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ORIGINAL ARTICLE

Review and evaluation of China's standards and regulations on the fuel consumption of motor vehicles

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Abstract Owing to fast-growing vehicle sales, China began in 2001 to develop vehicle energy conservation policies to help solve oil security and carbon dioxide (CO_2) emissions problems, and it has established a vehicle fuel consumption regulation system to contain vehicle fuel consumption growth. This regulation system includes technical standards, management rules, and fiscal policies. The system covers passenger cars, light-duty commercial vehicles, and heavy-duty commercial vehicles. This paper presents fuel consumption test methods, fuel consumption limits, and fuel consumption labeling standards for these vehicle categories. It also discusses the enforcement of these standards and their associated impacts on oil savings and CO_2 emission reductions, identifies problems with the policy implementation from both technical and administrative perspectives, and proposes recommendations to improve the current vehicle fuel consumption regulation system. In particular, we recommend that the central government improve the jurisdictional authority for vehicle energy conservation by clearly clarifying the responsibilities of different ministries, develop a long-term vision and middle-term targets to guide the policy and technology development, and strengthen the policy enforcement monitoring and evaluation.

Keywords Auto industry · Automotive energy conservation · Fuel consumption · CO_2 emissions · Standards and regulations

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1 Introduction

China has experienced fast growth in vehicle sales since 2000, and in 2009, China became the world's largest new-vehicle market. In 2012, China's vehicle sales and population amounted to 19.31 and 120.89 million, respectively (Zhang et al. 2013). Figure 1 shows the development trend of the Chinese civilian vehicle population since 2002. As a result of the fast-growing population, vehicles have become the major contributor to the increasing oil consumption in China. In 2011, vehicles consumed about 150 million tons of oil, accounting for about 60 % of total Chinese oil use (Wang and Jin 2014). With the continuous increase in the Chinese vehicle population, the share of oil consumption by vehicles will continue to rise.

Because China's oil consumption has rapidly increased while domestic oil production has grown slowly, China has increasingly relied on imported oil, and the gap between oil demand and supply is widening (Sheng et al. 2013). In particular, as shown in Fig. 2, China's oil consumption amounted to about 476 million tons in 2012, with a net oil import of 270 million tons, resulting in a 57 % dependence on oil imports (Lin et al. 2013).

In order to address the problems of oil security and the fast-growing carbon dioxide (CO_2) emissions from road transportation, China began to study and develop vehicle fuel consumption standards in 2001. Learning from international experience in this area, China has developed and implemented a series of vehicle fuel consumption standards related to vehicle tests, fuel consumption limits, and vehicle fuel consumption labeling. These standards cover both light-duty vehicles (LDVs), including passenger cars and light-duty commercial vehicles (LDCVs), and heavy-duty commercial vehicles (HDCVs).

The light-duty and heavy-duty vehicle standards provide a foundation for China to set up an administrative system to regulate vehicle fuel efficiencies. Under this administrative system, fuel consumption performance is one of the preconditions for vehicle models to obtain a market access permit. Any vehicle models that fail to meet fuel consumption standards are forbidden to be sold in China. Further, for LDVs, the system requires fuel consumption labels on vehicle windows in showrooms to enable consumers to purchase efficient vehicles. It also requires that vehicle fuel consumption data be published periodically on the official fuel consumption website of the Ministry of Industry and Information Technology (MIIT).

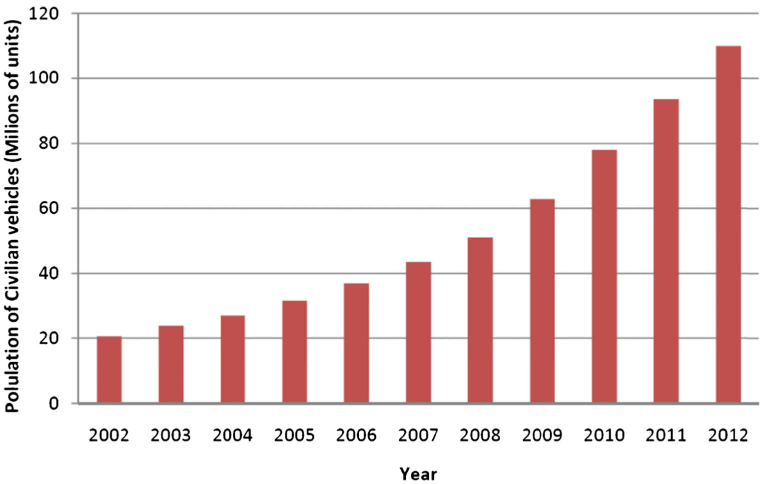

Fig. 1 China's on-road civilian vehicle population (Zhang et al. 2013)

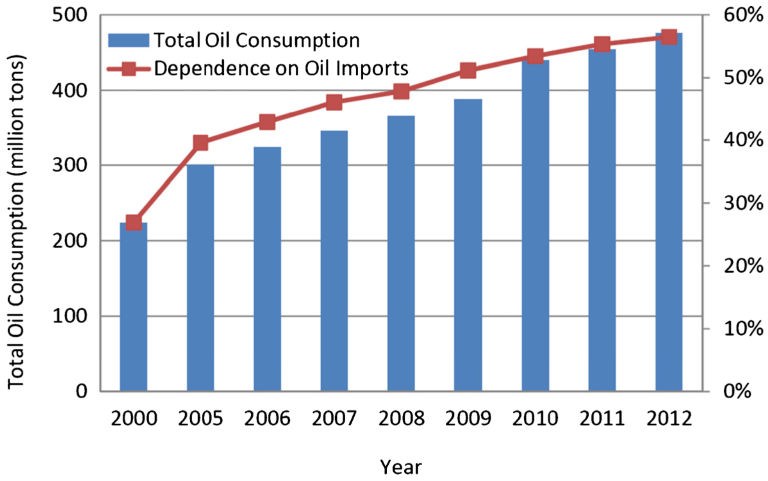

Fig. 2 Chinese annual total oil consumption and imported oil share (Lin et al. 2013)

Beginning in 2012, China established a mechanism for calculating the corporate average fuel consumption (CAFC) of passenger car manufacturers' fleets. In addition, China implemented several fiscal measures, including tax reductions and subsidies for purchasing passenger cars with good fuel consumption performance. Overall, the implementation of vehicle fuel consumption standards and fiscal measures has helped introduce fuel-efficient technologies to the market and reduce vehicle fuel consumption.

However, some problems were also observed during the implementation of these standards and relevant measures. Problems have included failure of vehicle test cycles to represent traffic conditions in China, a disconnection between fuel consumption and emission tests for HDCVs, and a lack of punitive measures against noncompliant vehicle models and manufacturers.

To continue its efforts to improve vehicle fuel efficiencies and to reduce CO_2 emissions, China intends to develop its own vehicle driving cycles, improve its fuel consumption testing methods, tighten fuel consumption standards, and include new energy vehicles (NEVs) (or electric-drive vehicle technologies), focusing on battery electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel-cell vehicles.

China will officially launch the 13th Five-Year Plan in 2015 and will adopt further energy conservation policies in 2016. This study analyzes and summarizes recent China's vehicle fuel consumption improvement efforts, evaluates the implementation of vehicle fuel consumption regulations, and identifies future challenges and opportunities for improvements.

2 Chinese vehicle fuel consumption regulatory systems

2.1 Overview

China initiated the development of vehicle fuel consumption standards and promotion policies in 2001. After more than 10 years of effort, governmental agencies, including the National Development and Reform Commission (NDRC) and the MIIT, have developed and enforced a series of standards for fuel consumption testing methods, fuel consumption limits, and fuel consumption labels. A complete system of fuel consumption standards for LDVs and a basic system for HDCVs were established; the categories addressed by these standards are shown in Table 1, and an outline of the system is given in Fig. 3.

2.2 Fuel consumption test methods

2.2.1 Light-duty vehicles

The first fuel consumption test method standard for LDVs was adopted in 2003 and revised in 2008. It is applicable to vehicles with a gross vehicle weight (GVW) not exceeding 3.5 t (i.e., LDVs). The test standard was developed according to ECE Regulation No. 101 within the framework of the United Nations Economic Commission for Europe (UN ECE). A test vehicle is driven on a chassis dynamometer through one urban cycle and one suburban cycle, as shown in Fig. 4, which represents the so-called New European Driving Cycle (NEDC). The fuel consumption of the test vehicle is calculated using the carbon balance method, which is based on measurements of CO_2, carbon monoxide, and hydrocarbon emissions during the driving cycle.

2.2.2 Heavy-duty commercial vehicles

The fuel consumption test method standard for HDCVs was developed on the basis of the road traffic situation and vehicle characteristics in China. It applies to gasoline and diesel commercial vehicles with a GVW of more than 3.5 t.

This standard specifies two parallel test methods. For basic vehicle models defined similarly to vehicle configurations in the United States, the fuel consumption shall be measured on a chassis dynamometer. For those models developed according to a basic vehicle model and not varying significantly from the basic model, the fuel consumption value can be obtained either through testing on a chassis dynamometer or through simulations with the engine test results as inputs. The acceleration and deceleration requirements of the World Transient Vehicle Cycle (WTVC) developed by the UN ECE (Heinz 2001) were modified to reflect the road traffic situation, vehicle characteristics, and driving behaviors in China; the revised driving cycle (Fig. 5) was designated in the Chinese-WTVC. Furthermore, the urban, rural, and motorway shares of the cycle were assigned for each category of HDCVs on the basis of real-world mileage surveys in China to calculate the combined fuel consumption value.

Table 1 Vehicle categories in China

Category	Usage	Primary features
M_1	For passengers	With not more than eight seats in addition to the driver's seat
M_2		With more than eight seats in addition to the driver's seat and a gross vehicle weight (GVW) not exceeding 5 t
M_3		With more than eight seats in addition to the driver's seat and a GVW exceeding 5 t
N_1	For goods	With a GVW not exceeding 3.5 t
N_2		With a GVW exceeding 3.5 t but not exceeding 12 t
N_3		With a GVW exceeding 12 t

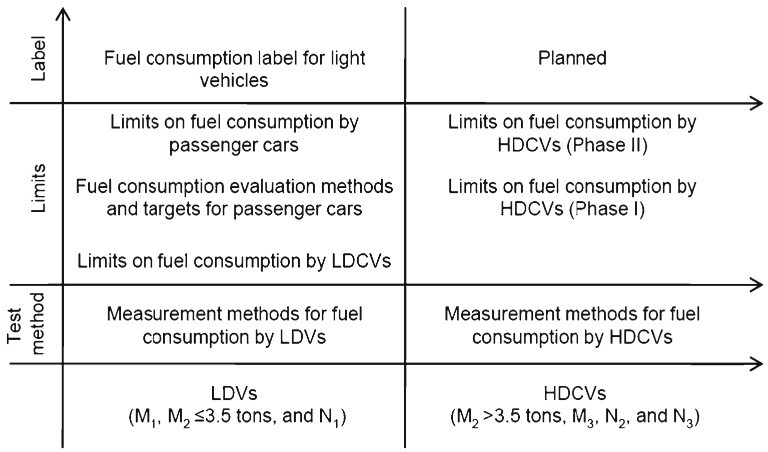

Fig. 3 Chinese system of vehicle fuel consumption standards and regulations

2.3 Fuel consumption limits

2.3.1 Passenger cars

The Phase I/II standards were the first mandatory national standard in China to control the fuel consumption of passenger cars. The standards were developed with consideration of the technical characteristics and driving patterns of passenger cars in China. Since the vehicle curb weight has the best correlation to fuel consumption, it was selected among key attributes as the reference parameter for fuel consumption limits. Passenger cars were classified into 16 groups on the basis of their curb weights. Among the 16 curb weight groups, the fuel consumption limits were designed to increase with the increase in curb weight. All vehicle models within a curb weight group were subject to a uniform fuel consumption limit. As light vehicles normally consume less fuel than heavy ones and in order to discourage sales of heavy and large vehicles, fuel consumption limits were designed to be stricter for the vehicles in the

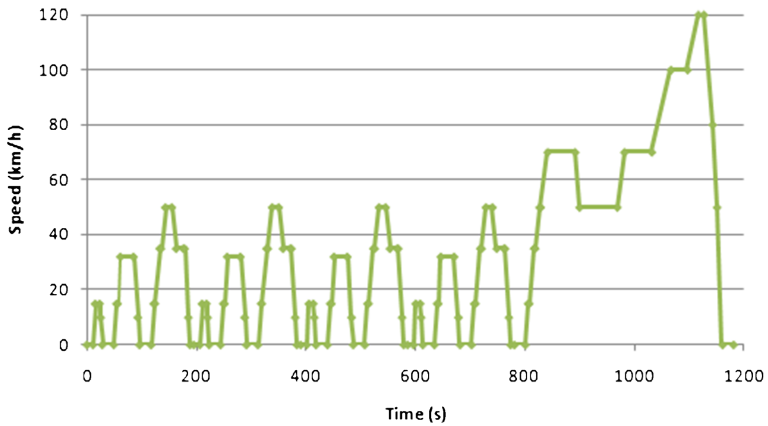

Fig. 4 New European Driving Cycle (NEDC) for testing the fuel consumption of LDVs in China

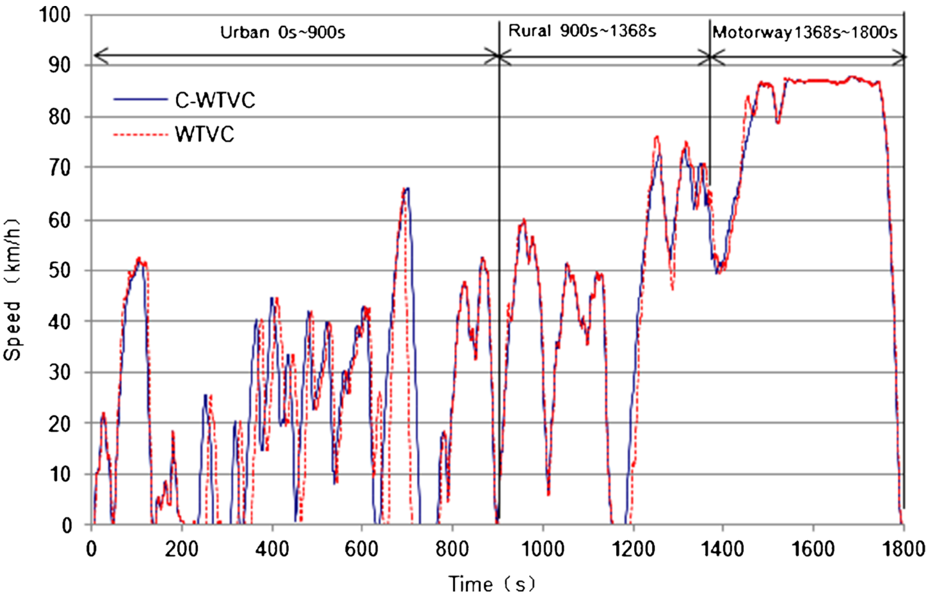

Fig. 5 World Transient Vehicle Cycle (WTVC) and Chinese-WTVC for HDCVs

heavier groups than for those in the lighter ones, with the hope of suppressing the potential upward trend in sales of heavy vehicles.

The Phase I/II standards control the fuel consumption of individual passenger car models. However, if the market generates more sales of bigger and heavier passenger cars, the fleet average fuel consumption will be out of control. Auto manufacturers have claimed that strong market demand exists for big, heavy luxury cars, but these cars cannot be sold because most of them fall into the heavier groups and cannot meet the more stringent fuel consumption limits. In order to control the fleet average fuel consumption and give auto manufacturers some flexibility in their product mixes, China issued the Phase III standard in 2011, which introduced the concept of CAFC in addition to the fuel consumption limits specified in the Phase I/II standards. In the CAFC standard, fuel consumption targets are set for each group of vehicles on the basis of their curb weights, and each auto manufacturer will have its own CAFC target according to the fuel consumption targets of vehicle groups and the production volume and mix of vehicle groups for this manufacturer. As long as the manufacturer satisfies its overall CAFC target, it could still produce and sell vehicle models not meeting the corresponding fuel consumption targets. In addition, a phase-in schedule (shown in Table 2) was introduced for the period from 2012 to 2015.

Table 2 Phase-in requirements for CAFC limits

Year	Ratio between CAFC and target value of CAFC
2012	109 %
2013	106 %
2014	103 %
2015 and beyond	100 %

As shown in Fig. 6, given the fact that certain vehicle technologies or attributes are widely deployed in the market but have adverse effects on vehicle fuel consumption, the fuel consumption limits and targets for vehicles with automatic transmissions or with more than three rows of seats are 6 % less stringent.

Unlike the United States, the European Union, and Japan, China has two parallel and complementary fuel consumption standards for passenger cars. The fuel consumption limits for passenger cars serve as the minimum requirements for each passenger car model. Production and sale are prohibited for those models failing to meet the limits. In addition, all domestic car manufacturers and car importers are required to comply with their individual CAFC targets, calculated on the basis of fuel consumption targets for vehicle groups, the production volume of each vehicle group, and the mix of the vehicle groups for each manufacturer or importer.

2.3.2 Light-duty commercial vehicles

In addition to the fuel consumption standard for passenger cars, fuel consumption limits have been set for LDCVs. These limits are applicable to commercial vehicles with a GVW not exceeding 3.5 t. The standard uses GVW and engine displacement as two attributes to classify vehicle models into different groups and set the corresponding fuel consumption limits. Table 3a, b, c, and d give the details of the categories and their corresponding fuel consumption limits. As in the case of passenger cars, to account for the diversified features of China's LDCVs with regard to technology, function, and fuel type, the standard has different limits for gasoline buses, diesel buses, gasoline trucks, and diesel trucks.

2.3.3 Heavy-duty commercial vehicles

Since fuel consumption test methods were established for HDCVs in 2011, China has carried out investigations on the fuel consumption of HDCVs by testing 314 HDCV models (Jin et al. 2011a). The test results were used to systematically analyze the fuel consumption and technical characteristics of HDCVs. After an evaluation of the effectiveness of various units, including

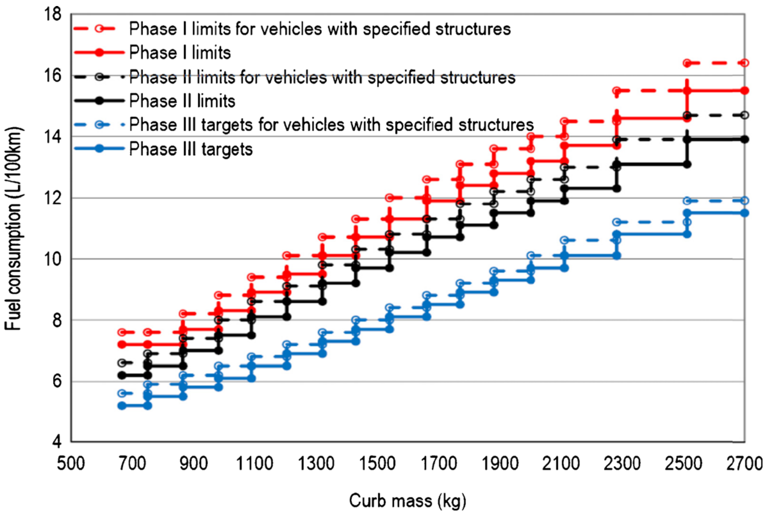

Fig. 6 Phase I/II limits and Phase III targets for passenger car fuel consumption rates

Table 3 Fuel consumption limits for gasoline and diesel vehicles

GVW (kg)	Engine displacement (L)	Phase I limits (L/100 km)	Phase II limits (L/100 km)
a Fuel consumption limits for gasoline vehicles in category N_1			
GVW≤2000	All vehicles	8.0	7.8
2000<GVW≤2500	V≤1.5	9.0	8.1
	1.5<V≤2.0	10.0	9.0
	2.0<V≤2.5	11.5	10.4
	V>2.5	13.5	12.5
2500<GVW≤3000	V≤2.0	10.0	9.0
	2.0<V≤2.5	12.0	10.8
	V>2.5	14.0	12.6
GVW>3000	V≤2.5	12.5	11.3
	2.5<V≤3.0	14.0	12.6
	V>3.0	15.5	14.0
b Fuel consumption limits for diesel vehicles in category N_1			
GVW≤2000	All	7.6	7.0
2000<GVW≤2500	V≤2.5	8.4	8.0
	2.5<V≤3.0	9.0	8.5
	V>3.0	10.0	9.5
2500<GVW≤3000	V≤2.5	9.5	9.0
	2.5<V≤3.0	10.0	9.5
	V>3.0	11.0	10.5
GVW>3000	V≤2.5	10.5	10.0
	2.5<V≤3.0	11.0	10.5
	3.0<V≤4.0	11.6	11.0
	V>4.0	12.0	11.5
c Fuel consumption limits for gasoline vehicles in category M_2			
GVW≤3000	V≤2.0	10.7	9.7
	2.0<V≤2.5	12.2	11.0
	2.5<V≤3.0	13.5	12.2
	V>3.0	14.5	13.1
GVW>3000	V≤2.5	12.5	11.3
	2.5<V≤3.0	14.0	12.6
	V>3.0	15.5	14.0
d Fuel consumption limits for diesel vehicles in category M_2			
GVW≤3000	V≤2.5	9.4	8.5
	V>2.5	10.5	9.5
GVW>3000	V≤3.0	11.5	10.5
	V>3.0	12.6	11.5

fuel consumption per 100 km, fuel consumption per metric ton per kilometer, and fuel consumption per 100 km per seat, vehicle weight was selected as the reference attribute and fuel consumption per 100 km was chosen as the unit. HDCVs are classified into groups and sub-groups based on their GVWs. Fuel consumption limits are specified for each sub-group.

As the first step to promote HDCV fuel conservation, China issued its voluntary industry standard on fuel consumption limits for HDCVs in 2011 (Jin et al. 2011b). It covers three HDCV categories with large production and sales volumes: trucks, semi-trailer towing vehicles, and buses. Following the industry standard, a stricter national standard was subsequently developed with all HDCV types covered.

As an example, Fig. 7 shows comparisons between fuel consumption limits and test results for new truck models in 2012. On average, the fuel consumption limits for trucks specified in the national standard are 12.5 % stricter than those of the industry standard, and about 45 % of new trucks in 2012 could satisfy the national standard, which was implemented in July 2014 (Jin et al. 2014a).

2.4 Fuel consumption rate labeling

Fuel consumption rate labeling for LDVs was introduced in 2009 to provide fuel efficiency information to consumers. It is applicable to gasoline and diesel LDVs with a GVW not exceeding 3.5 t. Currently, hybrid electric vehicles and alternative-fuel vehicles are exempt from the requirements. As shown in Fig. 8, the label not only indicates fuel consumption rate during urban, suburban, and combined driving cycles but also provides the fuel consumption limit that a given vehicle model must comply with.

3 Implementation of fuel consumption standards

3.1 Policies and measures for standard implementation

3.1.1 Market access permit control

China controls the establishment of auto manufacturers and the production and sales of vehicle models through the regular Announcement of Vehicle Manufacturers and Products (AVMP) system, which was administered by NDRC previously and by MIIT now. Vehicle models not

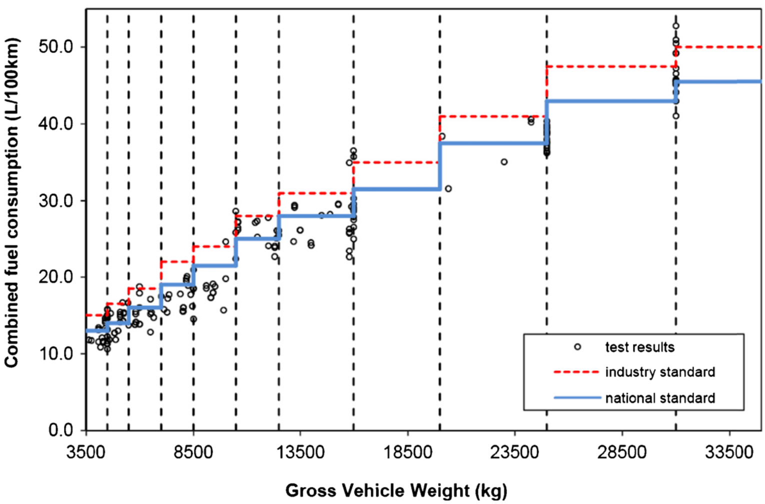

Fig. 7 Comparisons between fuel consumption limits and test results for trucks in 2012

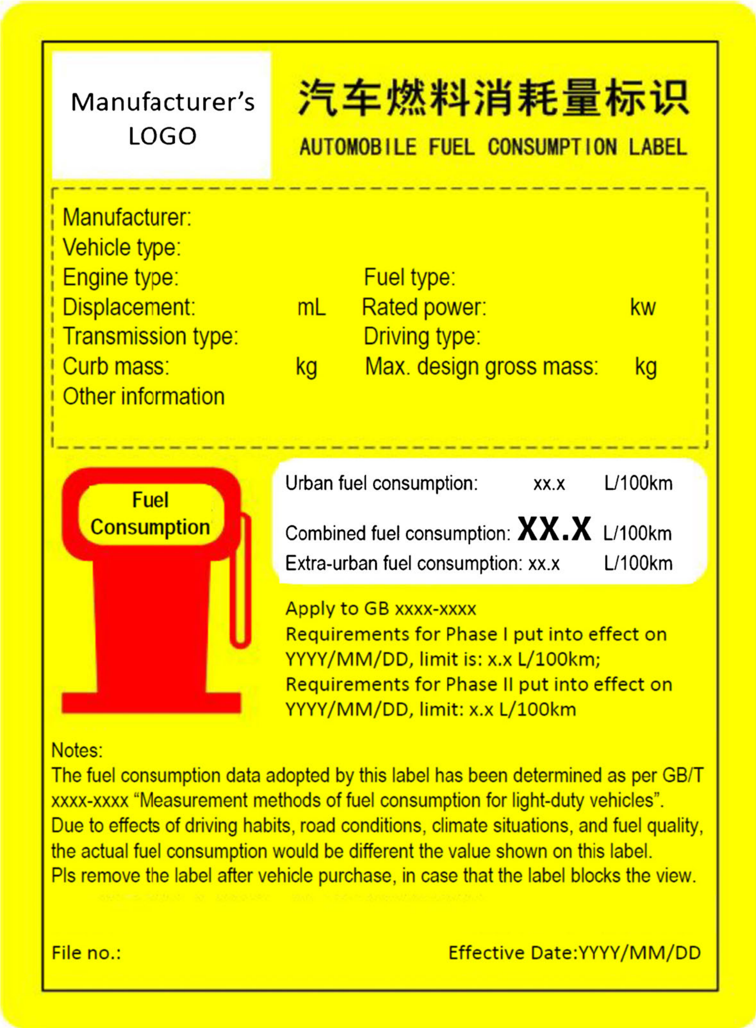

Fig. 8 Fuel consumption rate label for LDVs

included in the product catalog in the Announcement are not allowed to be produced, sold, or registered. According to the implementation dates for the fuel consumption standard schedule shown in Table 4, the NDRC added the fuel consumption requirements for passenger cars in 2005 and for LDCVs in 2008. Only vehicles complying with the corresponding fuel consumption limits can be approved to be listed in the AVMP for production, sales, and registration, and those not meeting the standards are eliminated from the product catalog. For example, in 2006, the NDRC eliminated 444 passenger car models from the AVMP product catalog owing to failure to comply with fuel consumption limits.

At the beginning of July 2012, the MIIT enforced the recommended industry standard for fuel consumption limits for HDCVs by incorporating the fuel consumption requirements for HDCVs into the AVMP. It also provided definitions of vehicle families and conditions for basic models and variant models of HDCVs.

Table 4 Implementation dates of fuel consumption limit standards

Vehicles	Phase I		Phase II	
	Newly approved vehicle models	Vehicle models in continued production	Newly approved vehicle models	Vehicle models in continued production
Passenger cars	July 1, 2005	July 1, 2006	Jan. 1, 2008	Jan. 1, 2009
LDCVs	No requirement	Jan. 1, 2009	Feb. 1, 2008	Jan. 1, 2011
HDCVs	July 1, 2012	July 1, 2014	July 1, 2014	July 1, 2015

3.1.2 Administrative system for labeling, documenting, and announcing the fuel consumption of LDVs

In 2008, the MIIT issued the Administrative Rule on Fuel Consumption Labeling of LDVs. The rule required fuel consumption rates of all newly produced or newly imported gasoline and diesel LDVs for sale in China to be reported to the MIIT, and required fuel consumption rate labels to be attached to vehicle windows beginning in January 1, 2010. The MIIT designated China Automotive Technology and Research Center (CATARC) to check and verify whether the requirements were being met by auto manufacturers and importers. The MIIT also publishes monthly LDV fuel consumption information at the government's official website.

3.1.3 Mechanism for calculating the CAFC of passenger car manufacturers

In its rule on Passenger Cars CAFC Calculation Method, issued in March 2013, the MIIT specifies the subject, scope, and method associated with calculating the CAFCs for passenger car manufacturers and importers and the procedure for collecting, reporting, and verifying fuel consumption data. The rule also specifies the system for calculating and publishing the CAFCs for domestic car manufacturers and car importers. Three specific measures are part of the rule. First, manufacturers are the basic subjects of the CAFC calculation. All manufacturers engaged in selling passenger cars in China, including domestic car manufacturers and car importers, are included in the scope of management. Fuel consumption data are reported, and the CAFC value for each car manufacturer is calculated. Second, CAFCs of domestic car manufacturers and car importers of the same brands are calculated independently from each other. Third, if a manufacturer exceeds its CAFC target, the surplus quota will be calculated and a banking and transfer system for the surplus quota will be established. Similarly to the CAFE credit scheme used in the United States, the surplus quota can be banked and carried forward for up to 3 years after the quota is earned.

3.1.4 Fiscal measures supporting vehicle fuel conservation

Fuel consumption standards have provided a basis for China to design fiscal and tax measures to encourage vehicle fuel conservation. In May 2010, China began to implement a fiscal measure to promote energy-conserving vehicles. Consumers who purchase passenger cars, including hybrid cars and dual-fuel cars, that have an engine displacement of not more than 1.6 L and meet the fuel consumption target specified in the Phase III standard will receive a subsidy of RMB 3000. In addition, starting in 2012, vehicle annual registration taxes for passenger cars meeting the Phase III fuel consumption standard were reduced by half.

3.2 Effects of implementing standards

With authorization by the NDRC and the MIIT, CATARC evaluated the effectiveness of the fuel consumption standard for passenger cars in 2006 and for LDCVs in 2010. Since 2011, on the basis of the fuel consumption labeling and documenting database, CATARC has been continuously monitoring and analyzing the fuel consumption and technical status of LDVs and publishing annual reports on LDV fuel consumption.

The fuel consumption standards shown in Fig. 3 and the supporting policies summarized in Table 5 have played a significant role in accelerating automotive energy conservation in China. Reductions in average fuel consumption have been observed in passenger cars, LDCVs, and HDCVs, as described below.

First, with the fuel consumption standard in place for passenger cars, the national average fuel consumption (NAFC) of passenger cars was reduced from 9.1 L/100 km in 2002 (Jin et al. 2006) to 7.4 L/100 km in 2012 (MIIT 2013). Consequently, the cumulative saved fuel from 2003 to 2012 was estimated to be 13.8 million tons and CO_2 emission reduction to be 45.4 million tons (Wang and Jin 2014). The saved fuel represented about 11 % of total fuel use in 2010, as shown in Fig. 9. These energy savings and CO_2 emission reductions were estimated with 2002 as the reference year and on the basis of the following assumptions: (a) only new passenger cars produced from 2003 to 2012 were taken into consideration; and (b) an annual mileage of 10,000 km was assumed for passenger cars (Wang et al. 2010).

Second, the NAFC of LDCVs was reduced from 9.9 L/100 km in 2006 to 8.8 L/100 km in 2009 (Jin et al. 2008, 2013), representing an annual rate of reduction of 3.6 %. The cumulative saved fuel for 2007 to 2012 was estimated to be 5.7 million tons and cumulative reduced CO_2 emissions to be 18.1 million tons (Jin et al. 2014a).

Third, with regard to HDCVs, it is estimated that cumulative saved fuel will amount to 5.0 million tons and CO_2 emission reductions to 15.6 million tons from 2013 to 2015. In particular, when Stage II standard for HDCVs is enforced, about 50 % of outdated HDCV models will be eliminated (Jin et al. 2014a).

Table 5 Measures supporting Chinese vehicle fuel consumption standards

Measure and scope	Implementation date		
Fuel consumption label for LDVs with a GVW not exceeding 3.5 t	Jan. 2010		
CAFC calculation for passenger cars with a GVW not exceeding 3.5 t	March 2013		
Subsidy for passenger cars with an engine displacement not exceeding 1.6 L and meeting fuel consumption targets	1st round: June 2010–Sept. 2011	2nd round: Oct. 2011–Sept. 2013	3rd round: Oct. 2013–Dec. 2015
Vehicle registration tax reduction for passenger cars with an engine displacement not exceeding 1.6 L and meeting fuel consumption targets	Jan. 2012		

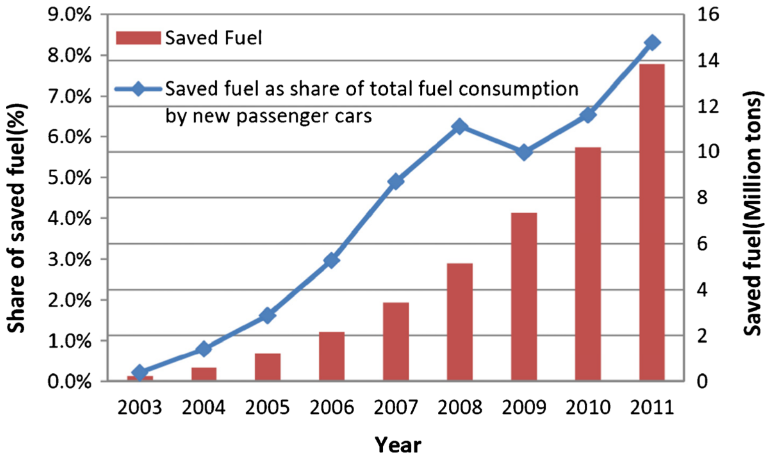

Fig. 9 Cumulative fuel saved by passenger car fuel consumption standards and saved fuel as percentage of fuel consumption in a given year

4 Problems identified in implementing fuel consumption standards and key issues for future consideration

4.1 Technical problems identified in implementing standards

4.1.1 Gaps between tested fuel consumption and actual fuel consumption

The NEDC driving cycle adopted to measure LDV fuel consumption (see Fig. 4) includes 4 km of urban driving and 7 km of suburban driving. This pattern is inconsistent with actual driving in China: Chinese LDVs operate primarily in urban areas with frequent starts, stops, accelerations, and decelerations. Mainly because of this inconsistency, fuel consumption tested on the NEDC is lower than that during actual driving. It was estimated that the actual fuel consumption level of Chinese passenger cars is about 16 % higher than that measured by testing on the NEDC (Huo et al. 2011).

Moreover, conformity-of-production (COP) testing with regard to the fuel consumption specified in the standard does not reflect actual on-road deterioration well. The fuel consumption associated with on-road deterioration is accounted for by using a fixed deterioration coefficient of 0.92 as specified in UN ECE R 101. However, actual test data indicated that the fixed rate of 0.92 is so easy to meet that manufacturers may take advantage of this in COP tests. For this reason, almost all Chinese and European manufacturers chose to adopt the fixed deterioration rate rather than the measured rates in COP tests (Wen et al. 2013).

The measurement method for fuel consumption of HDCVs also has technical shortcomings and needs to be improved. First, since requirements for gear shifting are not specified, the results of tests on chassis dynamometers with vehicles driven by different drivers can differ significantly. Second, the accuracy of the coast-down test is highly sensitive to environmental factors (such as wind speed), and the test is time-consuming and costly. Third, the gear-shifting strategy and the interpolation calculation of the analog computation program need improvements. There is a discrepancy between the results of interpolation calculations and the measured values from chassis dynamometer tests. Fourth, the Chinese-WTVC and the characteristic mileage distributions need improvements to be consistent with statistics of actual mileage and the results of fuel consumption surveys.

4.1.2 Disconnection between HDCV fuel consumption tests and emission tests

For LDVs, emissions and fuel consumption are measured by using the same test cycle in single tests. However, in the case of HDCVs, engine emissions are measured on an engine dynamometer, independently of fuel consumption measurement with the whole vehicle. The results of engine tests do not show a good correlation with the test results of whole vehicles.

In addition, the independence between emission tests conducted on engines and fuel consumption tests conducted on complete vehicles leads to the disconnection of the management of engine emissions and vehicle fuel consumption. To achieve good results in both emission tests and fuel consumption tests, vehicle manufacturers can take advantage of this disconnection and design different control strategies (Jin et al. 2014b). This practice results in no optimization for either energy conservation or emission reduction of HDCVs in China.

4.1.3 Potentially overstated CO_2 emission reductions from new energy vehicles

NEVs are considered as a solution to energy and environmental problems by many countries and regions around the world. As clearly specified in the Energy Conservation and New Energy Auto Industry Development Plan 2012–2020, the cumulative production and sales volume of EVs and PHEVs will reach 0.5 million by 2015. In 2020, the production capacity for EVs and PHEVs will reach 2 million, and their cumulative production and sales volume will amount to 5 million. However, the progress towards these targets has been slow. Even though China reached a historic high in EV production at about 83,900 in 2014, this is only 25 % of the target of 336,000 by 2015 specified in the national NEV pilot program, and there is only 1 year left for meeting the overall target (MIIT 2014a, b, c, 2015).

NEVs do represent a very promising solution to energy problems because of their ability to operate without petroleum fuels. However, unlike vehicles powered by combustion engines, for which most of the energy from the fuel is consumed by engines while the vehicles are operating, NEVs incur most energy losses during the electric power generation stage. Two key factors will have significant impacts on whether EV usage could result in CO_2 reductions in the future. One is the energy efficiency of EVs relative to that of conventional vehicles, and the other is the share of electricity from renewable energy sources. The fraction of electricity generated from coal is a critical parameter for evaluating the energy and environmental performance of NEVs. In 2012, coal-fired electricity accounted for 72 % of total Chinese electricity generation (Wei 2013), while the average energy efficiency of coal-fired power plants in China is currently only about 35 %. Studies at Tsinghua University using the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model have shown that the CO_2 emissions attributable to electric vehicles powered by coal-fired electricity could be equal to those of vehicles powered by gasoline combustion engines (Huo et al. 2010). If CO_2 emissions from upstream electricity production are ignored, the potential of NEVs to save energy and reduce CO_2 emissions will be overstated. It is necessary to compare the energy consumption of NEVs with gasoline or diesel vehicles throughout their lifecycles.

4.1.4 The lack of representative driving cycles for vehicle fuel consumption tests

As mentioned above, the road traffic conditions, vehicle mileage distribution, and driving habits of drivers in China differ from those in other countries. As a result, driving cycles developed in other countries cannot truly reflect the actual driving conditions in China. Some vehicle models developed on the basis of foreign driving cycles are unsuitable for road and traffic conditions in China and could have problems such as insufficient acceleration, lower reliability, and significantly poorer energy conservation and emission performance. These effects could be severe, especially in tropical, frigid, and plateau regions.

4.2 Administrative problems in implementation of standards

4.2.1 Vague Chinese automotive energy conservation laws

The United States, Japan, and the European Union have all passed and enforced special laws or acts to regulate and strengthen the administration of automotive energy conservation. For example, the United States passed the Energy Policy and Conservation Act in 1975. In Japan, motor vehicles were incorporated into the Energy Utilization Reasonability Law by means of specific requirements for automotive energy conservation, including administrative procedures, responsible bodies, and relevant parties' duties (METI 2008). However, the Energy Conservation Law in China neither stipulates clear administrative requirements and procedures for automotive energy conservation nor specifies clear responsibilities and authorities of relevant governmental agencies. The vagueness of the law remains a major obstacle to setting up comprehensive administrative policies and regulations on automotive energy conservation in China.

4.2.2 Overlapping and confusing administration of motor vehicles with multiple management responsibilities

China does not have a law to regulate all aspects of road vehicles systematically; instead, multiple government agencies manage the auto industry and vehicles in accordance with authorization from several different laws, and often, the authorization is unclear, causing overlaps and conflicts among the ministries. For example, according to the Administrative License Law, auto products should be governed by the agency responsible for the auto industry (the MIIT now). The Energy Conservation Law, however, authorizes the Ministry of Transportation (MOT) to implement energy conservation controls on vehicles for commercial transport of passengers or goods. Ideally, the two ministries should work together to share administrative functions, with the MIIT responsible for market access of new vehicle models based on their fuel consumption performance and the MOT responsible for monitoring real on-road performance and eliminating out-of-date vehicles from operation. In practice, however, because most vehicles in operation are owned by self-employed individuals or small transportation companies and are very difficult to monitor, the MOT has moved its management responsibilities upstream to the market access of new commercial vehicle models. Because vehicles in commercial operation constitute the overwhelming majority of commercial vehicles, the shifting of MOT's focus to market access has, in fact, caused an overlap with the MIIT in market access control for commercial vehicles but, at the same time, a gap in the monitoring of in-use vehicles. This administrative misallocation has not only had an adverse impact on automotive energy conservation but has also imposed double financial and administrative burdens on auto manufacturers.

4.2.3 Over-reliance on technical standards without long-term comprehensive policies in the administration of automotive energy conservation

Achieving automotive energy conservation is a long-term, systematic task requiring joint efforts of relevant governmental agencies, the auto industry, and consumers. In contrast to the United States, the European Union, and Japan, the most significant problem in the administration of automotive energy conservation in China is too much reliance on technical standards or regulations without comprehensive policy measures. As noted in Section 3.1.4, China has implemented several fiscal measures to encourage the purchase of energy-conserving vehicles with low fuel consumption, namely, providing subsidies for consumers and halving the annual vehicle registration tax. However, all these measures are temporary incentives for consumers and do not include any financial penalties for products or manufacturers that fail to achieve the specified performance. Without a comprehensive administrative mechanism, individual measures cannot be expected to have a long-term effect in guiding and regulating energy conservation in the auto industry.

4.2.4 Failure to control market access by imported cars with high fuel consumption

For a long time, domestic and imported vehicles have been regulated by different governmental agencies in China, and standards for fuel consumption limits have never been practically implemented to control market access by imported vehicles. For this reason, numerous vehicle models with high or substandard fuel consumption have been imported into China. In other words, a preferential policy has been in place for imported vehicles. As a result, domestic and overseas manufacturers are treated unequally, and the volume of imported vehicles with high fuel consumptions has steadily risen.

Exemption of imported vehicles from the fuel consumption limit standards has greatly offset the effectiveness of reducing the fuel consumption and CO_2 emissions of domestic vehicles. According to the MIIT, from July 1 to December 31, 2012, the average fleet fuel consumption for 83 domestic passenger car manufacturers was 7.3 L/100 km, and the average fleet fuel consumption for 25 imported passenger car dealers was 9.2 L/100 km, 25 % higher than the former (MIIT 2013).

The good news is that China has realized the adverse impacts of biased fuel consumption administration and has begun to correct it in newly released policies. The most influential policy to date is the CAFC calculation rule for passenger cars, which regulates domestic and imported vehicles equally.

4.2.5 Lack of punitive measures against substandard products and noncompliant manufacturers

As mentioned previously, in 2009, the MIIT issued and implemented an administrative rule that requires LDV manufacturers and importers to file fuel consumption information and attach fuel consumption labels to vehicle windows. However, as indicated by an actual survey, owing to the lack of a supervision system and punitive measures, the implementation of the standards depends primarily on the willingness of manufacturers and on social pressure. In practice, some manufacturers (domestic and overseas) fail to attach fuel consumption labels to vehicle windows as required, or they selectively attach labels only to the vehicles with low fuel consumption.

A similar problem occurs with regard to the rule on the passenger car CAFC calculation method. Since the rule only specifies the method and procedure for calculating the CAFC without mentioning punitive measures against noncompliance, manufacturers take a wait-and-see attitude. This adversely affects the achievement of the overall energy conservation objective for 2015.

4.3 Recommendations for future consideration

We present here a few recommendations to improve the development and implementation of Chinese vehicle fuel consumption standards. First, a comprehensive administrative system for automotive energy conservation needs to be established. This system should be designed to further develop and strengthen the legal and regulatory system for automotive energy conservation, to clearly define the responsibilities of different governmental agencies, to improve the management of automotive energy conservation, and to build a comprehensive administrative mechanism that covers fuel consumption standards, administrative policies, and fiscal measures.

Second, the fuel consumption measurement and evaluation system need to be improved. Fuel consumption testing methods for both LDVs and HDCVs need to be revised to closely represent Chinese consumer driving behaviors. The energy consumption of NEVs needs to be evaluated throughout the fuel life cycle. An equivalency conversion among different vehicle propulsion systems needs to be developed by considering the energy conversion efficiencies of different energy sources. Fuel consumption labeling requirements for LDVs should cover electric vehicles and alternative-fuel vehicles. Meanwhile, a fuel consumption labeling scheme for HDCVs should be developed.

Third, medium-term and long-term fuel consumption standards should be investigated. To respond to global energy and climate change problems, new efforts are being made to tighten vehicle fuel consumption standards and regulations in major countries. For example, the United States, the European Union, and Japan have issued fuel consumption standards and regulations for 2020 and beyond (see Fig. 10). In 2012, China specified strict fuel consumption requirements for passenger cars by 2020, but the targets for LDCVs and HDCVs have not yet been announced.

It is also important to look forward even further, to the potential goals for these three major vehicle categories by 2025 and 2030. A 2050 vision considering the needs for both energy conservation and climate change will also help guide the development of a technology roadmap and long-term policies.

5 Conclusions

It is expected that China will pass the United States to have the world's largest vehicle fleet in about 10 years. While there has been some success with the existing vehicle fuel consumption

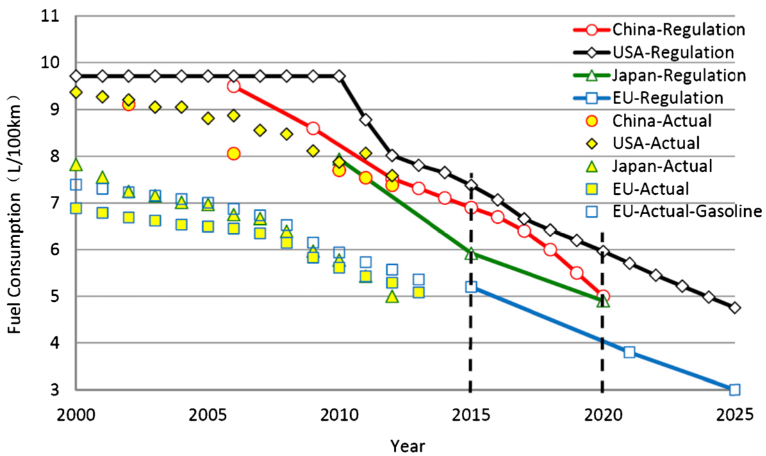

Fig. 10 Vehicle fuel consumption standards in major countries and regions

regulation system, in order to address its oil security problem and the global warming challenge, China needs to strengthen its vehicle fuel consumption regulations aggressively. Looking forward, the central government needs to set up a clear jurisdictional authority on vehicle energy conservation across ministries such as the NDRC, the MIIT, the MOT, and the Ministry of Environmental Protection. A clear long-term vision by 2050 and ambitious concrete medium-term targets by 2030 will help guide the policy development. Policy enforcement requires close monitoring, evaluation, and improvement to ensure expected impacts. Key technical issues, including test methods, driving cycles, and integrated emissions and fuel consumption testing, need further investigation and improvement.

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