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Guagnzhou Transport Sector Carbon Emission Roadmap Study

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Abstract. According to the relevant requirements of achieving carbon peak in 2030,different policy scenarios are set to simulate the future energy consumption demand and CO2 Emission Trend of Guangzhou's transportation field under different scenarios, and analyze the direction and path of low-carbon development in Guangzhou.The results show that in order to achieve carbon peak by 2030, it is necessary to establish a long-term mechanism of green development: first, deepen the adjustment of transport structure;Second, guide social green and low-carbon travel; Third, continuously promote the application of new energy; Fourth, build green transportation infrastructure; Fifth, improve the green traffic supervision system.

Keywords: Guangzhou transportation; carbon peak path.

1. Introduction

In December 2015, nearly 200 parties voted to adopt The Paris Agreement at the Paris Climate Change Conference.The agreement aims to keep the global average temperature rise below 2°C(compared with the pre-industrial global average) and work towards a target of less than 1.5°C[1].To do this, parties should peak their GHG emissions as soon as possible and achieve "net zero" GHG emissions by the second half of the century.

As the world's largest emitter of greenhouse gases, China submitted Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions[2] in June 2015,which details the National Climate Action Plan after 2020.

- To achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;
- To lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level; To increase the share of non-fossil fuels in primary energy consumption to around 20%; and To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level.
- To make a sustained effort in further implementing enhanced policies and measures in areas such as regime building, production mode and consumption pattern, economic policy, science and technology innovation and international cooperation.

Since then, Chinese leaders have repeatedly reaffirmed the 2030 carbon peak target, and there have been active commitments and actions at the national and local levels.

As a national pilot low-carbon city and national central city, According to the deployment of the CPC Municipal Committee and the Municipal Government to promote carbon peak and carbon neutrality, The municipal development and reform department coordinates the promotion of carbon peak and carbon neutrality in Guangzhou, and organizes the preparation of the action plan for promoting carbon peak in guangzhou.The transportation sector is not only an important source of energy consumption and carbon emissions, but also a key area to promote green development, achieve carbon peaking, and carbon neutrality[3].This paper finds out the carbon emission base of Guangzhou's transportation sector, analyzes and predicts the carbon emission trend in the transportation sector, and formulates the implementation path for promoting carbon peaking in the transportation sector(Fig. 1).

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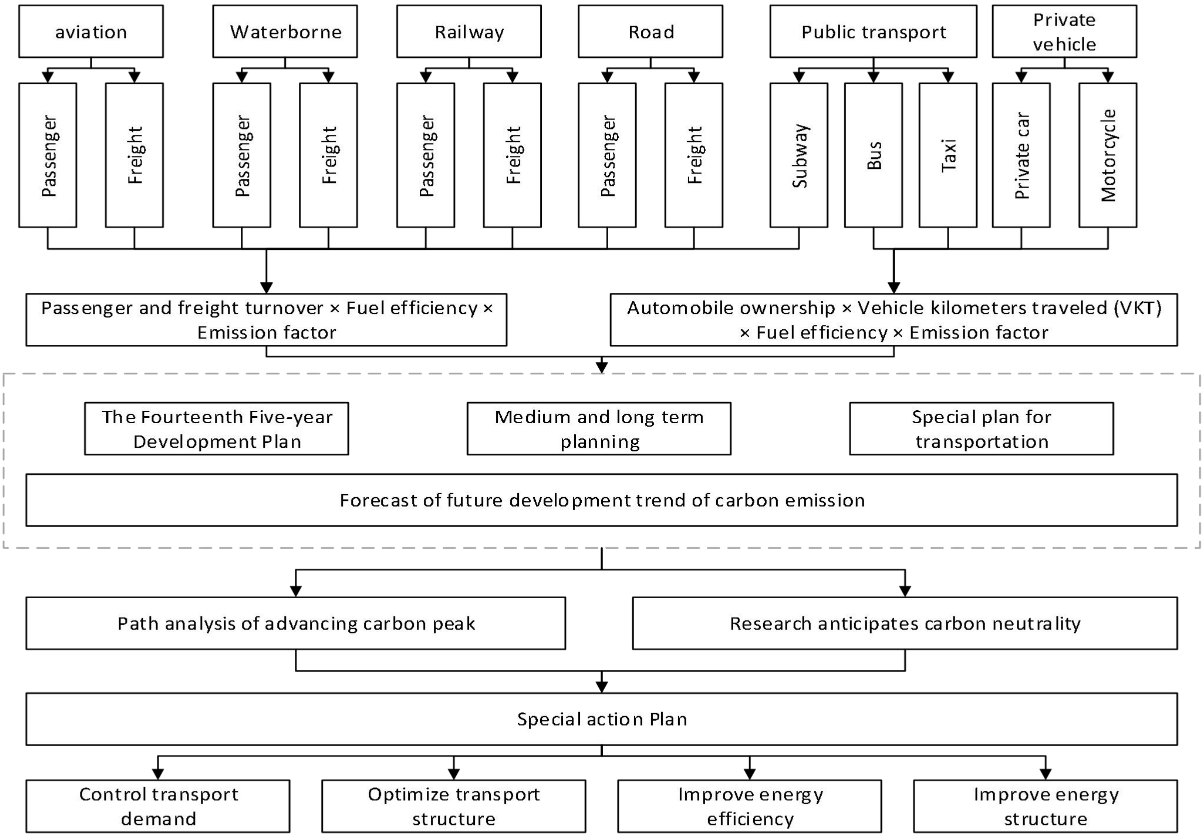

Fig. 1 Technical route of promoting carbon peak in Guangzhou.

2. Calculation and Analysis of Carbon Emissions in the Transportation Sector in Guangzhou

In external transportation areas,In 2019, the four major external transportation modes of civil aviation, water transportation, railways and highways completed a total of 498 million passengers, and the passenger turnover accumulated to 238 billion person-km; the total cargo transportation was 1350 million tons, and the cargo transportation turnover was 2.18 trillion ton-km.In 2020, a total of 327 million passengers were transported, with a total passenger turnover of 126 billion kilometers. A total of 910 million tons of goods were transported, and the cargo transport turnover was 2.16 trillion ton-km.Baiyun International Airport is one of the top 10 airports in the world. In 2019, its passenger throughput reached 73.4 million, ranking 11th in the world, and its cargo throughput reached 1.9 million tons, ranking 17th in the world. In 2020, the passenger throughput was 43.77 million, ranking first in the world.In 2019, the cargo throughput of Guangzhou Port reached 630 million tons, ranking fourth in the world. The container throughput was 23.2 million TEU, ranking the fifth in the world. In 2020, despite the impact of the epidemic, cargo throughput and container throughput still achieved a slight increase, reaching 640 million tons and 23.5 million TEU respectively.Guangzhou Railway Hub transported 145 million passengers and 19.6 million tons of freight. Guangzhou South Railway Station ranks first in terms of daily passenger flow (500,000 person-times) and daily number of emU stops (over 800 trips). In 2020, due to the impact of the epidemic, railway passenger and freight traffic decreased to 87.0 million and 17.9 million respectively.The number of road passengers was 180 million, with a significant decrease, and the number of road freight was 470 million tons, with relatively stable development.The postal industry has outgrown Beijing, Shanghai, Chongqing, Shenzhen and other major domestic cities to maintain a leading position in the country. In 2019, the volume of express delivery services reached 6.4 billion, ranking first in China for six consecutive years. In 2020, despite the impact of the epidemic, express delivery volume still increased to 7.6 billion.

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In urban traffic areas ， in 2019, the number of motor vehicles in the city was 2.9 million; the average daily motorized travel volume was about 25.2 million, the average daily passenger volume of the subway was 9.1 million, the passenger flow intensity ranked first in the country, and the average daily passenger volume of conventional buses was 6.1 million.In 2020, the number of motor vehicles in the city was 3.1 million, a year-on-year increase of 6.9%. Affected by the epidemic, the number of public transport passengers also dropped significantly, with the average daily number of subway passengers reaching 6.59 million, down 27.3 percent year-on-year, and the average daily number of regular bus passengers reaching 3.71 million, down 39.1 percent year-on-year.

3. Calculation and Analysis of Carbon Emissions in the Transportation Sector in Guangzhou

3.1 Statistical Boundary

This study covers the full range of all transport, including road, railway, civil aviation, water transport, urban rail transit, bus vehicles, taxis and non-operational transport. Non-operational transportation includes private cars, motorcycles, logistics vehicles, sanitation vehicles and other social vehicles. Due to the availability of data, this study does not include pipeline traffic and off-road traffic. Emissions from integrated transport hubs are only included in civil aviation, not general aviation.

The biggest characteristic of transportation emission sources is mobility, and the boundary problem needs to be clearly defined. The energy consumption and emission boundaries involved in this study are consistent with statistical data boundaries.The principle of territoriality applies to roads, civil aviation, water transport, buses, taxis and non-operational transport， which includes three aspects: first,direct emissions within the administrative boundaries of Guangzhou (emissions generated by vehicle driving in the city);second,related emissions generated by power consumption within the administrative boundaries of Guangzhou (such as subway and electric vehicles);third,trans-boundary or trans-boundary emissions (such as aviation and water transport) caused by activities within the administrative boundaries of Guangzhou.The calculation boundaries and scope of specific industries are as follows:

- Railway transport: Guangzhou Railway Group Co.,Ltd. is responsible for the carbon emission of passenger and freight trains originating and passing through Guangzhou.
- Civil aviation: carbon emission of passenger and cargo business of airlines registered in Guangzhou.
- Road transport: carbon emission of local road passenger transport, road freight, logistics, postal service and other industries in Guangzhou.
- Urban public transport: carbon emissions of conventional buses and taxis.
- Urban rail transit: Carbon emission of urban subway and urban tram operated by Guangzhou Metro Group.
- Individual transportation: carbon emission of local individual motorized transportation (private cars and motorcycles) in Guangzhou.
- Water transport: carbon emissions of ships operated by companies registered in Guangzhou.

3.2 Measurement Method and Parameter Calibration

At present, there are three main methods for calculating traffic carbon emissions, namely Top-Bottom, Bottom-Top and Whole life cycle methods[4][5].

From the perspective of total energy consumption, The Top-Bottom method calculates the total energy consumption of the transportation industry within the region, which is obtained by multiplying the total energy consumption by the fuel emission coefficient involved in transportation.From the perspective of terminal consumption of each transportation mode, The

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Bottom-Top method calculates the total energy consumption of each transportation mode in a region, which is obtained by multiplying the travel demand and activity level (mileage and turnover) of each mode of transportation by the energy consumption per unit activity level of the mode of transportation.The whole life cycle method is to count the total carbon emissions generated during the whole life cycle of production, operation and recycling of all kinds of transportation vehicles.This calculation adopts Top-Bottom and Bottom-Top accounting methods.

The calculation formula of carbon emission in guangzhou's transportation sector is as follows:

$$F_{kT} = \sum_i E_{km,i,k} \times D_i \times N_i \times F_{CO_2,k} + \sum_j E_{km,j,k} \times Q_j \times F_{CO_2,k} \quad (1)$$

$$F_T = \sum_{k=1}^{n} F_{kT} \quad (2)$$

- FT—Total carbon emission in transportation sector, in tons.
- FkT—Carbon emissions from the energy k source in the transport sector, in tons.
- n—Types of energy in the field of transportation
- Ekm,i,k—Energy consumption per 100 kilometers of the k-th energy of the i-th vehicle in the transportation field， i includes taxis, buses and trams, private cars, motorcycles, etc.
- Di—The annual transportation distance of the i-th vehicle, in 100 kilometers.
- Ni—Ownership of the i-th vehicle, in units of vehicles.
- Ekm,j,k—Passenger/freight turnover energy consumption for the kth energy source of the jth mode of transport in the transport sector， including road, waterway, civil aviation and rail transportation.
- Qj—The passenger/freight turnover of the j-th vehicle.
- FCO2,k—Carbon emission factor of the kth energy(Tab.1)

Table 1. Carbon emission coefficient of energy use in transportation sector

Type	Energy	Standard coal(kgce/kg||kwh)	Carbon dioxide emission (kgCO2/kgce)
Oils	Diesel	1.4571	1.73
	Gasoline	1.4714	1.73
	LPG	1.7143	1.73
	Kerosene	1.4714	1.73
	Fuel oil	1.4286	1.73
	Aviation kerosene	1.4714	1.73
Gas	LNG	1.7572	1.56
New energy	Hydrogen	4.8571	0
Electric power		0.30643	1.471

3.3 Data Sources

The calculation data of carbon emissions in the field of transportation mainly come from three aspects:

- Official statistics:Main indicators for transport, posts and telecommunications in the Statistical Yearbook 2010-2020.

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- Enterprise research data: operating data of transportation industry units from 2010 to 2020.
- Industry research data: the new round of guangzhou residents travel survey, the 2019-2020 supplementary traffic survey and data verification, 2010-2020 annual development report of the transport industry and other research reports.

3.4 Calculation Results in Recent Years

In recent years, the carbon emission in the transportation sector of Guangzhou has shown a rapid growth trend. In 2019, the total carbon emission in the transportation sector of Guangzhou was 27.6 million tons, an increase of 1.8 times compared with 2010, but the annual growth rate decreased from 7.8% in the 12th Five-Year Plan period to 5.6% in the 13th Five-Year Plan period (excluding 2020,Fig.2).

Carbon emission and change rate of Transportation in Guangzhou from 2010 to 2020 (unit: 10,000 tons)

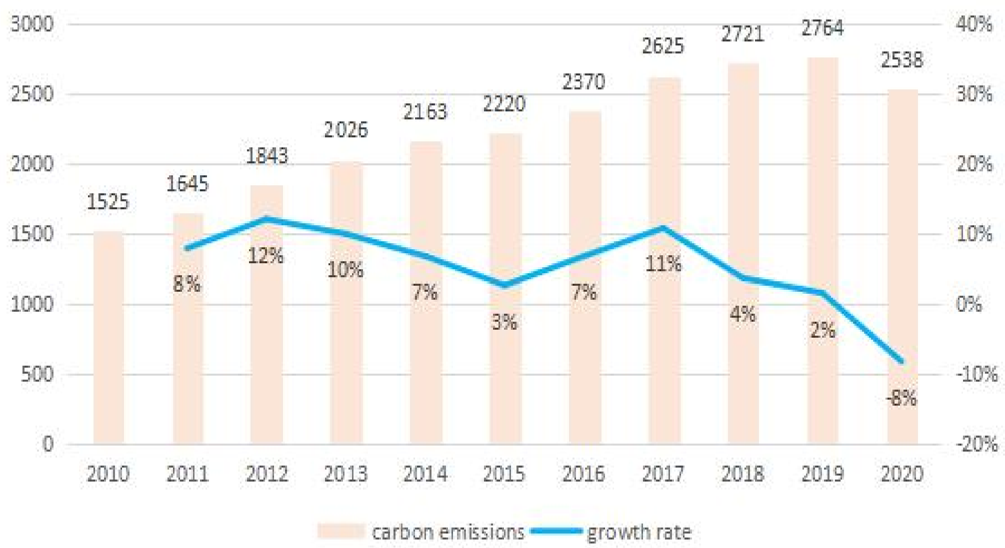

Fig. 2 Carbon emission and change rate of Transportation in Guangzhou from 2010 to 2020 (unit: 10,000 tons)

From the analysis of the carbon emission structure of all industries in the transportation sector, in 2019，the carbon emission of road transportation accounted for about 30.9%,Air transport accounted for 25.7% ; Urban transport accounted for 21.7% (bus 1.9%, taxi and ride-hailing 2.4%, subway 3.0%, private cars and motorcycles 14.4%); Water transport accounted for about 21.4% ; Rail transport accounts for about 0.3%.Affected by the epidemic,in 2020, road transport accounted for 36% of carbon emissions , air transport accounted for 19%, urban transport accounted for 23% (bus 1.7%, taxi and ride-hailing 1.8%, subway 3.1%, private car and motorcycle 16.5%), and waterway accounted for 22%. Rail transport accounts for about 0.3%.

3.5 Equations

Based on the current situation of emissions in the field of transportation in Guangzhou, taking 2035 as the target year, using the method of scenario analysis and under the established economic and social development objectives, two traffic development scenarios are designed:

- Baseline scenario: Based on the policy documents issued by Guangzhou, the existing policies and measures are implemented according to the current implementation intensity, and the transportation structure, energy structure and energy efficiency are optimized and improved compared with the current level.

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- Carbon peak scenario: on the basis of the baseline scenario, deepen the adjustment of transport structure, optimize transport organization and guide transport demand reasonably; Accelerate the electrification and low-carbon development of fuels, and further improve the energy efficiency of vehicles; Further develop urban public transport, control the demand for motor vehicle travel, and achieve the peak of carbon emissions in guangzhou's transport sector before 2030.

According to the results of the model, the carbon emission in Guangzhou will keep increasing in the future, but the increase will be significantly reduced. In the peak scenario, with the increase of energy saving and emission reduction measures, carbon emissions from guangzhou's transportation sector are expected to peak around 2030, with a peak amount of 33.7 million tons,a decrease of about 2.6 million tons from the baseline scenario in 2030(Fig.3).In terms of the average annual carbon emission growth rate, under the peak scenario, the average annual growth rate of transportation in Guangzhou will gradually decrease, reaching 2.9% in 2025, 1.1% in 2030 and -0.1% in 2035.Road transport and air transport accounted for the largest proportion of carbon emissions, accounting for 32% and 31% respectively. Urban transportation and waterway transportation accounted for 20% and 17% of carbon emissions, respectively. Rail transport was the least, accounting for about 0.3%(Fig.4).

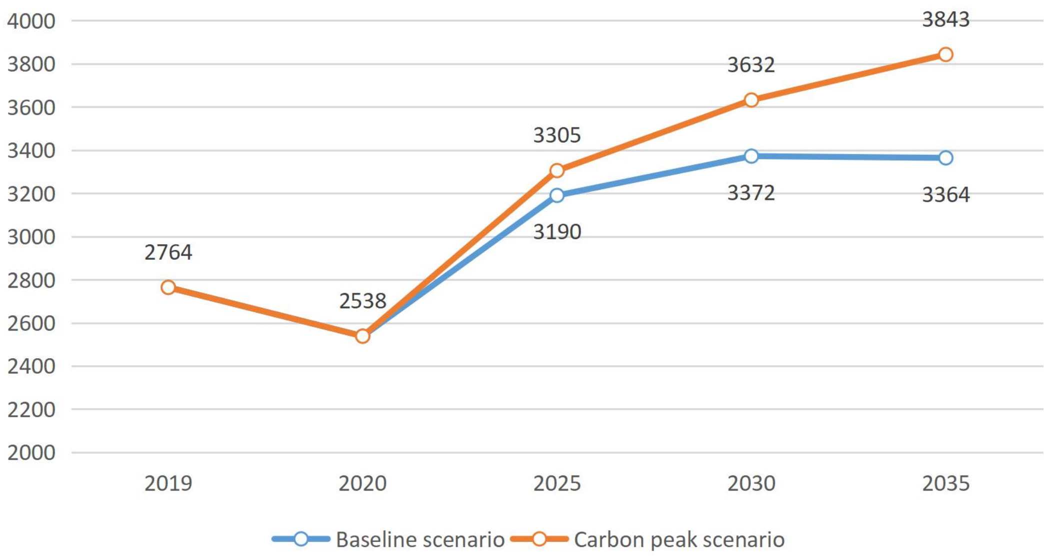

Fig. 3 Carbon emission of Transportation in Guangzhou in 2019-2035 (unit: 10,000 tons)

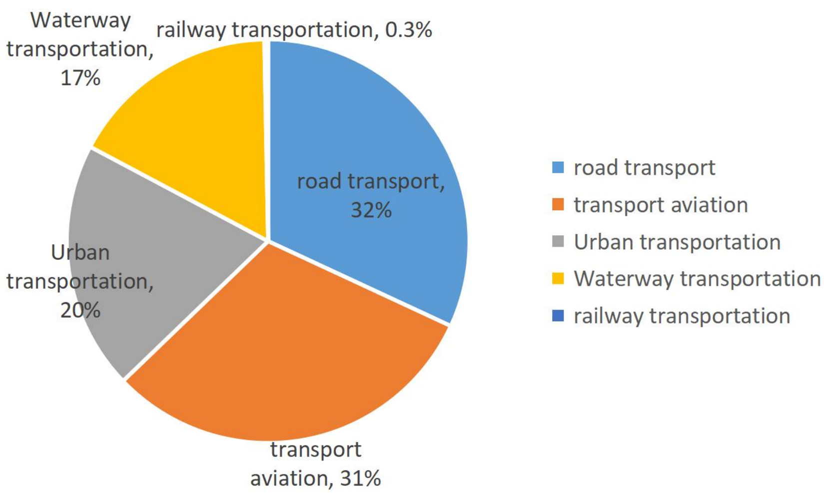

Fig. 4 Proportion of carbon emissions of different transportation modes in 2030 under carbon peak scenario

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4. Action Plan

4.1 Optimize the Transportation Structure

Accelerate the improvement of railway freight service capacity. Promote the construction of international dry port area with Datian container central station as the core and Guangzhou north station as the auxiliary, and build an international freight train assembly center in southern China; Optimize the railway organization mode and expand the "the Belt and Road" trains in Southeast Asia, ASEAN and the European Union; Speed up the construction of Nansha port railway, promote the railway into ports, large industrial and mining enterprises and logistics parks, and enhance the radiation capacity of railway transportation.

Accelerate the construction of port intermodal transport facilities. Accelerate the construction of Nansha Port Area Phase IV project, Guangzhou port 200,000-ton waterway project, Nansha port area river-sea intermodal barge berth and other facilities; Improve the function of inland dry port and support the liner of inland lighterage routes; Promote the technological transformation of supporting terminals, anchorages and other facilities for river sea intermodal transport in Guangzhou port area. Optimize domestic trade container routes, coordinate foreign trade container routes and inland water transportation, and realize transportation linkage.

Actively promote the development of multimodal transport mode. Promote the construction of multimodal transport hub and promote the development of sea rail transport and river sea transport business. Improve the construction of air hub collection and distribution system, promote high-speed railways, expressways and other connecting airports, and strengthen air rail combined transport and land air combined transport. Continue to promote the demonstration project of multimodal transport. By 2025, the volume of container hot metal intermodal transport in Guangzhou port will increase by more than 22% annually.

4.2 Guide Green Travel in Society

Create a green travel city. Consolidate the achievements of the "national public transport city construction demonstration city", accelerate the improvement of public transport service quality, improve the slow traffic system, vigorously cultivate the green travel culture, and widely mobilize the public to actively participate in the green travel action. By 2030, the share rate of green transportation in the central urban area will not be less than 83%.

Optimize and improve the urban public transport service system. Accelerate the construction of multi-level urban rail transit network. By 2025, the total mileage of urban rail transit will reach more than 800 kilometers; The coverage of rail transit stations in the central urban area within 800 meters has reached more than 65%. Continue to optimize the public transport network, encourage the development of diversified public transport services such as network buses, customized buses and convenient buses, promote the quality and characteristic development of urban public transport, and create an efficient, convenient and comfortable urban public transport service system. By 2030, the share of motorized travel of public transport in central urban areas will be over 63%.

Effectively manage car travel demand. Improve the construction of urban slow traffic system and build a safe, continuous and convenient network of non motorized lanes; Strengthen the connection between public transport system and slow traffic facilities. Strengthen urban parking management, formulate differentiated parking prices, and improve the utilization efficiency of urban parking facilities. Strengthen the monitoring and analysis of urban traffic operation status, promote the accurate management of urban traffic, and effectively reduce the travel demand of cars. By 2030, the city's small and medium-sized buses will strive to be controlled within 4.5 million.

4.3 Continue to Promote and Apply New Energy

Promote the application of new energy in public transport. Promote the electrification of buses. All new or updated buses in the city use pure electric vehicles, and realize the full electrification of buses in the central urban area by the end of 2023; By the end of 2025, the city's buses will be fully electrified. All new or updated taxis in the city will use pure electric, and all taxis will be fully electrified in 2028.

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Promote the application of new energy to private cars. Improve policies and measures for the promotion and application of new energy vehicles, and vigorously increase the proportion of individuals using new energy vehicles. By 2030, the sales volume of new energy vehicles in the city will reach more than 30% of the total sales volume of new vehicles.

Promote low-carbon transportation equipment. Encourage road transport enterprises to use new energy vehicles, and promote the alternative application of electric power, hydrogen fuel and liquefied natural gas vehicles in medium and heavy fuel trucks. Comprehensively promote new energy logistics and postal vehicles. By the end of 2025, the city's logistics distribution vehicles and postal vehicles will all use new energy vehicles. Continue to improve the electrification level of the railway system and achieve a railway electrification rate of more than 95% by 2030. Promote the demonstration application of clean energy ships, and strive to have no less than 200 inland LNG powered ships by 2030.

4.4 Construction of Green Transportation Infrastructure and Equipment

Promote low-carbon construction of transportation infrastructure. By 2030, green environmental protection materials and energy-saving and low-carbon processes will be fully adopted in the construction of transportation infrastructure. Promote the construction of energy-saving and low-carbon transportation hub stations, comprehensively promote the application of energy-saving technologies such as green lighting and energy-saving air conditioning, and reduce the operation energy consumption of transportation stations.

Promote the low-carbon upgrading of transportation infrastructure. Promote the transformation of port ship shore power facilities. By 2025, the coverage rate of port wharf berth shore power will reach 70% and the overall utilization rate of wharf shore power will reach 20%. Promote the clean transformation of transportation operation equipment. By 2030, the operation machinery in the port area and logistics park will be basically clean, the vehicle equipment in Baiyun International Airport will be basically electrified, and the installation and utilization rate of aircraft auxiliary power unit (APU) replacement facilities in the airport will reach 100%.

Strengthen the research, development and application of subway energy-saving technology. Actively promote the application of key technologies of intelligent and efficient refrigeration, train regenerative braking energy inverter feedback device and other new energy-saving technologies and equipment of Metro. Fully implement the fine management and control of energy conservation at subway stations. By 2030, carbon emission intensity per unit turnover of urban subway will be reduced by more than 10 percent compared with 2020.

4.5 Improve the Green Traffic Supervision System

Improve the promotion mechanism of green development. Combined with the development of various transportation industries, study and formulate relevant policies and measures to promote energy-saving, low-carbon and sustainable development of transportation, and clear out existing transport laws and regulations that do not fit the development of green and low-carbon transport.

Improve the statistical and monitoring capacity of transportation energy carbon emissions. Under the framework of the city's energy statistics system, strengthen the statistics and verification of basic data of transportation energy consumption. Strengthen the statistical accounting capacity of carbon emissions in the field of transportation and improve the statistical monitoring capacity of carbon emissions in the field of transportation.

Strengthen the supervision of key energy users in transportation. Strengthen the assessment of energy consumption targets, and establish an early warning and regulation mechanism for energy consumption of key energy users.

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