Chapter 6
Fuel Cell Electric Vehicles (FCEVs)

In the global context of transition to green and low-carbon economy, hydrogen energy is expected to become the direction of a new round of energy technology change by virtue of its cleanliness, high efficiency and rich reserve. Major countries and regions around the world are speeding up the layout of an industry chain around hydrogen energy, and their interests to hydrogen industry have been increasing. This chapter, from the perspective of fuel cell Electric vehicles (FCEVs), studies the development of China's fuel cell Electric vehicle (FCEV) industry, and the operation characteristics and hydrogen charging characteristics of FCEVs, providing a certain reference for evaluating the development achievements of China's FCEV industry and deploying development ideas in the future.

6.1 Development Status of Fuel Cell Electric Vehicle Industry

Fuel cell electric vehicles are in the scale promotion stage, and in the period covered by the 13th Five-Year Plan, where a total of 7345 FCEVs have been put into operation.

Driven by the subsidy policy and demonstration cluster effect, China's FCEV industry has moved from the industrial introduction stage to the scale promotion stage. In 2017, the development of FCEVs began to take wing, and the sales in that year exceeded 1000 units and was up to 1275, boasting a YoY increase of 102.70%. Since 2018, the sales of FCEVs have continued to increase. In 2019, in contrast to the overall decline of production and sales of NEVs under the effect of the reduction of NEV subsidies, the production and sales of FCEVs increased at a high speed with annual sales up to 2737 units, and scale demonstration and promotion achieving a significant effect (Fig. 6.1).

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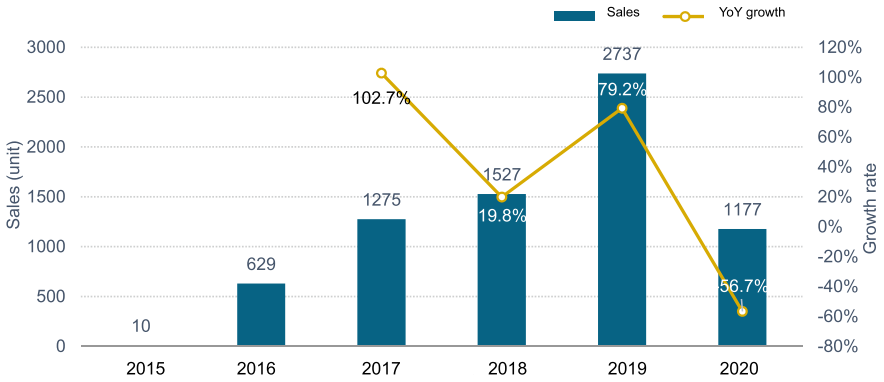

Fig. 6.1 Sales growth of FCEVs in China over the years. *Source* China Association of Automobile Manufacturers (CAAM)

In the first half of 2020, due to the superimposed effect of multiple factors including the COVID-19 outbreak, the reduction of subsidies and the cyclic fluctuation of market, the sales of FCEVs dropped heavily. Then, after the epidemic was quickly controlled, the market was gradually recovered, and throughout 2020, the sales of FCEVs reached 1177. In the period covered by the 13th Five-Year Plan, the total number of FCEVs put into operation was above 7000, laying a solid foundation for the scale promotion of NEV industry in the period of the 14th Five-Year Plan.

By the end of 2021, more than 120 hydrogen charging infrastructures have been constructed.

With the promotion of fuel cell electric vehicles, the market demand for hydrogen energy is increasing, and the construction of hydrogen charging stations has achieved remarkable results. On the one hand, the unit hydrogen charging capacity of the hydrogen charging station has increased significantly, with the daily hydrogen charging capacity gradually being increased from 200 kg/day to 500 kg/day or even 1000 kg/day; On the other hand, the construction of hydrogen charging infrastructure has accelerated, and as of December 31, 2020, more than 128 hydrogen charging stations have been constructed, in which 96 hydrogen charging stations have been put into operation. The development of hydrogen energy facilities in China varies from region to region. Currently, the hydrogen energy is mainly sourced from industrial by-product hydrogen, and considering this, the eastern coastal region, where the technical background and regional economy are strong, has obvious advantages, and is expected to achieve rapid growth in the scale of hydrogen charging stations and then promote the "point-to-surface" linked development of the region.

6.2 Analysis of FCEV Operation Characteristics

The National Monitoring and Management Platform can monitor the operation of FCEVs in real time, and ensure the operation safety of FCEVs through the analysis and diagnosis of their operation data. This section analyzes the operation characteristics of FCEVs from such dimensions as online rate and travel characteristics, with an aim to guiding the operation of FCEVs around China and, therefore, providing importance reference for the market-based promotion of the FCEV industry.

6.2.1 Access Characteristics

The cumulative access of FCEVs has exceeded 6000, consisting mainly of operating vehicles.

As of December 31, 2020, a total of 6002 FCEVs have been accessed to the National Monitoring and Management Platform, including 2222 FCEV buses (37.02%) and 3153 FCEV logistics vehicles (52.53%) (Fig. 6.2), which indicates that the demonstration and promotion of FCEV commercial vehicles have achieved a significant effect.

The promotion of FCEVs is mainly implemented in the eastern developed provinces, with the promotion in TOP10 provinces accounting for 95.7%.

As of December 31, 2020, the FCEV access in TOP10 provinces was 5744, accounting for 95.7% of the total FCEV access in China (Fig. 6.3). Among those provinces, Guangdong ranked first with an access of 2415 vehicles and a proportion of up to 40.2% in total FCEV access, followed by Shanghai, with an access of 1376 vehicles and a proportion of 22.9% in total FCEV access.

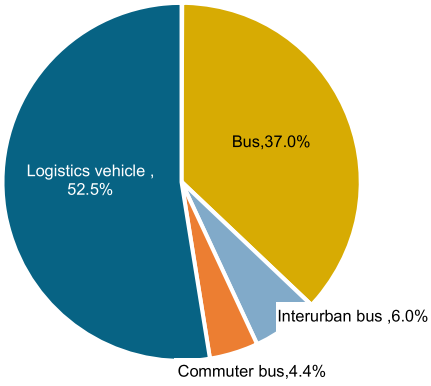

Fig. 6.2 Distribution of FCEVs in different application scenarios

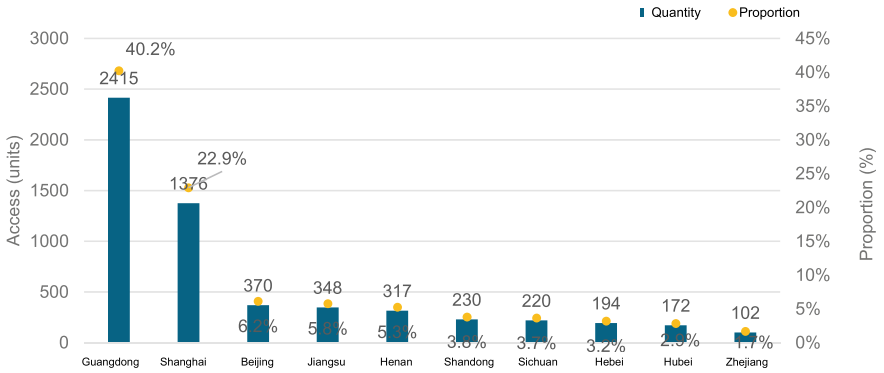

Fig. 6.3 TOP10 provinces in FCEV access in 2020

6.2.2 *Online Rate Characteristics*

The overall online rate of FCEVs is increasing steadily year by year.

As shown in Fig. 6.4, the average monthly online rate of FCEVs is increasing year by year, and in 2020, it was 75.00%, with an increase of 11% compared with 2019. However, the FCEV industry is still in demonstration and promotion stage, and the overall online rate of FCEVs is lower than the overall online rate of NEVs, which is closely related to factors such as the maturity of infrastructure and the convenience of use in the initial stage of industrial development.

As the curve shows (Fig. 6.5), the online rate of FCEVs in 2020 was stable, except for January and February when the online rate dropped below 60%. After March, as the epidemic eased and the subsidy policy of FCEVs of "replacing subsidies with

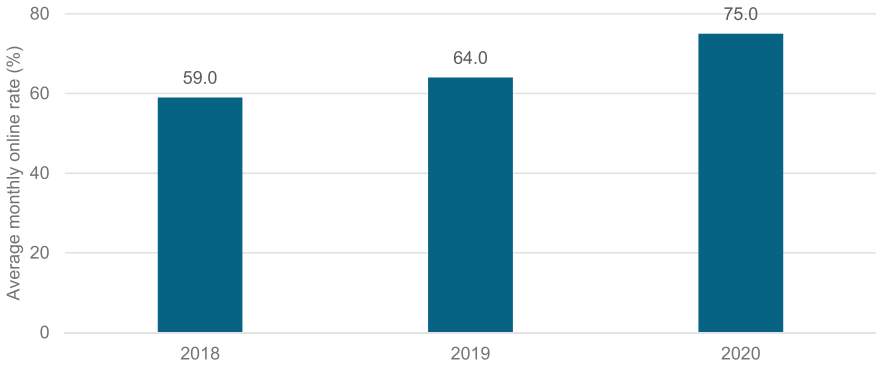

Fig. 6.4 Average monthly online rate of FCEVs

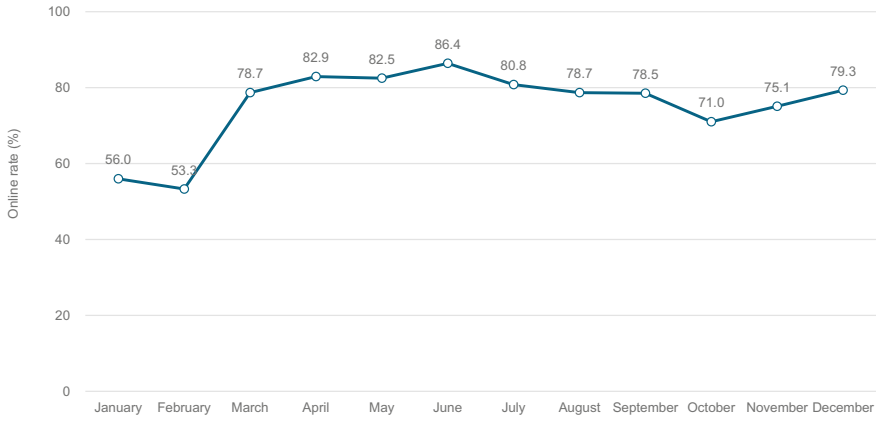

Fig. 6.5 Monthly online rate of FCEVs in 2020

rewards" was adopted, the monthly online rate of FCEVs rose continuously, and peaked in June and July with a value of 86.40%.

To sum up, with the continuous advancement of FCEV demonstration zones in various regions, the improvement of the overall industrial chain of hydrogen fuel cells, and the improvement of the industrial supporting environment, it is expected that the operation intensity of FCEVs will continue to increase, and the monthly online rate will rise steadily.

The online rate of FCEV buses is higher than that of FCEV logistics vehicles.

From the respective of application scenarios, FCEV buses and FCEV logistics vehicles, as the two main application scenarios of FCEVs, have become the "test field" of FCEVs in China due to their advantages including fixed operating routes and easy layout of industrial chain. According to the data over the years, the online rate of FCEV buses and logistics vehicles in 2020 increased at different rates compared with 2019 (Fig. 6.6). Specifically in 2020, the average monthly online rate of FCEV buses was 87.00% with an increase of 3% compared with 2019; the online rate of FCEV logistics vehicles increased quickly to 69.00% with an increase of 12% compared with 2019; according to the online rate in different application scenarios, the online rate of FCEV buses was generally higher than that of FCEV logistics vehicles.

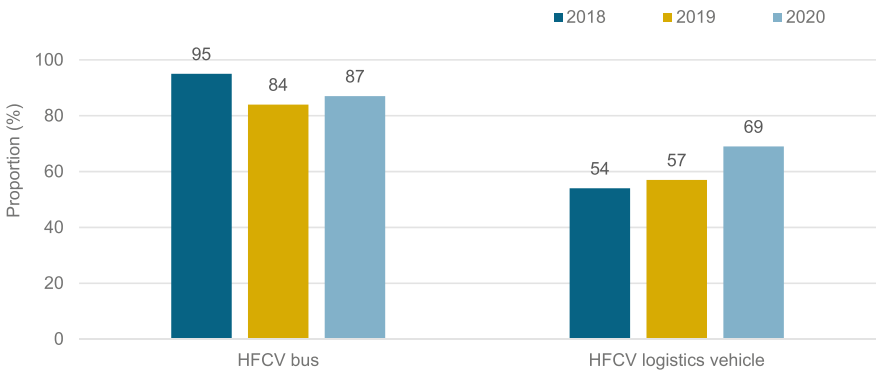

Fig. 6.6 Average monthly online rate of FCEV buses and logistics vehicles over the years

6.2.3 Travel Characteristics

(1) Mileage

As of December 31, 2020, the cumulative mileage of FCEVs has exceeded 100,000,000 km.

As of December 31, 2020, the cumulative mileage of FCEVs has reached 106,420,000 km. In 2020, the cumulative mileage of FCEVs was 75,770,000 km, increasing by 176.5% compared with last year. It can then be concluded that the annual mileage of FCEVs takes off exponentially.
Considering from the application scenarios, the mileage of FCEVs is mainly contributed by FCEV buses and logistics vehicles (Fig. 6.7). As of December 31, 2020, the cumulative mileage of FCEV buses and FCEV logistics vehicles has reached 56,758,000 km and 42,290,000 km, accounting for 53.3% and 39.7% of the total mileage of FCEVs, respectively.

In 2020, the single-vehicle daily mileage of FCEVs was mainly 0–40 km and 120–200 km, and the distribution of FCEVs with high mileage shows an obvious "migration" trend.

As the distribution shows, the single-vehicle daily mileage of FCEVs was mainly 0–40 km in 2018 and 2019, with the FCEVs in such single-vehicle daily mileage section accounting for about 45% (Fig. 6.8). The distribution of FCEVs with a single-vehicle daily mileage of 40–200 km is relatively even, which indicates that FCEVs play a certain role in short-distance logistics transportation; in 2020, the proportion of FCEVs with a high single-vehicle daily mileage increased significantly, and specifically, the proportion of FCEVs with a single-vehicle daily mileage of 120–200 km was 36.2%, which is significantly higher than that in the previous two years mainly due to the layout optimization of the hydrogen charging infrastructure and the improvement of the performance of the on-board hydrogen charging system.

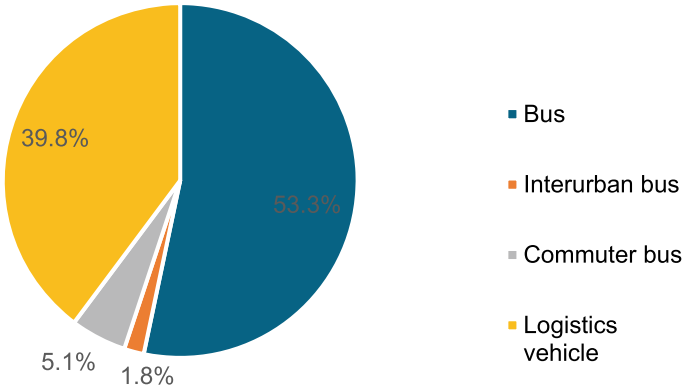

Fig. 6.7 Distribution of single-vehicle daily mileage of FCEVs in different application scenarios

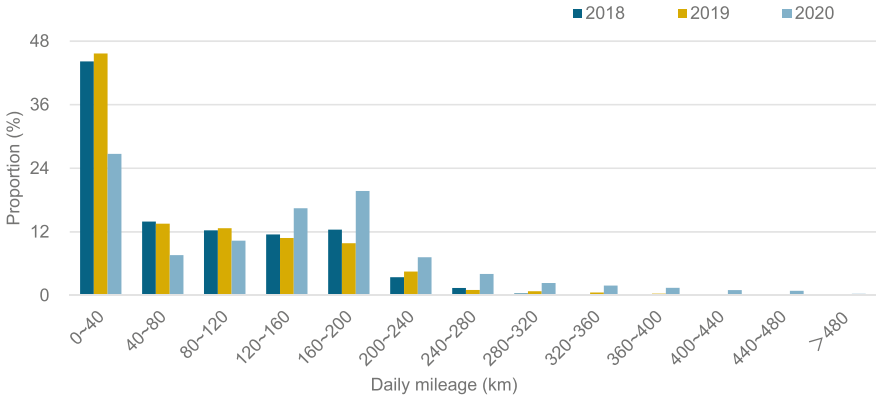

Fig. 6.8 Distribution of single-vehicle daily mileage of FCEVs

However, FCEVs are still in the operation demonstration stage at present, and are mainly applied in urban transportation.

The single-vehicle daily mileage of FCEV buses is mainly within 200 km, and the proportion of FCEV logistics vehicles with a single-vehicle daily mileage above 200 km is higher than that of FCEV buses.

Considering from the application scenarios, the single-vehicle daily mileage of FCEV buses in 2020 was mainly below 200 km, with the proportion of FCEV buses with such a single-vehicle daily mileage up to 95.41% (Fig. 6.9), and among them, the FCEV buses with a mileage of 80–200 km accounted for 58.04%; most of the FCEV buses are applied in urban public transportation.

The distribution of single-vehicle daily mileage of FCEV logistics vehicles is relatively discrete. Compared with FCEV buses, the proportion of FCEV logistics vehicles with a single-vehicle daily mileage above 200 km is much higher, and among

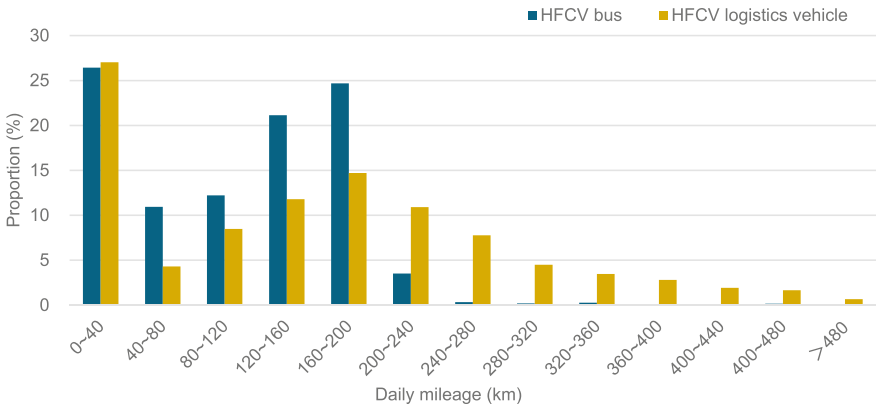

Fig. 6.9 Distribution of single-vehicle daily mileage of FCEV buses and logistics vehicles in 2020

them, the FCEV logistics vehicles with a single-vehicle daily mileage above 400 km account for 4.23%, indicating that FCEV logistics vehicles have gradually shown their potential in cross-city transportation.

(2) Travel duration

As of December 31, 2020, the cumulative travel duration of FCEVs has exceeded 3,880,000 h.

As of December 31, 2020, the cumulative travel duration of FCEVs has reached 3,884,000 h (Fig. 6.10), and in 2020, it was 2,722,000 h, increasing by 1,722,000 h (i.e., 171.2%) compared with 2019. Considering from the application scenarios, the cumulative travel duration of FCEVs is mainly contributed by FCEV buses and logistics vehicles. As of December 31, 2020, the cumulative travel duration of FCEV buses and FCEV logistics vehicles have reached 2,381,000 h and 1,147,000 h, accounting for 61.3% and 29.5% of the total cumulative travel duration of FCEVs, respectively.

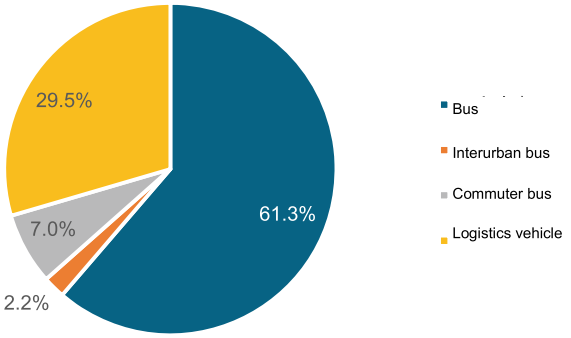

Fig. 6.10 Distribution of travel duration of FCEVs in different application scenarios

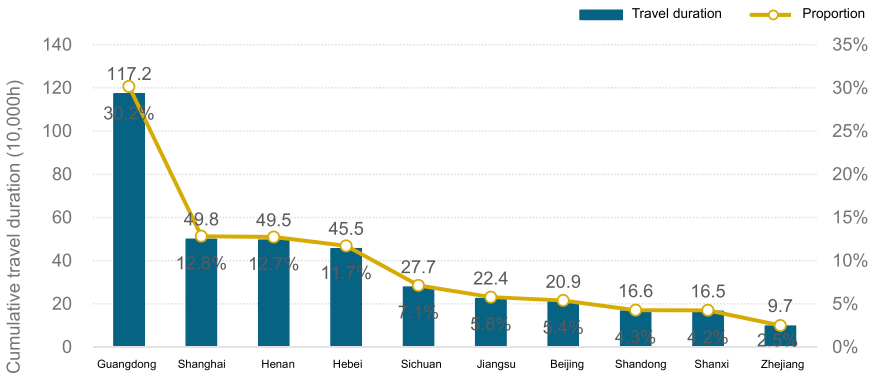

Fig. 6.11 Ranking of TOP10 provinces in cumulative travel duration of FCEVs

The cumulative travel duration of FCEVs in TOP10 provinces is 3,758,000 h, accounting for 96.7% of the total cumulative travel duration in China.

As the distribution in various provinces shows, by the end of 2020, the cumulative travel duration of FCEVs in TOP10 provinces was 3,758,000 h, accounting for 96.7% of the total cumulative travel duration of FCEVs in China (Fig. 6.11). Among those provinces, Guangdong ranked first with a cumulative travel duration of 1,172,000 h and a proportion of up to 30.2% in total cumulative travel duration of China; this is followed by Shanghai, Henan and Hebei with a cumulative travel duration of more than 450,000 h. These figures demonstrate that the FCEVs have achieved a good demonstration operation effect.

The proportion of FCEVs with long single-vehicle daily travel duration is increasing, indicating that the operation intensity of FCEVs has gradually increased.

The distribution of single-vehicle daily travel duration of FCEVs is relatively discrete, that is to say, there are FCEVs operating in each time period. Compared with 2018 and 2019, the proportion of FCEVs with long single-vehicle daily travel duration increased in 2020 (Fig. 6.12), especially the FCEVs with a single-vehicle daily travel duration of more than 6 h, indicating that the operation intensity of FCEVs has gradually increased.

The proportion of FCEV buses with a long daily travel duration is higher than that of FCEV logistics vehicles.

Overall, the proportion of FCEV buses with a long daily travel duration is higher than that of FCEV logistics vehicles (Fig. 6.13). Considering from the application scenarios, the single-vehicle daily travel duration of FCEV buses is mainly above 5 h, and those FCEV buses are mainly applied in urban public transportation; the distribution of single-vehicle daily travel duration of FCEV logistics vehicles is somehow polarized, and specifically, on the one hand, the FCEV logistics vehicles

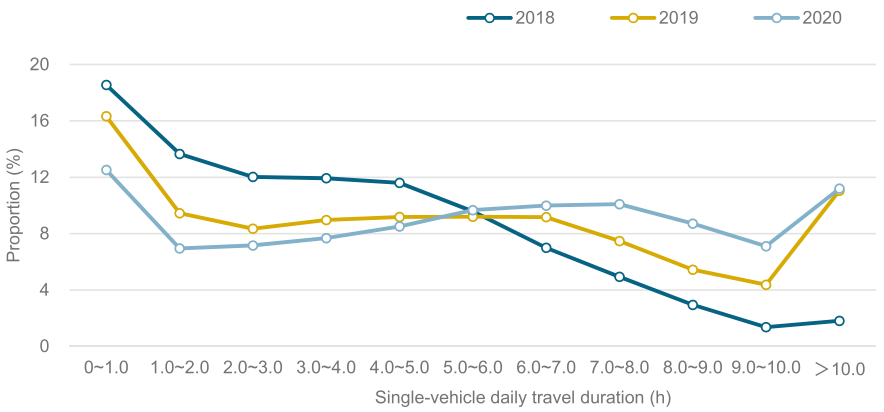

Fig. 6.12 Distribution of single-vehicle daily travel duration of FCEVs from 2018 to 2020

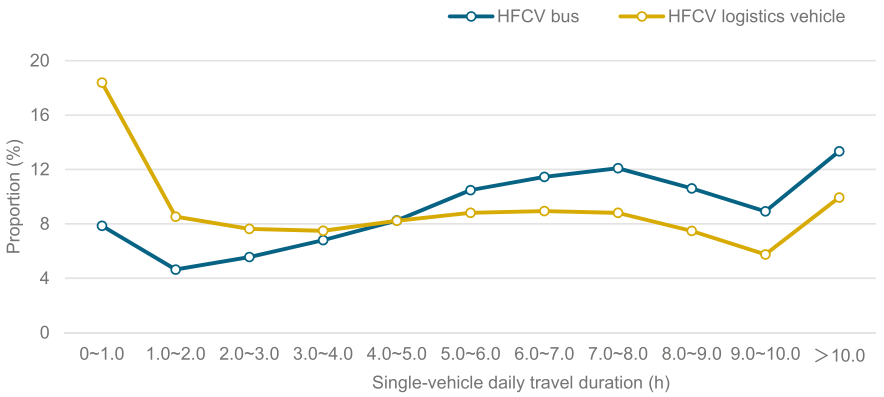

Fig. 6.13 Distribution of single-vehicle daily travel duration of FCEV buses and logistics vehicles in 2020

with a daily travel duration below 2 h take a large proportion, and are mainly applied in short-distance logistics transportation in the city; the FCEV logistics vehicles with a daily travel duration above 10 h account for 10%, indicating that some FCEV logistics vehicles are applied in cross-city transportation.

6.2.4 Hydrogen Charging Characteristics

The distribution of the hydrogen charging start time is discrete, and the proportion of FCEVs refueled intermittently during the operation is relatively high.

According to the data requirements for fuel cell in GB/T32960.3-2016 *Technical specifications of remote service and management system for electric vehicles—Part 3: Communication protocol and data format*, the "hydrogen maximum pressure" is defined as the basis for hydrogen charging. But for the purpose of this report, the maximum pressure difference of hydrogen fuel cell of ≥15 MPa is selected as the basis for hydrogen charging,[1] and based on it, the effective data of hydrogen charging duration can be calculated, and abnormality treatment, if necessary, can be made for hydrogen charging duration.

According to the operation data of FCEVs on the National Monitoring and Management Platform, the distribution of hydrogen charging start time is relatively discrete. As shown in Fig. 6.14, the hydrogen charging is concentrated at 10:00–11:00 and 16:00. The layout of the hydrogen charging stations directly affects the intermittent hydrogen charging of FCEVs during operation. In addition, we will also see a small peak of hydrogen charging around 20:00 at night.

The hydrogen charging duration of FCEVs is short, and FCEVs have advantage over electric vehicles in terms of energy supplement efficiency.

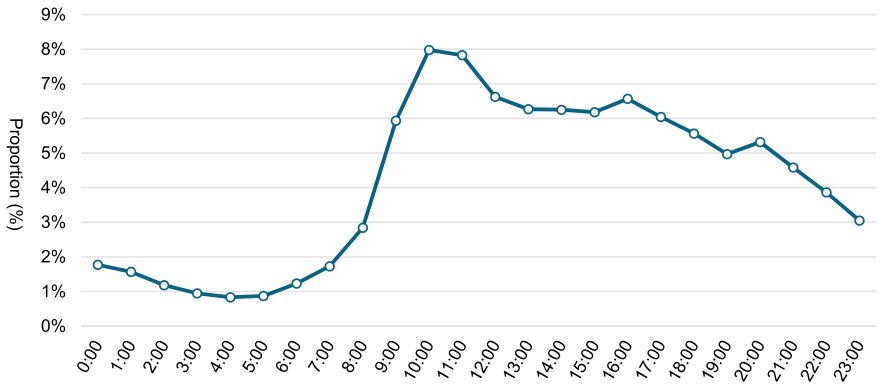

Fig. 6.14 Distribution of hydrogen charging start time of FCEVs in 2020

[1] Reason for selecting the maximum hydrogen pressure difference of ≥15 MPa as the basis for hydrogen charging: according to the probability distribution of the maximum hydrogen pressure difference of all hydrogen charging behaviors, the hydrogen pressure difference of more than 90% hydrogen charging behaviors is above 15 MPa, so this value is taken as the basis for calculating the effective hydrogen charging data.

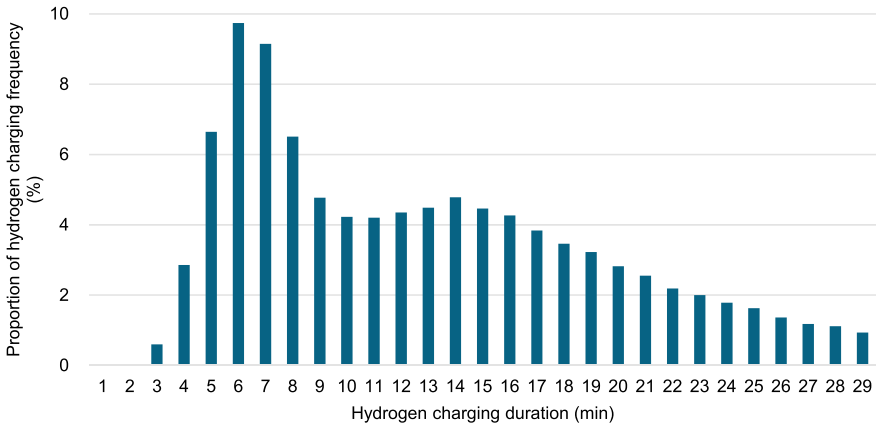

Fig. 6.15 Distribution of hydrogen charging duration of FCEVs in 2020

This report, through the statistics of hydrogen charging duration of FCEVs on the National Monitoring and Management Platform in 2020, selects the FCEVs with a hydrogen charging duration of less than 30 min as valid calculation samples, and calculates based on an interval of 1 min to generate the distribution of hydrogen charging duration of FCEVs. As shown in Fig. 6.15, the hydrogen charging duration of some vehicles is 4–5 min, and 13–15 min for other vehicles. These figures tell that the hydrogen charging duration of FCEVs is short, and FCEVs have advantages over BEVs in terms of energy supplement efficiency.

6.3 Summary

Hydrogen energy, as an ideal link medium for the efficient use of traditional petrochemical energy and the large-scale development of renewable energies, is an ideal choice for large-scale and deep decarbonization of transportation sector. In recent years, the central and local governments have continuously strengthened their support and guidance for the hydrogen energy industry. As the main force driving the growth of the downstream application market, FCEVs have achieved remarkable results in demonstration and application in recent years. This chapter, based on the big data of operation of FCEVs on the National Monitoring and Management Platform, makes the following conclusions:

The promotion and application of FCEV commercial vehicles has achieved remarkable results. The development and application of hydrogen energy industry in China follows the principle of "FCEV commercial vehicles first FCEV passenger cars followed". With the continuous support of national research plans and demonstration programs, the technical reliability, durability and maturity of some FCEV buses and logistics vehicles meet the actual operational needs, and FCEV technology

has achieved good operation results in fields of buses and logistics. As of December 31, 2020, the access of FCEVs to National Monitoring and Management Platform has exceeded 6000, of which 5375 are FCEV buses and logistics vehicles, accounting for 89.55% of the total FCEV access in China; from the perspective of mileage, the cumulative mileage of FCEVs in China has exceeded 100,000,000 km and the cumulative travel duration has exceeded 3,880,000 h, among which, the contributions of FCEV buses and logistics vehicles to cumulative mileage and cumulative travel duration of FCEVs are more than 99,048,000 km and 3,528,000 h, respectively.

The promotion of FCEVs is mainly implemented in the developed eastern coastal region. According to the regional distribution of complete vehicles, Jiangsu, Shandong, Zhejiang, Guangdong and other provinces in developed coastal region have adopted a large number of policies for fuel cell industry at a high density, and the hydrogen energy industry there enjoys a high development fever; according to the regional distribution of promotion, the promotion of FCEVs takes place more in developed eastern provinces, with the FCEVs promoted in Guangdong and Shanghai, as of December 31, 2020, accounting for 40.2% and 22.9% of the total FCEVs promotion in China.

FCEVs have significant advantages in mileage and energy supplement efficiency. With the advancement of fuel cell technology and hydrogen storage system technology, FCEVs have strong advantages in the fields of long-distance buses, and urban/intercity medium-/long-distance freight transportation. According to the operation data of FCEVs in Foshan on the National Monitoring and Management Platform, the average daily mileage of FCEV buses is above 200 km, and that of FCEV logistics vehicles is above 400 km; as for the hydrogen charging behavior, the FCEVs in China have a shorter hydrogen charging duration (specifically, the hydrogen charging duration is 4 ~ 5 min for some vehicles, and 13 ~ 15 min for other vehicles), and thus they have advantage over electric vehicles in terms of energy supplement efficiency. In the medium and long term, FCEVs are expected to be promoted and applied in the fields of heavy-duty trucks, buses, and long-distance logistics vehicles. To make full use of the complementary relationship between FCEVs and electric vehicles, promotion mode and market cultivation mode should be explored based on different application scenarios to give full play to the potential of FCEVs in long range and energy supplement efficiency.

The number and layout rationality of hydrogen charging stations are important for the promotion and application of FCEVs. Through the statistics of hydrogen charging duration of FCEVs on the National Monitoring and Management Platform, the hydrogen charging duration is mainly 4–5 min and 13–5 min. At present, the market scale of hydrogen charging station in China is small due to high construction cost and small profit margin, and the operation of hydrogen charging stations mainly depends on the government subsidies, and in view of this, the advantage of some FCEV commercial vehicles in long range has not been effectively unleashed. Therefore, it is necessary to expand a stable hydrogen energy supply system according to local conditions to ensure and promote the sound operation of the FCEV industry.