Study on Energy Consumption Structure of Guangdong Transportation Sector

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Abstract. Transportation energy is an important component of energy consumption. The research on the energy consumption structure of Guangdong Province's transportation energy will help to predict the space for energy development, formulate energy development strategies and energy plans. At the same time, it also provides a scientific basis for China Southern Power Grid Corporation to realize the transformation of enterprise and energy. This paper uses the GCAM model, a bottom-up method, to study the trend of Guangdong's transportation energy consumption structure by combining transportation technology, transportation mode, and transportation demand forecasting methods. It is found that the growth rate of transportation energy in Guangdong will slow down and decline after reaching the peak. Electricity consumption will become a major part of transportation energy consumption, and passenger turnover and cargo turnover will gradually increase.

1. Introduction

The transportation sector’s greenhouse gas emissions is increasingly concerned by the international community due to its high energy consumption. With the booming of economy and the acceleration of urbanization, China's transportation sector has also been developing rapidly, gradually becoming the third largest emission sector, after energy supply and industrial production. Therefore, it is urgent to research on the energy development transformation of the transportation sector and seek for a low-carbon energy consumption structure.

As the largest province of energy consumption in China, Guangdong Province has played an active role in energy saving and emission reduction. Guangdong government has launched a series of documents, such as “Guangdong Blue Sky Project Plan” [1] and “environmental protection planning of Guangdong Province” [2]. In response to the national policies of air pollution prevention, a series of measures have been carried out, such as raising the fuel oil standard, raising the emission standard of some industrial products as well as limiting straw combustion. But Guangdong Province still faces greater policy pressure on some indicators, such as energy consumption per unit GDP, carbon emission per unit GDP and total emission of typical air pollutants. During the 13th Five-Year Plan period, Guangdong Province has undertaken national allocation targets of a reduction in energy consumption per unit of GDP by 17% and carbon emissions per unit of GDP by 20.5% [3], which are the highest among the provinces and cities.

Therefore, only by studying the energy consumption trend of the transportation sector and judging its energy consumption characteristics and future development trend, can we quantitatively analysis...
the energy development trend, so as to promote the energy revolution and energy transformation.

2. Methodology

2.1. The framework of transport energy forecast in Guangdong Province

In this paper, the GCAM model is used to predict energy consumption of Guangdong transportation sector. Firstly, the traffic mode and the transportation technology under each mode are divided. We predict the medium and long-term passenger and freight turnover in Guangdong Province by parameters and generalized transportation price. Secondly, a variety of transportation modes compete within the TIMES model, and a variety of technologies compete within the same mode. Then the turnover of each mode and various transportation technologies are allocated, and the energy consumption of each mode and each technology is calculated. Finally, under the influence of different policies, the generalized transportation price of various modes and technologies changes, thus forming different distribution patterns of passenger and freight turnover. Energy consumption can be calculated by models and by technological turnovers.

2.2. Classification of transportation modes and technologies

The forecast for the transportation module covers the period from 2010 to 2050, with a 1-year modeling interval. With consideration of traffic heterogeneity, the transportation is divided into two categories: passenger and freight, and transport modes and technologies in Guangdong Province are shown in table 1 and table 2.

| Mode       | Category        | Power technology          | Fuel       |
|------------|-----------------|----------------------------|------------|
| Steam locomotive | Steamer         | Coal                       |
| Diesel locomotive  | Compression engine  | Diesel                     |
| Electrified railway | Electrified railway  | Electric power             |
| High-speed railway  | Traction system   | Electric power             |
| Urban railway      | The third rail power supply | Electric power |
| Motorcycle        | Spark-ignition engine | Gasoline                  |
| Electric motorcycle | Spark-ignition engine | Electric power |
| Gasoline passenger car | Spark-ignition engine | Gasoline                  |
| Diesel passenger car | Compression ignition engine | Diesel             |
| Natural gas passenger car | Compression ignition engine | Natural gas |
| LPG passenger car  | Compression ignition engine | LPG                       |
| Electric passenger car | Storage battery   | Electric power             |
| Gasoline bus      | Spark-ignition engine | Gasoline                  |
| Diesel bus        | Compression ignition engine | Diesel             |
| Natural gas bus   | Compression ignition engine | Natural gas |
| LPG bus           | Compression ignition engine | LPG                       |
| Electric bus      | Storage battery   | Electric power             |
| Inland vessel     | Compression ignition engine | Diesel             |
| Coastal vessel    | Compression ignition engine | Diesel             |
| Ocean vessel      | Compression ignition engine | Diesel             |
| Airplane          | Turbine engine    | Aviation kerosene          |

Table 1. Passenger transport modes and technologies in Guangdong Province
Table 2. Freight transportation modes and technologies in Guangdong Province

| Mode          | Category               | Power technology       | Fuel         |
|---------------|------------------------|------------------------|--------------|
| Railway       | Steam locomotive       | Steamer                | Coal         |
|               | Diesel locomotive      | Compression ignition engine | Diesel     |
|               | Electrified railway    | Electrified railway    | Electric power |
| Freight       | Agricultural vehicle   | Compression ignition engine | Gasoline    |
| transport     | Gasoline truck         | Spark-ignition engine  | Diesel       |
|               | Diesel truck           | Compression ignition engine | Natural gas |
|               | LPG truck              | Compression ignition engine | LPG         |
|               | Electric truck         | Storage battery        | Electric power |
| Water carriage| Inland vessel          | Compression ignition engine | Diesel     |
|               | Coastal vessel         | Compression ignition engine | Diesel     |
|               | Ocean vessel           | Compression ignition engine | Diesel     |
| Civil         | Airplane               | Turbine engine         | Aviation kerosene |
| aviation      |                        |                        |              |

2.3. Traffic demand prediction method
In this study, traffic demand elasticity equation is used to predict the growth of traffic service demand [4]. This method has been developed for a long time and is widely used at home and abroad. Among them, the demand for passenger transportation services is expressed in terms of passenger turnover, and the unit is “person-kilometres”. The demand for freight transportation services is expressed in terms of freight turnover, in “ton-kilometres”. Transport demand is affected by factors such as the level of economic development, income of residents, population and transport service prices.

3. Results and analysis

3.1. Analysis of Transportation Energy Consumption in Guangdong Province under the Baseline Scenario.
The passenger and cargo turnovers in Guangdong Province refer to the turnover of the whole society, and its value is higher than that in the statistical yearbook for the transportation sector [5]. As shown in Figure 1 and Figure 2, under the basic scenario, passenger turnover increases from 614.27 billion passenger-kilometer in 2010 to 1986.82 billion passenger-kilometer in 2050 with an increase of 223.4%; Cargo turnover increases from 774.10 billion ton-kilometer in 2010 to 3303.12 billion ton-kilometers in 2050 with an increase of 326.7%.
From the perspective of the structure of each mode of passenger transportation (Figure 3), the proportion of civil aviation eventually increases from 18.6% in 2010 to 23.8% in 2050; the proportion of water carriage is only 0.1% in 2010. The proportion of highway mode increases firstly and then decreases under the competition of railway and civil aviation, from 70.1% in 2010 to 57.3% in 2050. While the proportions of subway and railway continue to increase from 3.7% and 7.4% in 2010 to 5.5% and 13.4% in 2050 respectively. In terms of the structure of each transportation mode of freight (Figure 4), the proportion of civil aviation increases slightly that eventually increases from 0.4% in 2010 to 0.7% in 2050. The proportion of water carriage reaches 47.1% in 2010, but with the continuous increase of cargo turnover and the limitation of water carriage capacity, its proportion gradually reduces to 40.6% in 2050. The proportion of highway slowly decreases from 48.3% in 2010 to 40.0% in 2050.

3.2. Analysis of Transportation Energy Consumption in Guangdong Province under Multiple Scenarios

This study constructed five single-policy scenarios and one comprehensive scenario for the transportation sector. In the six scenarios, the specific policy measures and effects are shown in the table 3.

| Scenario       | Policies and measures                          | Effects                                                                 |
|----------------|-----------------------------------------------|-------------------------------------------------------------------------|
| Scenario 1    | Fuel tax                                      | Increases the energy cost of fuel vehicles                              |
| Scenario 2    | Carbon tax                                     | Increases energy costs for cars                                          |
| Scenario 3    | Fuel economy                                   | Improves fuel economics and reduces energy consumption intensity        |
| Scenario 4    | Car taxes and new energy vehicle subsidies    | Reduce non-energy costs of electric vehicles                            |
| Scenario 5    | Vigorously developing rail transit             | Improves the speed of rail transit and reduces the generalized transport price of rail transit |
| Scenario 6    | Superposition of the above five policies      | Above overlay                                                           |

In scenario 3, the fuel economics of railways, subways, highways, waterways and civil aviation are further improved by 30%, 25%, 30%, 25%, and 20% by 2050; In scenario 4, under the case of the government subsidies for the purchase of new energy vehicles and reducing taxes and fees, the depreciation and taxes of new energy vehicles are further reduced by 20% in 2050; In scenario 5, it is assumed that the speed of rail transit further increases by 30% compared with the basic scenario in 2050.

In multiple scenarios, the passenger turnover of Guangdong Province has some changes (Figure 5). Relative to the basic scenario, the passenger turnovers of scenarios 3-6 increase, and the turnovers of
scenarios 1-2 decrease, with the highest passenger turnover in scenario 3. The impact on the cargo turnover is shown in Figure 6. The turnovers in scenarios 3, 5, and 6 increase, and the turnovers of scenarios 1, 2, and 4 decrease, with the highest cargo turnover in scenario 5.

Figure 5. Comparison of passenger turnover in six traffic scenarios

Figure 6. Comparison of cargo turnover in six traffic scenarios

In terms of energy consumption (Figure 7), compared with the basic scenario, the energy consumption of all scenarios declines to some extent, with the highest decline in the comprehensive scenario, followed by scenario 3. In terms of electricity consumption (Figure 8), compared to the basic scenario, electricity consumption declines in Scenario 3, while electricity consumption in other scenarios increase, and scenario 4 has the fastest increase in the single policy scenario.

Figure 7. Comparison of energy consumption in six scenarios

Figure 8. Comparison of power consumption in six scenarios

The changes of the indicators in the six scenarios are summarized in Table 4. The passenger and cargo turnovers of the comprehensive scenario (scenario 6) increase by 4.43% and 2.12%, compared with the basic scenario. Electricity consumption increases by 65.84% while energy consumption decreases by 39.53%.

Table 4. Comparison of indicators of six scenarios

| Decline ratio(100%) | Passenger turnover | Cargo turnover | Energy consumption | Electricity consumption |
|---------------------|--------------------|----------------|-------------------|------------------------|
| Scenario 1          | -4.15%             | -2.85%         | -12.98%           | 42.75%                 |
| Scenario 2          | -1.32%             | -0.84%         | -2.39%            | 6.49%                  |
| Scenario 3          | 7.82%              | 2.58%          | -22.57%           | -26.68%                |
| Scenario 4          | 0.48%              | -0.70%         | -4.84%            | 49.98%                 |
| Scenario 5          | 1.13%              | 3.07%          | -1.60%            | 5.62%                  |
| Scenario 6          | 4.43%              | 2.12%          | -39.53%           | 65.84%                 |

From the perspective of energy structure (Table 5), relative to the basic scenario, the proportion of electricity in the comprehensive scenario rises to 12.3% in 2050. The proportion of diesel and other oil products increase slightly, while the proportion of natural gas and liquefied petroleum gas has little change.
Table 5. Comparison of energy share of the six energy scenarios in 2050

| Energy share by 2050 (100%) | Base value | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
|-----------------------------|------------|------------|------------|------------|------------|------------|------------|
| Gasoline                    | 43.0%      | 37.7%      | 42.9%      | 41.6%      | 39.4%      | 43.2%      | 30.5%      |
| Diesel                      | 31.1%      | 34.9%      | 31.6%      | 28.8%      | 31.2%      | 30.6%      | 32.2%      |
| Liquefied petroleum gas     | 0.4%       | 0.5%       | 0.4%       | 0.4%       | 0.4%       | 0.4%       | 0.4%       |
| Other oil products          | 19.5%      | 17.7%      | 18.7%      | 23.5%      | 20.5%      | 19.4%      | 23.0%      |
| Natural gas                 | 1.6%       | 2.0%       | 1.6%       | 1.5%       | 1.4%       | 1.6%       | 1.6%       |
| Electric power              | 4.5%       | 7.3%       | 4.9%       | 4.2%       | 7.1%       | 4.8%       | 12.3%      |
| Total                       | 100.0%     | 100.0%     | 100.0%     | 100.0%     | 100.0%     | 100.0%     | 100.0%     |

4. Conclusions

This paper refers to the GCAM model and actual situation of Guangdong’s transportation energy consumption to form localized traffic parameters. Through analyzing passenger and freight turnover, transportation technology structure, transportation vehicle ownership, and transportation energy consumption in Guangdong Province, it predicts the development trend of Guangdong's transportation energy consumption in 2050. From the perspective of energy structure, the proportion of gasoline has dropped significantly, and the proportion of diesel and other oil products has increased slightly. The proportion of natural gas and liquefied petroleum gas has little change, and the proportion of electricity increases. In terms of energy consumption, the energy consumption of Guangdong's transportation sector will gradually increase from 2010, and it will reach a peak in energy consumption in 2040, then gradually decrease to 10.8672 million tons of standard coal in 2050. Compared with the basic scenario, the energy consumption in all scenarios has declined to some extent. From the perspective of transportation capacity, the passenger and cargo turnovers increase significantly. It is suggested to take measures to optimize the energy structure, such as using new energy vehicles and levying energy tax. Meanwhile, it is necessary to establish a clean and low-carbon energy supply system and reduce pollutant emissions.

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