BRIEFING

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The Stage 4 proposed amendment to China's heavy-duty vehicle fuel consumption standard: ICCT reflections

Authors: Shiyue Mao, Liuhanzi Yang, and Yichen Zhang

INTRODUCTION

China's heavy-duty vehicle (HDV) sector consumes about half of total on-road fuels with only a fraction (~10%) of the nation's vehicles.[1] Over the past decade, China has limited the fuel consumption of the HDV fleet. In 2012, China mandated an HDV fuel consumption standard, known as Stage 1, and amended it twice, in Stages 2 and 3. ICCT has analyzed and summarized key information related to Stages 1-3 in previous work.[2] In June of 2022, a Stage 4 proposal was published by the government for public comment. (Figure 1.)

1 Oscar Delgado, *Stage 3 China Fuel Consumption Standard for Commercial Heavy-Duty Vehicles*, (ICCT: Washington, DC, 2016), https://theicct.org/publication/stage-3-china-fuel-consumption-standard-for-commercial-heavy-duty-vehicles/.

2 Shiyue Mao, Pierre-Louis Ragon, and Felipe Rodríguez, *The Evolution of Commercial Vehicles in China: A Retrospective Evaluation on Fuel Consumption Standards and Recommendations for the Future*, (ICCT: Washington, DC, 2021) https://theicct.org/publication/the-evolution-of-commercial-vehicles-in-china-a-retrospective-evaluation-of-fuel-consumption-standards-and-recommendations-for-the-future/; Shiyue Mao and Felipe Rodríguez, *The Evolution of Heavy-Duty Vehicles in China: A Retrospective Evaluation of CO_2 and Pollutant Emissions from 2012 to 2021*, (ICCT: Washington, DC), https://theicct.org/publication/china-hvs-ndc-tia-evolution-hdv-emissions-oct22/.

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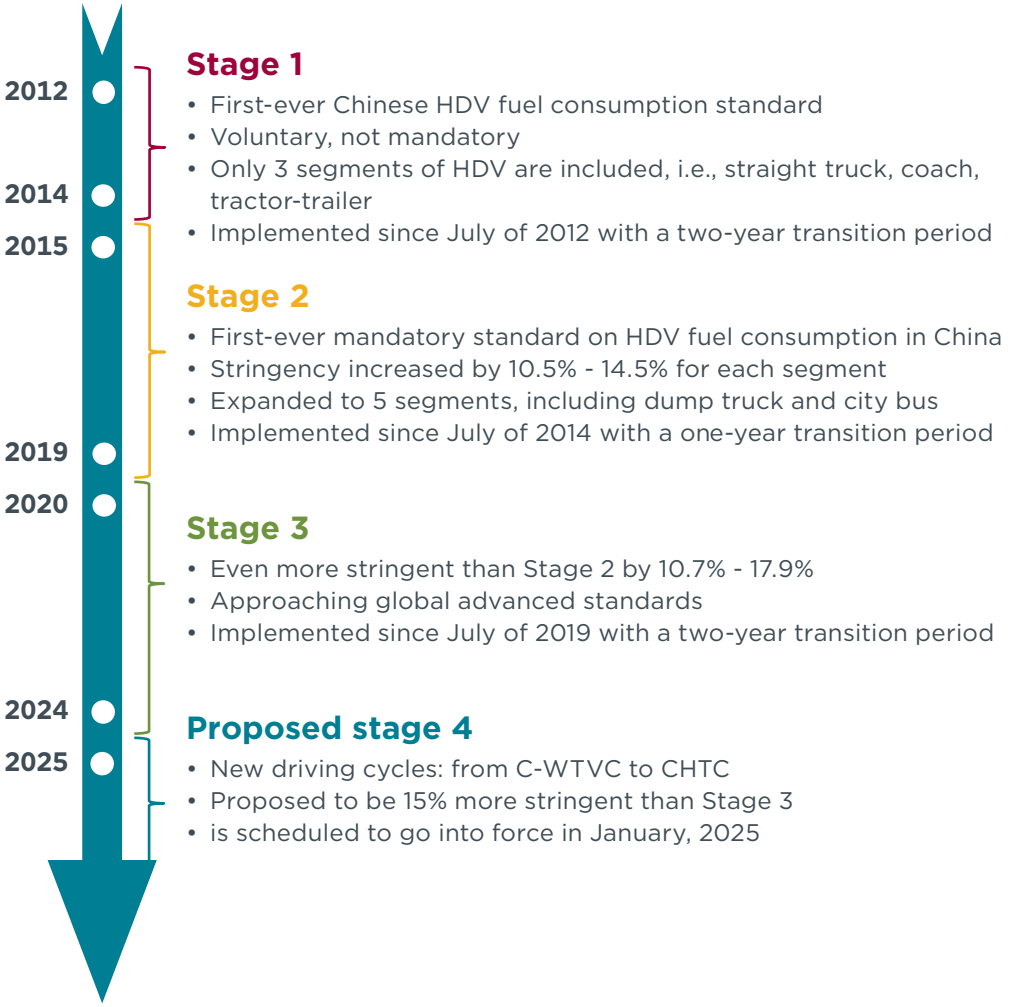


Figure 1. Timeline of China HDV fuel consumption standards

HIGHLIGHTS OF THE PROPOSAL

The China Automotive Technology and Research Center (CATARC) proposed the updated regulation, which retains the same scope as the last two stages of national standards (GB 30510), by setting limits on fuel consumption of new straight trucks, dump trucks, tractor-trailers, coaches, and city buses with a gross vehicle weight greater than 3,500 kg. Similar to the previous two stages, the Stage 4 standard will regulate heavy-duty vehicles with diesel and gasoline engines. The new standard is scheduled to take effect on January 1, 2025 for new type-approvals[3], and on July 1, 2026 for all new heavy-duty vehicles in China.

Stage 4 builds on Stage 3 in several major ways, by

» Proposing more stringent fuel consumption limits for vehicle categories

» Applying new driving cycles (CHTC) for new vehicle type-approvals

» Harmonizing the conversion rate of CO_2 emissions as 2,600 g/L for diesel and 2,370 g/L for gasoline

» Clarifying the criteria for type-approval of new variant models.

3 Legacy models that are type-approved before January of 2025 will still be sold during a transition period.

FUEL CONSUMPTION LIMITS

Figure 2 illustrates detailed limits for each gross weight range of vehicle categories. Stage 4 is designed to follow the practice of previous regulations and incorporate step-like and per-vehicle limits. The limits under Stage 4 are 20% to 30% lower than those of Stage 2. However, the stringency varies across vehicle segments and weight categories. Figure 3 illustrates the detailed development on limits from Stage 2 to Stage 4 for each weight category and segment.

China aims to achieve "a leading position in the world" in terms of HDV fuel efficiency regulations. The new proposal is estimated to tighten fuel consumption standards by ~15%[4] as a general target across all vehicle segments.

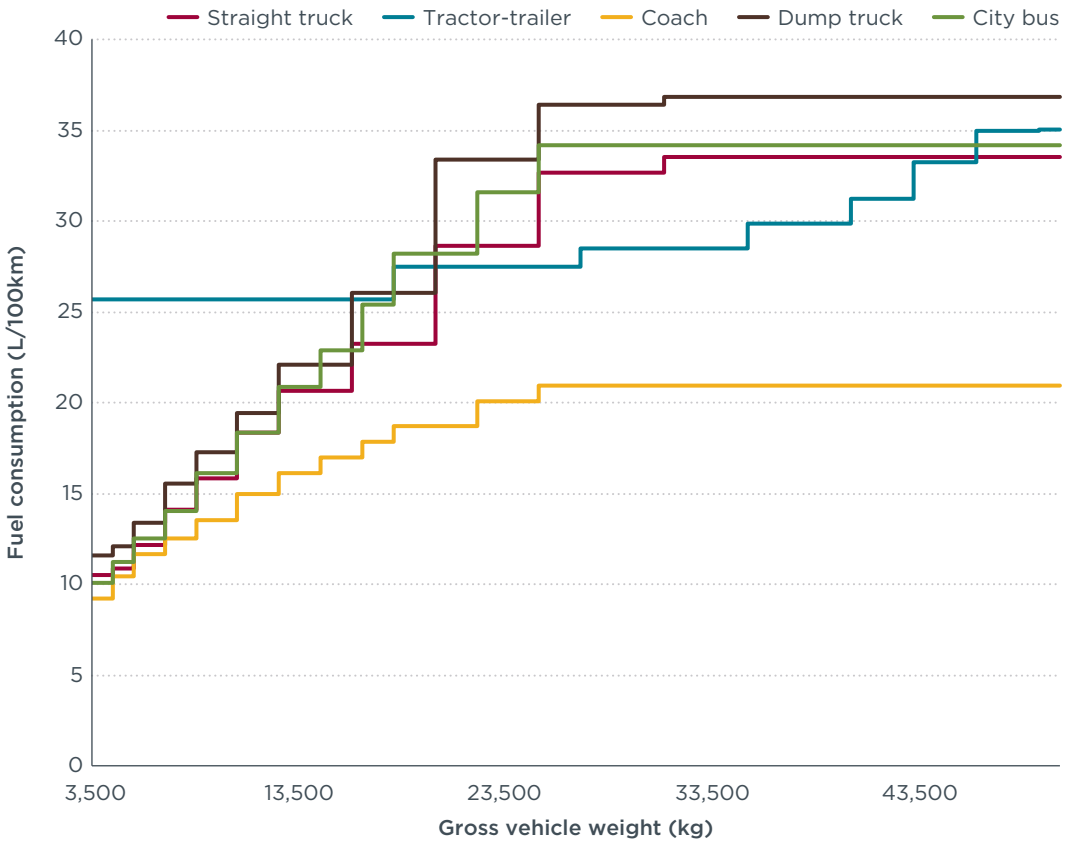


Figure 2. Proposed Stage 4 fuel consumption limits by vehicle category under CHTC cycles

4 This is not an official commitment, but 15% stringency over Stage 3 would be the major achievement of Stage 4, according to a statement from the proposal composer. Reference: https://mp.weixin.qq.com/s/pmWjt8FwUw5wvTNrUoWRsw

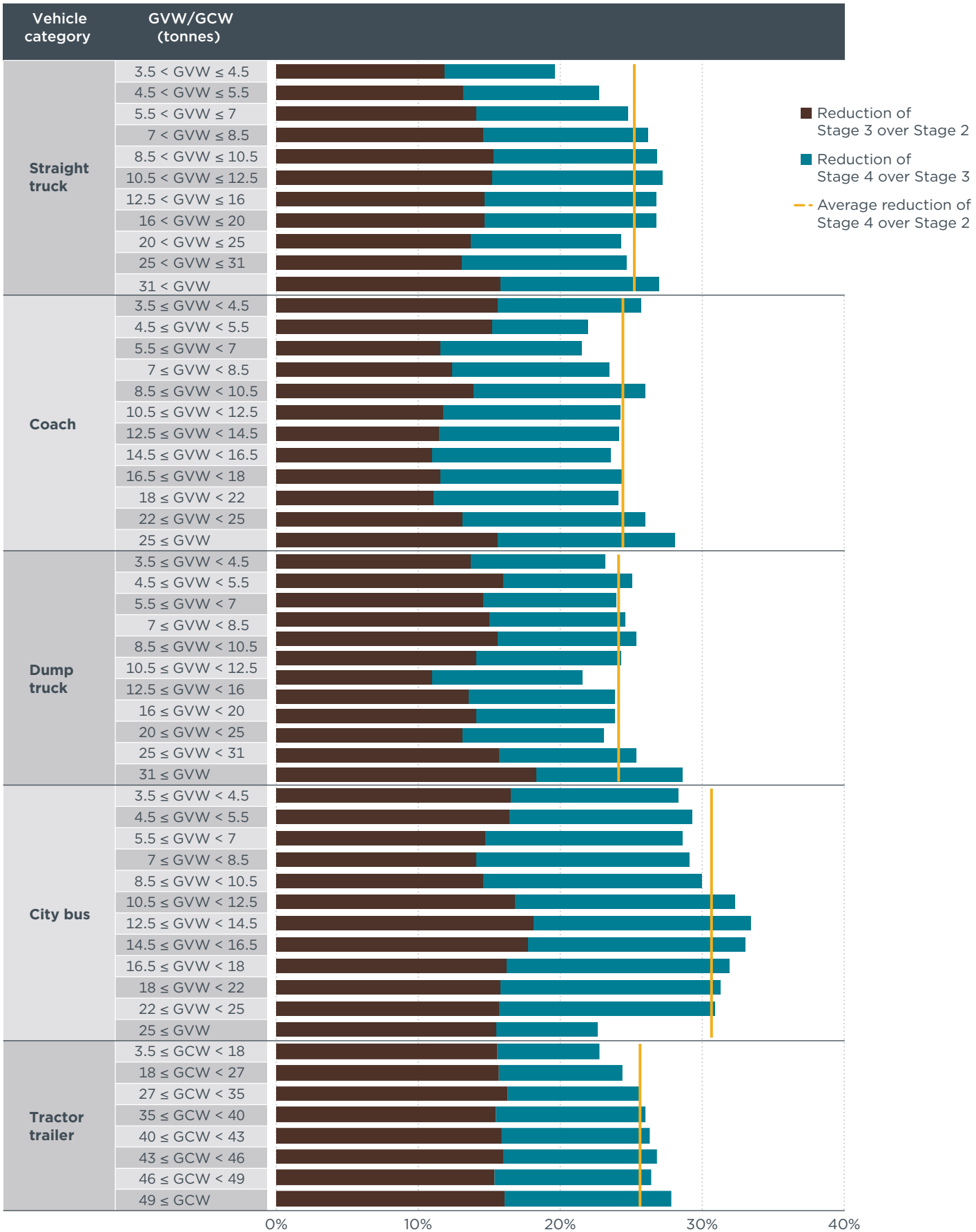


Figure 3. Stringency of each fuel consumption standard (Stage 2 to proposed Stage 4), all values are normalized to C-WTVC

TESTING CYCLES

In the Stage 3 standard, the China-World Transient Vehicle Cycle (C-WTVC) was used to evaluate fuel consumption in the laboratory. The C-WTVC has an urban portion, a rural portion, and a highway portion (Figure 4). Due to huge differences in operational scenarios and vehicle specifications across vehicle categories, vehicle categories with different GVWs get different weights in the C-WTVC. For example, the fuel consumption of a 31-tonne tractor-trailer is calculated by weighting the highway portion at 90% and the rural portion at 10% in the C-WTVC, while the fuel consumption of a city bus is calculated weighting the urban portion at 100% in the C-WTVC. However, the C-WTVC was adjusted based on the World Transient Vehicle Cycle so it cannot fully represent real-world driving conditions in China. In addition, it is difficult to reflect real-world operating characteristics of multiple vehicle categories using a uniform driving cycle. Therefore, CATARC was commissioned by MIIT to develop a driving cycle that reflects real-world driving conditions in China. A total of 21 million kilometers' worth of driving data was collected in 41 cities in 2017, covering all five segments and more than 1200 HDVs. Based on these real-world data, China Heavy-duty Commercial Vehicle Test Cycles (CHTC) were developed for each vehicle segment (Figure 5). The new cycles were published in a national standard[5] in 2019 and will be used for fuel consumption measurement in Stage 4.

Compared to C-WTVC, the new cycles are judged by CATARC to be a closer estimation and representation of the real-world driving of HDVs. After switching the driving cycle from C-WTVC to CHTC, type-approved fuel consumption values increased by 5%, 2.7%, and 2.8% for dump truck, straight truck, and tractor-trailer models, respectively; also, city buses and coaches have 18% and 16.8% higher fuel consumption values under the CHTC, according to the official commentary document on Stage 4.[6]

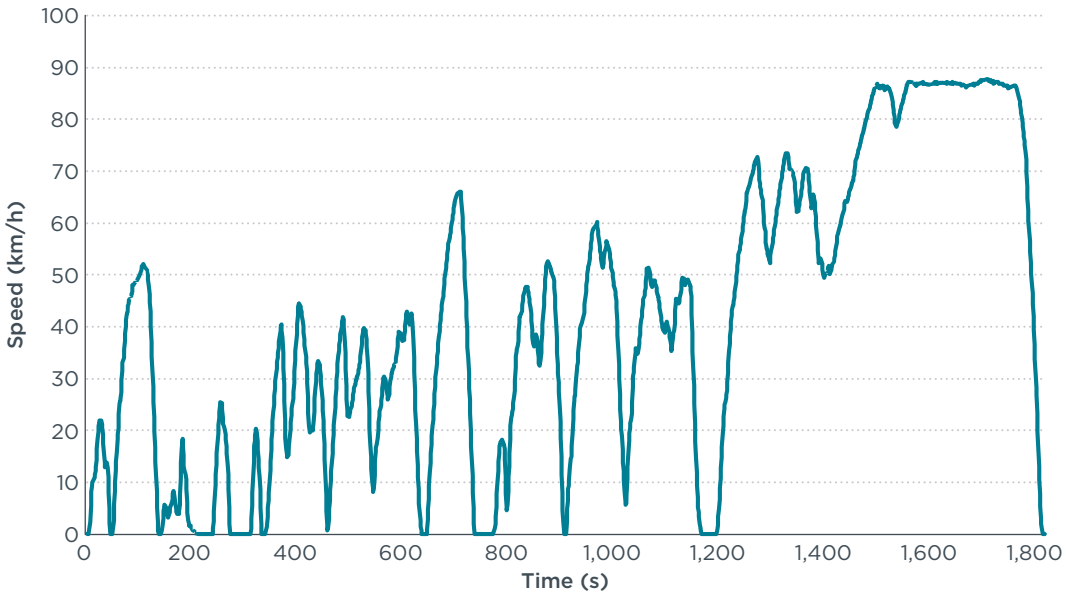


Figure 4. C-WTVC time-speed profile

5 China automotive test cycle- Part 2: heavy-duty commercial vehicles (GB/T 38146.2-2019), https://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=4C7F76459A8B840DAEFB2B16B33C397D

6 MIIT and CATARC,"公开征求《汽车软件升级通用技术要求》等九项强制性国家标准的意见" 2022, http://www.caam.org.cn/chn/10/cate_112/con_5236005.html.

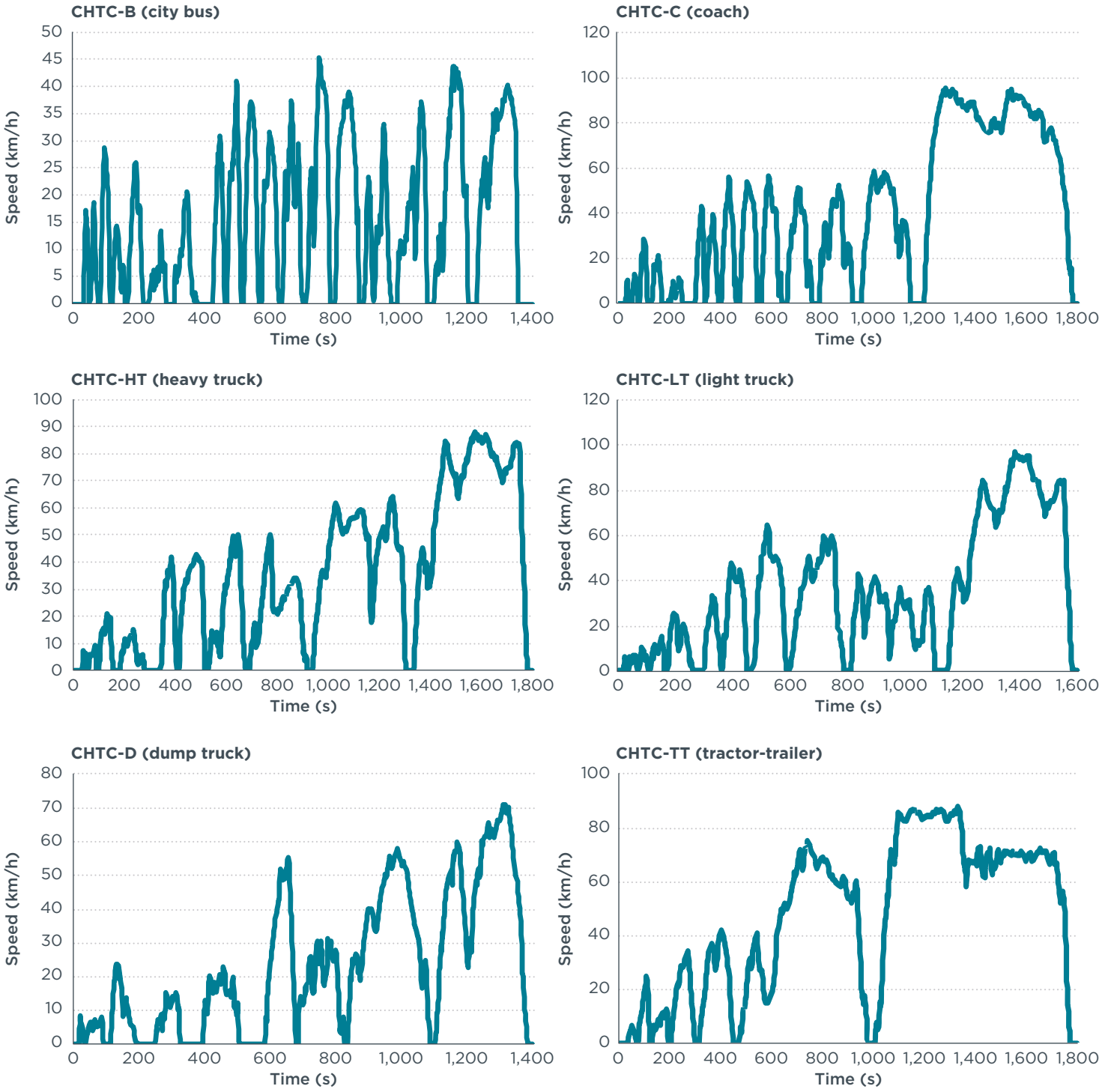


Figure 5. CHTC time-speed profiles for each vehicle category

Table 1. Characteristics of CHTC and C-WTVC driving cycles

Characteristics	Unit	CHTC-B	CHTC-C	CHTC-LT	CHTC-HT	CHTC-D	CHTC-TT	C-WTVC
Time	s	1310	1800	1652	1800	1300	1800	1800
Distance	km	5.49	19.62	15.88	17.33	8.37	23.22	20.51
Maximum speed	km/h	45.60	95.70	97.00	88.50	71.40	88.00	87.8
Maximum acceleration	m/s^2	1.26	1.25	1.14	1.14	1.24	0.81	0.917
Maximum deceleration	m/s^2	-1.32	-1.28	-1.17	-1.21	-1.08	-1.04	-1.033
Average speed (including stops)	km/h	15.08	39.24	34.62	34.65	23.19	46.44	40.997
Average driving speed (excluding stops)	km/h	19.43	47.98	39.49	40.16	29.07	50.82	-
Average acceleration	m/s^2	0.48	0.43	0.34	0.31	0.36	0.28	-
Average deceleration	m/s^2	-0.54	-0.48	-0.41	-0.45	-0.40	-0.36	-
Acceleration ratio	%	29.16	26.22	27.78	24.22	24.00	17.44	-
Deceleration ratio	%	25.88	22.56	23.55	18.06	22.08	15.78	-
Cruise ratio	%	22.60	33.00	36.32	44.00	33.69	58.17	-
Idle ratio	%	22.37	18.22	12.35	13.72	20.23	8.61	-

CONVERSION RATE OF CO_2 EMISSIONS

The proposal introduces an official formula to convert fuel consumption (L/100km) to CO_2 emissions (g/km).

$$R_{co2} = K_{co2} \times FC_L/100$$

Where:

R_{co2} is the estimated CO_2 emissions in g/km calculated from the fuel consumption of the vehicle model;

K_{co2} is the conversion factor in g/L, which equals to 2.37×10^3 for gasoline and 2.60×10^3 for diesel vehicle models; and

FC_L is the fuel consumption in L/100 km of the vehicle model.

TYPE-APPROVAL OF NEW VARIANT MODELS

Heavy-duty vehicles come in thousands of variant types to meet the demand of business owners for different use cases. In Stage 4, the criteria for type-approval of new variant models is clarified and emphasized. When a new variant model is being type-approved, the limit of fuel consumption shall be constant with respect to the base model when the new model:

- is manufactured by the same manufacturer with identical engine displacement, ignition type, fuel type, fuel intake system, ECU strategy, cylinder number and layout, etc.
- has 75%-100% of engine power of the base model
- has the same or less intake resistance (rated rotation speed, 100% payload)
- has the same or less exhaust back pressure of engine (rated rotation speed, 100% payload)
- has the same or less maximum power absorbed by engine-driven equipment at rated speed
- is classified as the same vehicle category, i.e., tractor-trailer, dump truck, straight truck, city bus, or coach

» is the same vehicle type and dimension: e.g., single- or double-deck bus
» has the same driver cabin
» has no more than 105% of the frontal area of the base model
» is no more than 105% of the width and height of the base model
» are no more than 105% of the gross vehicle weight of the base model
» has the same powertrain as the base model
» has the same gear type with no fewer gears than the base model
» has no more than 108% of total gear ratio of the base model
» has the same or larger static load radius of tire
» regards radial and diagonal tires as identical for the purposes of type-approval.

ANALYSIS OF THE STAGE 4 PROPOSAL

STRINGENCY OF THE STAGE 4 PROPOSAL

After normalizing to the C-WTVC, the Stage 4 proposal tightens fuel consumption limits for tractor-trailers, coaches, straight trucks, and dump trucks by 8%-18%. Straight trucks and dump trucks are the segments with the largest freight activity, measured in tonne-km. The Stage 4 proposal tightens fuel consumption limits by 11.2% (dump truck) and 12.6% (straight truck), failing to realize the communicated target of 15% stringency over Stage 3 (Figure 6).

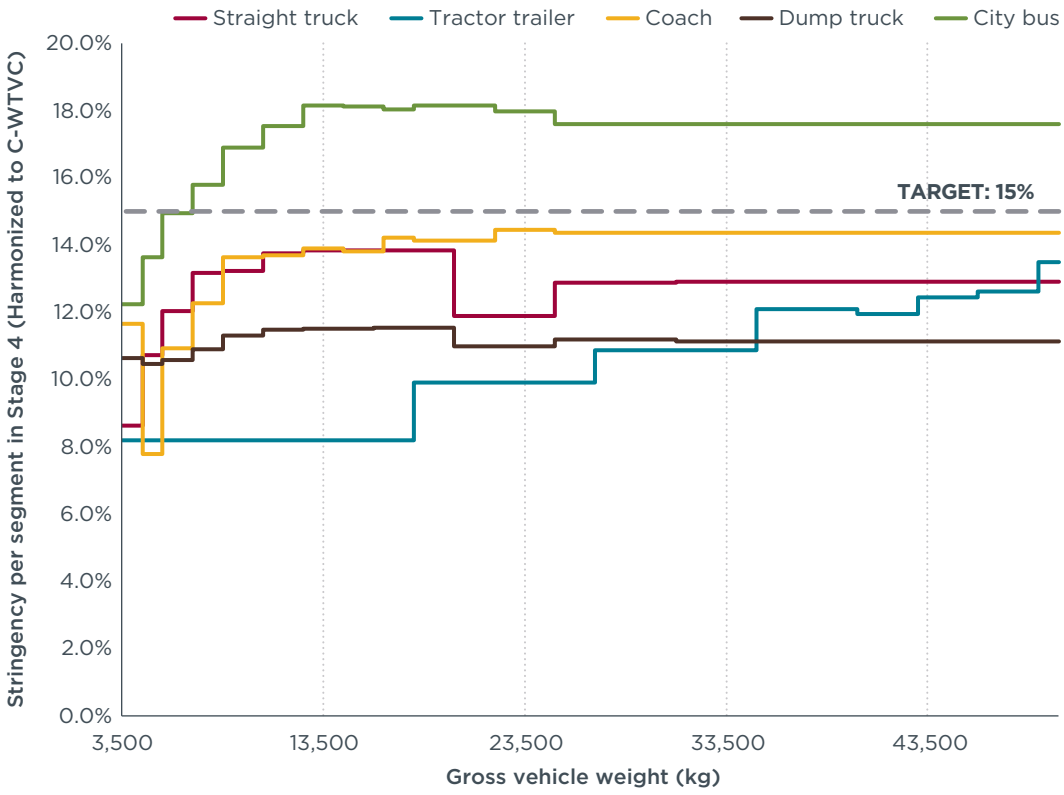


Figure 6. Stringency of vehicle categories by Stage 4 (proposed) over Stage 3

Table 1 shows the fuel consumption share of dump trucks and straight trucks by different weight ranges and the corresponding stringency of Stage 4 compared to Stage 3. Dump trucks and straight trucks contribute about 65% of the CO_2 emissions of all HDV categories, but the stringency of Stage 4 compared to Stage 3 only ranges

from 8.6% to 13.9%, much lower than the communicated stringency of 15%. According to public type-approval fuel consumption and sales data in 2021, heavy dump trucks with GVW of 20 to 25 tonnes and straight trucks with GVW of 3.5-4.5 and 12.5-16 tonnes consumed most fuels among all HDV categories. However, no special efforts are made in the proposal to curb fuel consumption in these weight ranges. This fact also implies that the Stage 4 proposal's effectiveness in reducing fuel consumption will be weaker than expected.

Table 2. Fuel consumption share and stringency information about dump trucks and straight trucks

GVWR (tonnes)	Dump truck		Straight truck	
	Fuel consumption share in 2021 (%)	Stringency of Stage 4 relative to Stage 3 (%)	Fuel consumption share in 2021 (%)	Stringency of Stage 4 relative to Stage 3 (%)
3.5-4.5	2.1	10.6	**8.0**	**8.6**
4.5-5.5	0	10.5	0	10.7
5.5-7.0	0.1	10.6	0.4	12.0
7.0-8.5	1.0	10.9	2.0	13.2
8.5-10.5	0.8	11.3	2.9	13.2
10.5-12.5	1.8	11.5	2.7	13.7
12.5-16	2.0	11.5	**7.9**	**13.9**
16-20	4.4	11.5	4.9	13.8
20-25	**7.1**	**11.0**	6.8	11.9
25-31	4.9	11.2	4.7	12.9
>31	0.1	11.1	1.2	12.9
Pct across all segments	**24.5**		**41.6**	

A RETROSPECTIVE EVALUATION OF THE STAGE 1, 2, AND 3 STANDARDS

Historical data shows that Stage 1-3 standards have not achieved significant fuel consumption improvement below the 2013 baseline. Using the type-approval data, Figure 7 shows the weighted-average fuel consumption of each HDV segment in China from 2013 to 2021. The China Stage 1 fuel consumption standard, which is a voluntary standard, filled the gap in fuel consumption limits for HDVs in China. However, due to lenient limits in the standard, the Stage 1 standard failed to play an adequate role in reducing the fuel consumption of HDVs in China. After the implementation of the Stage 1 standard in 2012, the average fuel consumption of dump trucks and straight trucks increased, and the weighted-average fuel consumption values of newly sold vehicles in 2015 were even higher than the base year 2013, by 15-20%.[7] The implementation of the Stage 2 fuel consumption standard in 2015 was a major effort, with the average fuel consumption of the HDV fleet in 2018 decreasing by about 20% compared to 2015, when Stage 2 took effect. In July of 2021, China officially implemented the Stage 3 fuel consumption standard for all new HDVs, but the average fuel consumption of all new HDVs sold in 2021 is only about 3% lower than the baseline of 2013, which can be found in Figure 7.

Over the entire period, the dump truck showed significant increases year by year, revealing an entirely different development pattern from other segments. This is mainly

7 Mao and Rodríguez, *The Evolution of Heavy-Duty Vehicles in China*.

due to an increase in weight and power for dump trucks; a 30% increase in power can be identified for dump trucks during the last decade, according to a report by ICCT.[8]

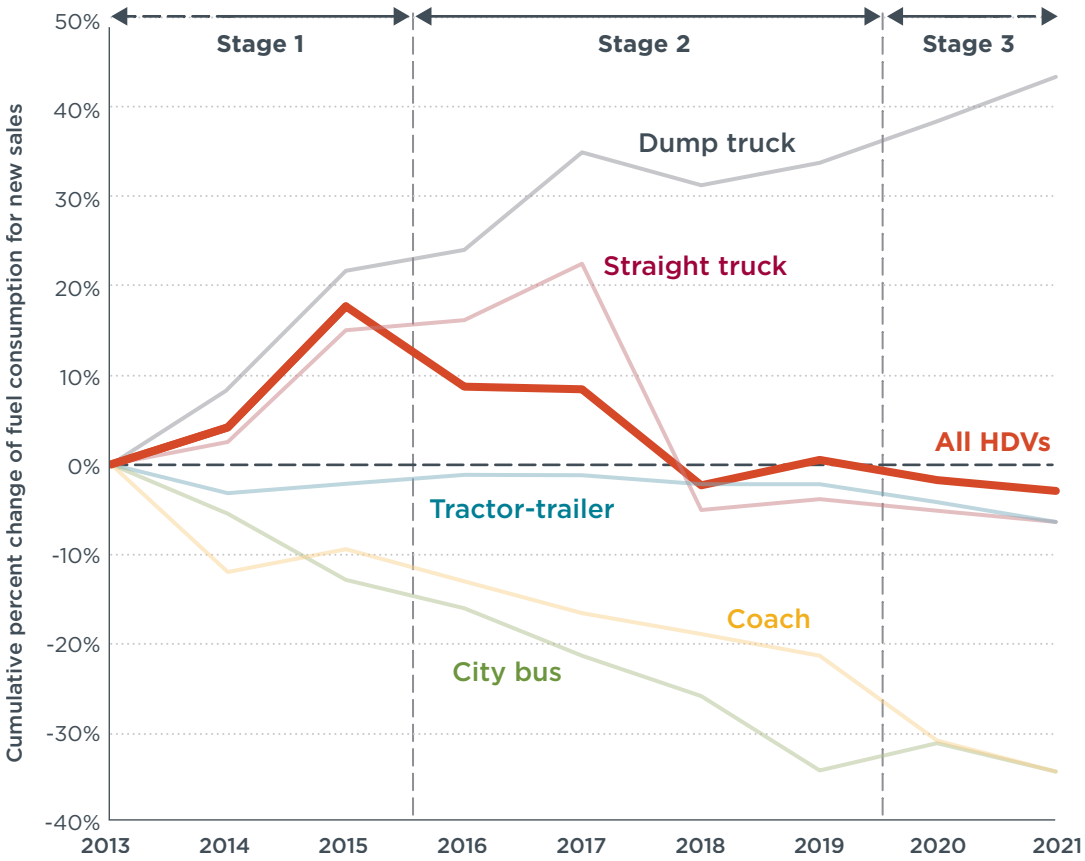
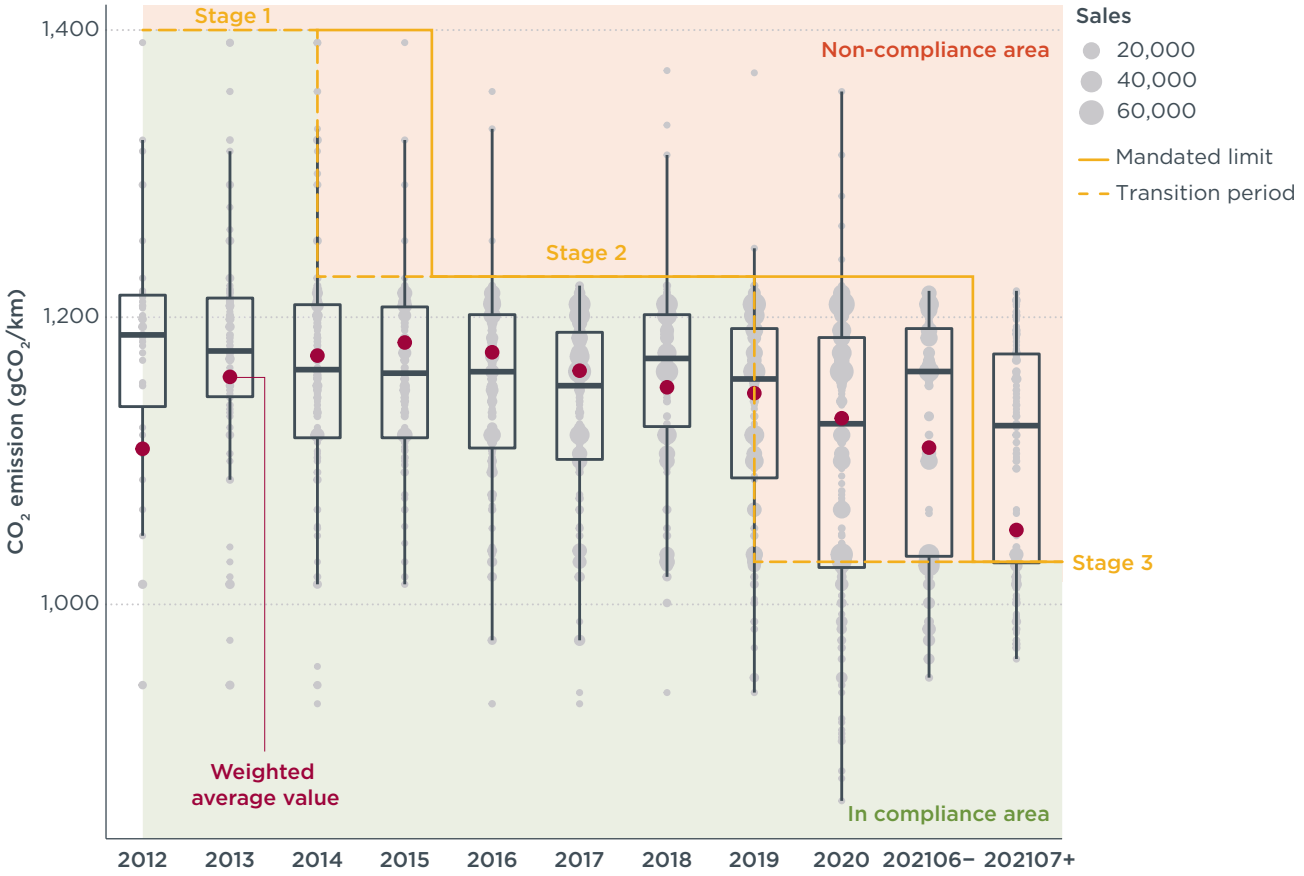


Figure 7. Weighted-average fuel consumption for heavy-duty vehicles, 2013-2021

Figure 8 shows development of fuel consumption of the new vehicle fleets of 46-49 tonne tractor-trailers between 2012 and 2021. Overall, the Stage 1 and Stage 2 standards are both lenient for this specific segment. Before implementation of Stage 2, the average fuel consumption of new tractor-trailers from 2012 to 2014 already met the Stage 2 requirements. After Stage 2 went into effect in 2015, the average fuel consumption of tractor-trailers (GVW ranging from 46 to 49 tonnes) tended to decrease. About 5% of the new tractor-trailers in this segment then met the Stage 3 standard five years before the implementation of the standard. Overall, the data suggests that Stage 1 and Stage 2 standards are too conservative to play an active role in pushing manufacturers to improve HDV fuel efficiency; Stage 3 functions well by capping fuel consumption in the heaviest weight category of tractor-trailers.

8 Mao and Rodríguez, *The Evolution of Heavy-Duty Vehicles in China*.



Note: The red dot represents the average value of CO_2 emissions in each year; all emissions are converted from fuel consumption with a conversion factor of 2,600g CO_2/(Liter of diesel * 100 km), according to the Chinese Stage 3 HDV fuel consumption testing standard. The yellow dashed line refers to a limit during the transition period for newly type-approved models with fresh MIIT registry code only, and the solid line indicates the standards for all updated type-approval models (including new type approvals and variants). Specifically, "202106-" and "202107+" refer to the first (January to June) and second (July to December) half of 2021, respectively.

Figure 8. Fuel consumption of tractor-trailers, 46-49 tonnes, during 2012-2021
Source: Mao and Rodríguez, The Evolution of Heavy-Duty Vehicles in China

TECHNOLOGICAL POTENTIAL

Type-approval data shows that the most fuel-efficient technologies currently available can still achieve up to a 20% improvement in fuel consumption from the proposed Stage 4 standard. As shown in Figure 9, type-approved values for ~10% of the new coaches in 2021 were below the limits in the Stage 4 proposal, which indicates that these coaches have already met the fuel efficiency requirement from the newly proposed stage before being enacted. Similarly, 2.7% of the new dump trucks and 3.6% of new straight trucks sold in 2021 already met the proposed Stage 4 limits. As an extreme case, the lowest type-approved value of straight trucks is 19% lower than the proposed Stage 4 limit. The most fuel-efficient case of dump trucks is likely 20% lower. This implies that advanced fuel-efficient technologies are available under the Stage 4 proposal, so Stage 4 can set more stringent limits and ambitious targets to encourage manufacturers developing and applying the advanced fuel-efficient technologies. While the application of these technologies increases upfront costs, these technologies also offer great fuel savings, benefits that exceed technology and maintenance costs by 1.2–5.0 times.[9]

9 Dan Meszler, Oscar Delgado, and Liuhanzi Yang, *Heavy-Duty Vehicles in China: Cost-Effectiveness of Fuel-Efficiency and CO_2 Reduction Technologies for Long-haul Tractor-trailers in the 2025–2030 Timeframe*, (ICCT: Washington, DC, 2019), https://theicct.org/publication/heavy-duty-vehicles-in-china-cost-effectiveness-of-fuel-efficiency-and-co2-reduction-technologies-for-long%e2%80%91haul-tractor%e2%80%91trailers-in-the-2025-2030-timeframe/.

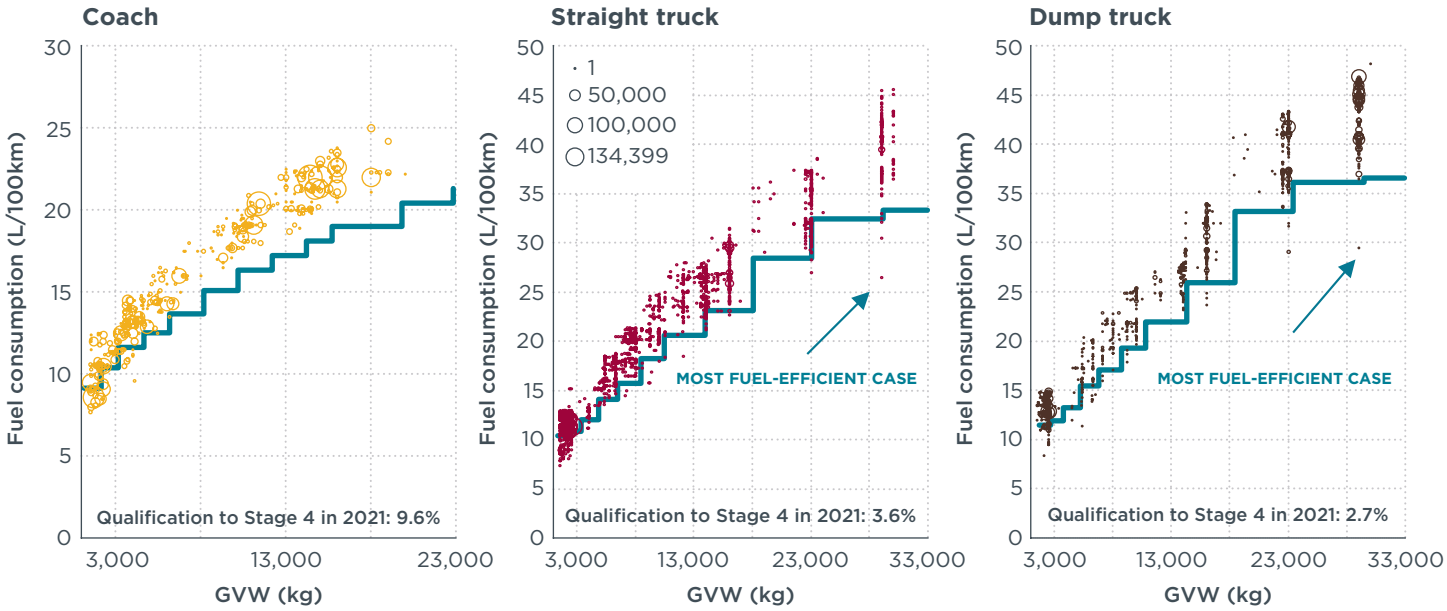


Figure 9. Type-approved values and Stage 4 limits in 2021

A POTENTIAL PATHWAY TO CARBON PEAKING AND CARBON NEUTRALITY

To achieve China's goal of carbon peaking and carbon neutrality,[10] we suggest that the Stage 4 fuel consumption standard be at least 20% more stringent compared to Stage 3. In a previous study, ICCT evaluated future GHG emissions under two policy scenarios: one with policies implemented or announced before September 1, 2020 (the Adopted policies scenario), and the other one for scenarios based on world-leading best practices (the High ambition scenario, Figure 10).

ICCT's simulation shows that the BAU scenario cannot help China achieve carbon peaking and carbon neutrality by 2030 and 2060, respectively; on the other hand, the high-ambition scenario may fulfill the commitment China announced with more stringent regulations on on-road transportation, where HDV is the key. More specifically, the average fuel consumption of HDV fleets should be reduced by 30% in 2030 compared to 2020 to meet the GHG reduction target under the high-ambition policy scenario. Assuming a consistent annual tightening rate, new diesel HDV fuel consumption needs to be reduced by at least 20% in 2026 compared to 2020.[11]

10 Alexander Chipman Koty, "China's Carbon Neutrality Pledge: Opportunities for Foreign Investment," *China Briefing News*, May 6, 2021, https://www.china-briefing.com/news/chinas-carbon-neutrality-pledge-new-opportunities-for-foreign-investment-in-renewable-energy/.

11 Lingzhi Jin, Zhenying Shao, Xiaoli Mao, Joshua Miller, Hui He, and Aaron Isenstadt, *Opportunities and Pathways to Decarbonize China's Transportation Sector during the Fourteenth Five-Year Plan Period and Beyond*, (ICCT: Washington, DC, 2021), https://theicct.org/publication/opportunities-and-pathways-to-decarbonize-chinas-transportation-sector-during-the-fourteenth-five-year-plan-period-and-beyond/.

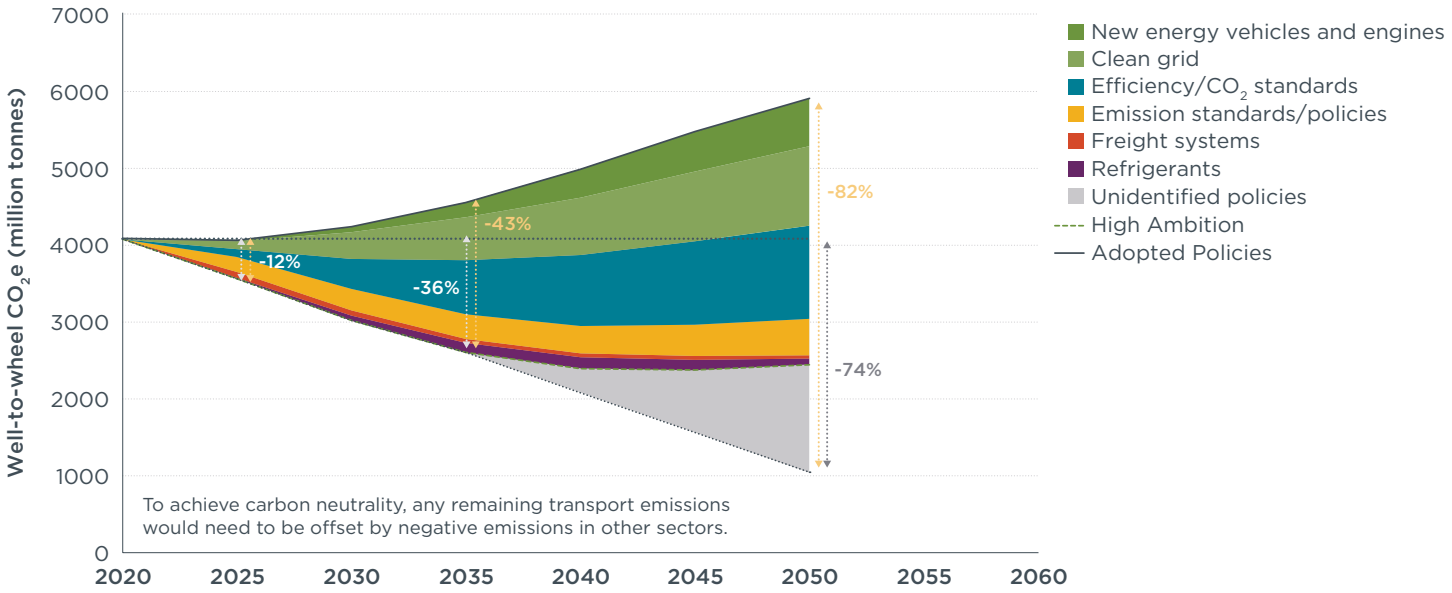


Figure 10. GHG emission development in China's transportation sector under the high-ambition scenario, 2020-2050

Source: Lingzhi Jin, Zhenying Shao, Xiaoli Mao, Joshua Miller, Hui He, and Aaron Isenstadt, Opportunities and Pathways to Decarbonize China's Transportation Sector during the Fourteenth Five-Year Plan Period and Beyond, (ICCT: Washington, DC, 2021), https://theicct.org/publication/opportunities-and-pathways-to-decarbonize-chinas-transportation-sector-during-the-fourteenth-five-year-plan-period-and-beyond/.

NEXT STEPS

The proposal was opened for public comment from June to August of 2022. Subsequent steps in finalizing the regulation were not announced as of the time of this writing.