Evaluation of Energy Consumption Status and Energy-Saving Effect in the Industry of Transportation in China

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Abstract. This paper has analyzed the trends of total energy consumption and energy consumption structure in the industry of transport in China since 2005. Energy saving quantity in the industry of transportation since the “11th Five-Year Plan” has been measured, combined with energy-saving policies and key energy-saving measurement introduced by the transportation industry, and based on the trend of energy consumption which are derived from the unit turnover and comprehensive turnover under the four modes of transportation of roads, railways, waterways and civil aviation since 2005. The research results provide a comprehensive and systematic analysis of energy consumption and energy saving in the industry of transportation, which provide reference for relevant research by government and related industry workers.

1. Introduction
As the third largest terminal energy field outside of industry and life, transportation plays an increasingly important role in national economic and social development. Over the years, transportation energy consumption including transportation industry, non-industry and non-operating social vehicles has increased in proportion to energy consumption in the whole society, and its growth rate is greater than the growth rate of energy consumption in the whole society. At the same time, the transportation system covers five modes of transportation such as roads, railways, waterways, civil aviation and pipelines, and each mode of transportation has many types of vehicles which lead to big differences in fuel type and energy consumption.

2. Transportation Energy Consumption Status in the industry of transportation

2.1. Overall energy consumption
In the current statistical system in China, the transportation industry only includes transportation enterprises engaged in social operations or operational tools. The corresponding energy consumption statistics only include the fuel consumption of its transportation vehicles. The fuel consumption of some roads or water transportation vehicles, those are not from transportation industries, and a large number of social non-operating vehicles are not included in the energy consumption statistics in the industry of transportation. According to the full caliber, the energy consumption of transportation system is re-adjusted in this paper.

On the whole, with the continuous enhancement of transportation capacity and the continuous expansion of transportation scale, the energy consumption of transportation in China is showing a
rapid growth trend. From 2005 to 2017, the mileage of railway, highway, waterway and civil aviation has increased by 68.4%, 42.7%, 3.3%, and 274.3%, respectively. Passenger traffic turnover has increased by 122.0%, 5.1%, 14.3%, and 365.2%, respectively. And the scale of transportation is maintaining a sustained and rapid growth. Driven by this, in 2005-2016, the transportation energy consumption in China increased from 196.83 million tce in 2005 to 437.64 million tce in 2016, with an increase of 122.3% and an average annual growth rate of 7.5%. Among them, the energy consumption of transportation in 2010 has increased by 47.0%, compared with 2005. And the average annual growth during the “11th Five-Year Plan” period is 8.0%. The energy consumption of transportation in 2015 has increased by 46.1%, compared with 2010. And the average annual growth during the “12th Five-Year Plan” period is 7.9%. Overall, the growth rate of energy consumption in the industry of transportation has been at a relatively fast development level for a long time, and its proportion of terminal energy consumption has continuously increased.

Figure 1. The energy consumption of transportation in China since the “11th Five-Year Plan”

2.2. The key part of using energy

The modern transportation system mainly includes five transportation modes: road, waterway, aviation, railway, and pipeline. Pipeline transportation is not included in the scope of this study because of the smaller volume of pipeline transportation and the different energy consumption characteristics compared with the other four modes. The four modes of transportation have different types of fuel consumed. Among them, road transport vehicles mainly use road vehicles such as civilian vehicles, private cars, and operating vehicles, which mainly consume gasoline and diesel, as well as a small amount of natural gas, liquefied petroleum gas and electric energy. Water transportation vehicles mainly rely on ships, which mainly consume diesel. Railway transportation vehicles include diesel locomotives and electric locomotives, which mainly consume diesel and electricity currently. Air transportation vehicles are aircraft, which mainly consume aviation kerosene.

In general, the energy products in the industry of transportation include refined oil, natural gas and electricity in China. Among them, the proportion of refined oil consumption is over 95%, the total consumption of diesel and gasoline accounts for more than 75%, which is a key energy-consuming variety for the transportation industry, and fuel oil and kerosene consumption are relatively small. However, the energy consumption in the industry of transportation in China has a certain degree of change in recent years. With the continuous expansion of the scale of automobiles and the rapid development of electric vehicles, the proportion of gasoline has experienced a rise and then decline, from 2005 in recent years. 5. 33.5% rose to 39.0% in 2015 and then fell to 34.6% in 2016. Under the pressure of the environment, with the strengthening of the control of diesel vehicles and other factors, the proportion of diesel oil has decreased year by year, from 48.3% in 2005 to 41.7% in 2016. As the aircraft transportation volume keeps increasing year by year, the proportion of kerosene has increased continuously, from 5.5% in 2005 to 9.5%. Driven by the rapid development of electrified railway and
electric vehicles, the proportion of electric energy has been rising, from 2.2% in 2005 to 3.5% in 2016. The proportion of LPG and natural gas is stable overall.

Figure 2. Sub-category energy consumption structure in the field of transportation in China

3. Energy-saving policies and measures in the industry of transportation

3.1. Energy-saving policies
Energy-saving policies in the industry of transportation in China have gone through several stages: the concept, policy exploration, target clearing and system advancement and so on. Since the 1980s, the Ministry of Transport has successively formulated and implemented a series of rules and regulations such as the “Regulations for the Implementation of Energy Conservation Management in the Transportation Industry”, “Measures for Energy Conservation Awards” and “Outline of Energy Conservation Technology Policy for the Transportation Industry”. During the “10th Five-Year Plan” period, the energy-saving work in the industry of transportation has officially embarked on the track of scientific, legal and standardized. In particular, as the first medium and long-term plan for energy saving, the “Medium and Long-term Special Plan for Energy Conservation” was issued by China in 2004, in which transportation was listed as a key field for energysaving. During the “11th Five-Year Plan” period, the industry of transportation has put forward energy-saving and emission-reduction targets, that is, the energy consumption per unit of transported trucks in 2010 and 2020 can decrease by 5% and 16% respectively compared with that in 2005, the energy consumption of transported units of transported ships can decrease by 10% and 20% respectively, and the comprehensive energy consumption of throughput can decrease by 5% and 10% respectively. At this moment, the energy saving of the transportation industry has entered a clear and forceful stage. The “Twelfth Five-Year Plan” was a crucial period for transformation and development of the transportation industry, in which low-carbon transportation policies, such as “Guiding Opinions on Building a Low-Carbon transportation System”, “Interim Measures for the Administration of Special Funds for Energy Conservation and Emission Reduction of Transportation”, and “Notice on Further Improving the Detection, Supervision and Management of Fuel Consumption of Road Transportation Vehicles”, have been introduced one after another, and energy saving in the industry of transportation has entered a stage of systematic advancement.

3.2. Key energy-saving measures
In recent years, based on their respective energy types, energy-using structures, and energy-using characteristics, transportation modes such as roads, railways, waterways, and aviation have adopted
strong energy-saving and emission-reduction measures, which mainly involve structural energy saving, technical energy saving and management of energy saving and so on. Among them, highway energy-saving measures mainly include improving vehicle fuel efficiency, optimizing vehicle transportation capacity structure, increasing the promotion of new energy vehicles, promoting the application of alternative energy for vehicles, strengthening the promotion and application of new energy-saving technologies, and promoting the construction of intelligent information transportation systems, etc. Railway energy-saving measures mainly include promoting electrified railways, constructing energy-saving railway transportation structures, promoting new energy and renewable energy along railway stations, enhancing the promotion and application of energy-saving technologies and energy-saving products, and strengthening energy-saving management in railway transportation. Water transportation energy-saving measures mainly include promoting port shore power, upgrading channel grade, optimizing fleet structure, developing energy-saving ship type and energy-saving technology, carrying out intelligent ship management and real-time energy consumption monitoring, etc. The civil aviation energy-saving measures mainly include implementing the coastal bridge shore power technology, promoting non-fossil energy applications such as photovoltaics at the airport, promoting the application of bridge-borne equipment to replace aircraft APU, aero-engine weight reduction technology, improving aircraft transportation efficiency and optimizing dispatch routes, etc.

4. Trends in energy consumption and energy-saving effects in the industry of transportation

As an important energy-consuming field in China, the industry of transportation has great potential in energy saving and emission reduction. Relevant research shows that the average fuel consumption per 100 tons of vehicles in China is more than 20% higher than that of developed countries, among which truck transportation is nearly 50% higher, and inland vessels is 20% higher than that of developed countries. These indicate that transportation industry in China has greater potential in energy saving and emission reduction. Since the “11th Five-Year Plan”, energy saving and emission reduction have achieved positive results in the field of transportation in China, driven by a series of measures such as national policies, technology, and management.

4.1. Trends in energy consumption under different transportation modes

The energy consumption per unit of transportation volume of roads, railways and waterways has been declining as a whole, and the energy consumption per unit of transportation volume of civil aviation has remained at a high level. The energy consumption per unit of transport capacity of highway continued to decline, from 750 kgce/(10000 t•km) in 2005 to 406 kgce/(10000 t•km) in 2017, with an average annual rate of 5.0%, of which there was a rapid decline in 2011, and then there was a steady decline. The unit transportation turnover energy consumption of railway showed a steady downward trend, except for a slight rebound in 2015 and 2016, which fell from 64.8 kgce/(10000 t•km) in 2005 to 43.3 kgce/(10000 t•km) in 2017, with an annual average speed of 3.3%. The trend of energy consumption per unit transportation turnover of waterway is close to that of the highway, and the overall trend continued to decline, from 84.1 kgce/(10000 t•km) in 2005 to 35.7 kgce/(10000 t•km) in 2017, with an average annual rate of 6.9%. Among them, the decline in 2011 was rapid, and then tended to be stable. The energy consumption per unit of transportation volume of civil aviation remained high, rising in a wave from 4945 kgce/(10000 t•km) in 2005 to 5134 kgce/(10000 t•km) in 2017, with an average annual growth rate of 0.3%. 
Figure 3. Energy consumption of unit transportation turnover of railway, highway, waterway and civil aviation since the 11th Five-Year Plan

Since the turnover is divided into two types: passenger turnover and freight turnover, the comprehensive turnover (conversion turnover) is calculated by superimposing the passenger turnover into the freight turnover and then superimposing with the freight turnover. Overall, four transportation modes in China such as road, railway, waterway and civil aviation, have increased to varying degrees in turnover. The conversion turnover of highway showed an upward trend, rising again after the decline in 2014 and 2015, from 4849.2 billion t•km in 2010 to 6774.9 billion t•km in 2017, with an average annual growth of 6.1%. The conversion turnover of railway grew slowly, from 3640.6 billion t•km in 2010 to 4041.9 billion t•km in 2017, with an average annual growth rate of 1.5%. The conversion turnover of waterway has continued to grow rapidly, from 6845.2 billion t•km in 2010 to 9868.9 billion t•km in 2017, with an average annual growth of 5.3%. The conversion turnover of civil aviation is small but growing rapidly, from 47 billion t•km in 2010 to 108.3 billion t•km in 2017, with an average annual growth of 12.7%.

4.2. Energy-saving effect in the industry of transportation

Highway is a key energy-saving area. The energy-saving potential of railways and waterway is relatively small, and the energy-saving completion of civil aviation is relatively poor. As the key energy-saving area, the total energy saving of highway has reached 16.83 million tce since the “11th Five-Year Plan”, and the total energy saving of highway has reached 57.26 million tce since the “12th Five-Year Plan”. The energy saving situation of railway and waterway is similar. The total energy saving of railway and waterway have respectively reached 5.61 million tce and 4.04 million tce since the “11th Five-Year Plan”, and the total energy saving of railway and waterway have respectively reached 1.04 million tce and 10.15 million tce since the “12th Five-Year Plan”. The energy saving situation of civil aviation is not optimistic. In some years, there is even an increase in energy consumption. The total energy saving in the “11th Five-Year Plan” is 2.63 million tce, and the total energy saving in the “12th Five-Year Plan” is -99 million tce. Overall, the total energy savings totaled 29.11 million tce during the “11th Five-Year Plan” period, and the total energy savings totaled 67.46 million tce during the “12th Five-Year Plan” period.

Table 1. The energy saving situation of the four transportation modes over the years

| transportation modes | energy saving | 11th Five-Year | 12th Five-Year |
|----------------------|--------------|----------------|----------------|
|                      | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| highway              | 750  | 727  | 712.5 | 480  | 460  | 462  | 446  | 431  | 416  | 406  |
| railway              | 64.8 | 53.3 | 49.4  | 47.8 | 47.4 | 46.6 | 45.4 | 46.7 | 47.1 | 43.3 |
| water transport      | 84.1 | 80.0 | 78.2  | 44.9 | 43.2 | 41.1 | 35.9 | 36.1 | 35.8 | 35.7 |
| civil aviation       | 4945 | 4480 | 4385  | 4940 | 5147 | 5063 | 5147 | 5152 | 5134 | 5134 |
5. Conclusions and recommendations
The growth rate of energy consumption in the industry of transportation has been at a relatively fast development level for a long time, and its proportion in terminal energy consumption continues to increase. Strengthening energy saving and consumption reduction in the field of transportation will play a positive role in controlling the total energy consumption of the country and air pollution control.

5.1. Carry out differentiated energy conservation measures for different transportation modes
Under the premise of following the paths and measures of energy saving and emission reduction in the field of entire transportation, energy-saving and emission-reduction technologies with strong pertinence should be adopted to ensure that energy saving is effective for various transportation modes such as roads, railways, waterways, and civil aviation, which need to based on the type of energy use, the structure of energy use, and the characteristics of energy use.

5.2. Promoting the issuance of energy-saving and emission-reduction policies in the field of transportation
Policies need to be promoted, such as further enriching and improving energy-saving and emission-reduction policies in the field of transportation, formulating more detailed energy-saving and emission-reduction targets, promoting more abundant economic-incentives and stricter environmental-protection policies, and strengthening new energy-saving technologies. R&D, increasing administrative supervision.

5.3. Optimize transportation structure in the field of transportation
There are obvious energy-saving and emission-reducing effects by adjusting transportation structure. Therefore, the following suggestions can be made: the transportation structure is adjusted towards railways and waterways, and the proportion of road transportation turnover is reduced to The transport structure can be adjusted towards rail and waterways to achieve a comprehensive improvement in transport volume, air-ship ratio, load factor and daily utilization rate of civil aviation.

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