 PHEV, accounting for 30.1%.

To calculate the carbon emission reduction contribution of NEV during usage phase, it is necessary to first extract data from the Tianjin NEV safety monitoring platform, including the configuration parameters of the NEV models, such as electricity consumption, curb weight, vehicle type and level, as well as the actual driving mileage data of the vehicles. Based on the vehicle configuration parameters of different NEV models, baseline vehicles can be determined, which should have the same transportation service capacity as the NEV models. According to Equation (2) and Equation (3), the baseline emissions and project emissions of different vehicles can be calculated, and then the carbon emission reduction contribution can be calculated using Equation (1). The overall process of carbon emission reduction contribution calculation based on NEV monitoring big data is shown in Figure 1.

According to calculations, the carbon emission reduction contribution of NEPV during usage phase in Tianjin in 2022 is 171400 tons, with an average annual carbon emission reduction contribution of about 0.721 tons per vehicle.

3.1. Carbon emission reduction contribution of NEPV in different technological types

As shown in Figure 2, in 2022, BEV and PHEV accounted for 73% and 27% of the carbon emission reduction contribution of NEPV during usage phase in Tianjin, achieving 126000 tons and 45500 tons of carbon emission reduction, respectively. BEV have an advantage in carbon emission reduction due to high ownership and strong carbon emission reduction performance per vehicle.
3.2. Carbon emission reduction contribution of NEPV in different vehicle types

The carbon emission reduction contribution of NEPV of different vehicle types is shown in Figure 3. As shown in Figure 3, among the carbon emission reduction contribution of NEPV in Tianjin, 2022, cars made the largest contribution, at 116000 tons, accounting for 67.7%. The carbon emission reduction contribution of sport-utility vehicles (SUVs) is 43700 tons, accounting for 25.5%, ranking second. The multi-purpose vehicles (MPVs) and minibuses have lower carbon emission reduction contribution, with a 1400 tons and 400 tons respectively, accounting for 0.8% and 0.2%, respectively. In addition, 5.8% of carbon emission reduction cannot be determined as belonging to a specific vehicle type due to missing data fields. The high penetration rate of NEV in the car market is the main reason for the significant contribution of cars to carbon emission reduction during usage phase.

![Figure 3. The proportion of carbon emission reduction contribution of NEPV of different vehicle types](image)

3.3. Carbon emission reduction contribution of NEPV in different vehicle classes

The proportion of carbon emission reduction contribution of NEPV of different vehicle classes is shown in Figure 4. In 2022, A-class vehicles had the largest carbon emission reduction contribution of NEPV in Tianjin, reaching 70800 tons, accounting for 41.3%. B-class vehicles made the second largest contribution, with a carbon emission reduction of 49200 tons, accounting for 28.7%. A00-class vehicles, C-class vehicles, and A0-class vehicles have relatively similar carbon emission reduction contributions, accounting for 20000 tons, 11900 tons, and 9300 tons, respectively. The proportions of A00-class vehicles, C-class vehicles, and A0-class vehicles are 11.7%, 6.9%, and 5.5%, respectively.

![Figure 4. The proportion of carbon emission reduction contribution of NEPV of different vehicle classes](image)

3.4. Carbon emission reduction contribution of NEPV in different usage scenarios

Figure 5 shows the carbon emission reduction contribution of NEPV of different usage scenarios. In 2022, the carbon emission reduction contribution of non-business NEPV in Tianjin was 123900 tons, accounting for 72%. The carbon emission reduction contribution of renting and business NEPV is 47500 tons, accounting for 28%. In the total number of NEPV in Tianjin, private cars account for a huge proportion, about 80.2%, which is why non-business NEPV contribute significantly to carbon emission reduction.

![Figure 5. The proportion of carbon emission reduction contribution of NEPV of different usage scenarios](image)

3.5. Carbon emission reduction contribution of TOP10 companies

Figure 6 shows the carbon emission reduction contribution of TOP10 companies. In 2022, GAC Aion, BYD, and Tesla made significant carbon emission reduction contributions of NEPV during usage phase in Tianjin, with carbon emission reductions of 29100 tons, 22900 tons, and 16100 tons respectively, accounting for 17.0%, 13.4%, and 9.4%. More than 60% of GAC Aion vehicle models in Tianjin are online car-hailing vehicles, with a high average annual mileage, ranking first in Tianjin. And GAC Aion is among the top active vehicles in Tianjin. Therefore, GAC Aion has made a significant contribution to carbon emission reduction. The significant contribution to carbon emissions reduction of BYD is due to the fact that the number of active vehicles ranks first in Tianjin. In addition, Tesla, FAW Toyota, BAIC, Great Wall Euler, SAIC Roewe, and Chery are also among the top ten contributors to carbon emission reduction in Tianjin due to their high number of active vehicles. Haoqing Emgrand is similar to GAC Aion, with a majority of online car-hailing vehicles and an average annual mileage ranking among the top ten in Tianjin. Therefore, its contribution to carbon emission reduction is among the top ten in Tianjin. This also indirectly confirms that the contribution of carbon emission reduction is mainly determined by two factors: the number of active vehicles and the average annual mileage traveled.

![Figure 6. The proportion of carbon emission reduction contribution of NEPV of different usage scenarios](image)
Figure 6. The carbon emission reduction contribution of TOP10 companies

Among the 29100 tons of carbon emission reduction contribution generated by GAC Aion, the contribution of GAC Aion S is particularly prominent, accounting for 84.5%. Next is GAC Aion Y, which contributes 10.7% to carbon emission reduction contribution of GAC Aion. Guangqi Aion S and Guangqi Aion Y are currently the main models in the online car-hailing market, especially Aion S, which is known for its high cost-effectiveness and is the darling of the online car-hailing market. Aion S has two important advantages: a large number of active vehicles and high annual driving mileage, making it the main force contributing to the carbon emission reduction contribution of GAC Aion.

4. Conclusions and prospect

Based on the above analysis and results, we can draw the following conclusion:

(1) The vehicle ownership and actual mileage are the main factors affecting the carbon emission reduction during usage phase of NEV. Both of the factors have a positive impact on carbon emission reduction contributions.

(2) The carbon emission reduction contribution of BEV far exceeds that of PHEV. On the one hand, PHEV have lower electric driving range and lower emission reduction potential per vehicle compared to BEV. On the other hand, the ownership of PHEV is also much lower than that of BEV.

(3) The carbon emission reduction contribution in Tianjin is mainly from GAC Aion and BYD. The main reason that GAC Aian has made the greatest carbon emission reduction contribution is the high travel frequency of online car-hailing vehicles. The significant contribution to carbon emission reduction of BYD is due to the far leading ownership.

At present, several auto companies have released comprehensive electrification strategies. With the continuous expansion of the ownership of NEV, the travel frequency of NEV will also be further increased, and the potential for carbon emission reduction will increase year by year.

At present, Tianjin has initiated research and exploration work on local carbon inclusive mechanisms. In the future, if the local carbon inclusive system in Tianjin includes NEV usage in the incentive scenario, the carbon emission reduction contribution during usage of NEV can be promoted to the local carbon market for trading. By utilizing the benefits of carbon trading, users can be further encouraged to use NEV for transportation, thereby promoting the development of the new energy vehicle industry.

REFERENCES


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