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EVALUATION OF REAL-WORLD FUEL CONSUMPTION OF LIGHT-DUTY VEHICLES IN CHINA

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EXECUTIVE SUMMARY

There is growing evidence globally and in China of the gap between laboratory test findings and real-world carbon dioxide (CO_2) emissions and fuel consumption (Tietge et al, 2017). Building on previous work, this project uses different sources of real-world CO_2 emissions and fuel consumption data for light-duty vehicles (LDVs) to analyze real-world patterns in support of regulatory program development.

The study starts with an updated summary of consumer experience data that are representative of fleet trends. Then, new analyses are conducted using detailed vehicle fuel consumption data collected from two testing measures—real-world testing with portable emission measurement systems (PEMS) and chassis dynamometer tests in the laboratory. The objective of this research is to explore policy approaches that can improve real-world fuel consumption performance, especially for compliance with the 2015-2020 standards and the development of longer-term, 2025-2030 standards.

Based on consumer-reported and official fuel consumption records, the average divergence between real-world and type-approval consumption widened by around 21 percentage points between model year (MY) 2007 and MY 2017, reaching 34% in MY 2017 (Figure ES-1). The annual increase in the gap has also accelerated from one percentage point from 2013 to 2014 to five percentage points from 2016 to 2017.

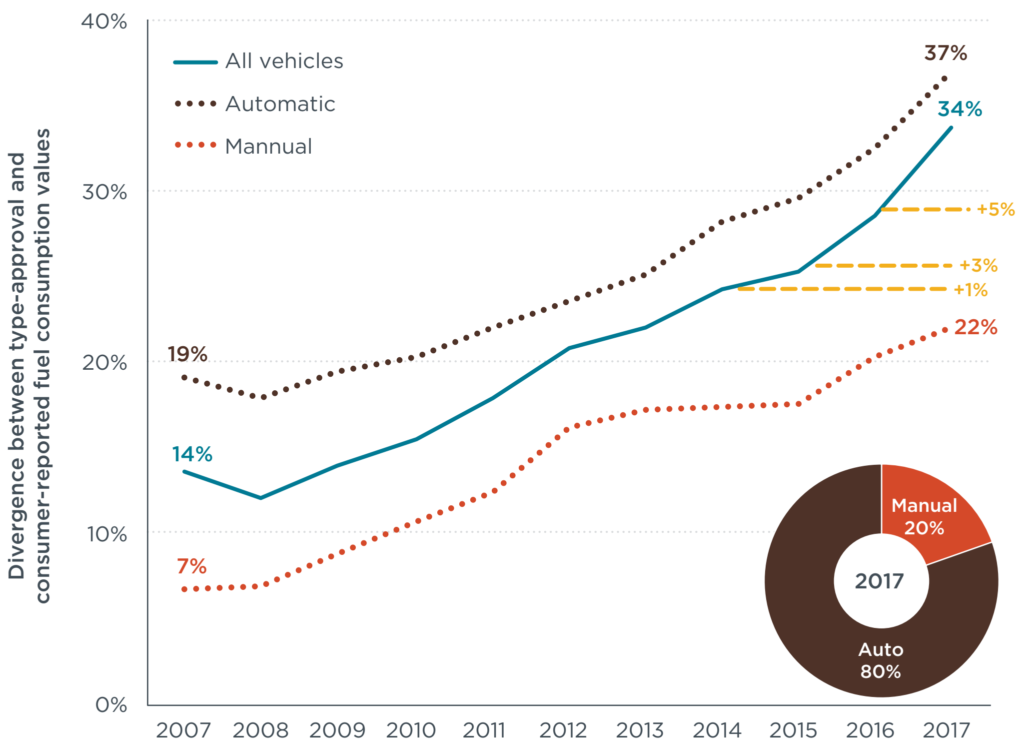

Figure ES-1. Divergence between consumer-reported and official fuel consumption by transmission type

Emissions as measured by the real-world driving emissions (RDE) test using PEMS with certain dynamic boundary condition requirements were compared with findings from dynamometer tests in the laboratory. For two vehicles tested using the RDE protocol, the average CO_2 emissions of valid RDE tests were on average 50% higher than the NEDC test result and 31% higher than the WLTP test result (Figure ES-2). This gap is consistent with findings from consumer-reported fuel consumption rates.

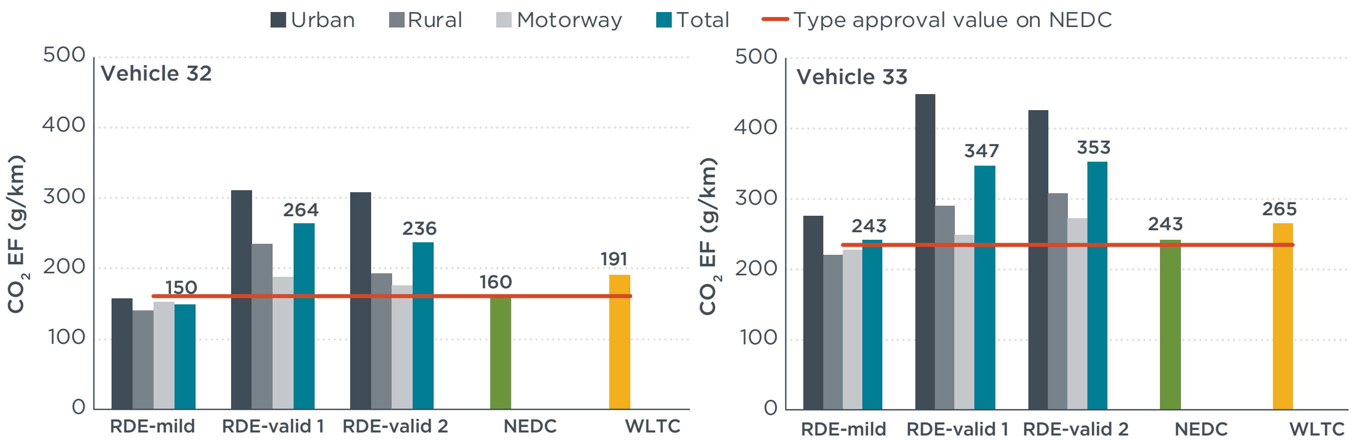

Figure ES-2. RDE and laboratory CO_2 emissions for vehicles 32 and 33.

Chassis dynamometer testing in the laboratory compared fuel consumption differences for the same two vehicles under as many as 10 test procedures. Figure ES-3 shows that the CO_2 emissions over the standard NEDC test cycle (Test 1) for both vehicles were very close to the type-approval value, confirming that the vehicles were representative and working properly. Comparing differences in CO_2 emissions among different test procedures shows that road load parameters, test cycles, cold/hot start, ambient temperature, and use of air conditioning have significant impacts on CO_2 emissions. The highest CO_2 emissions of Vehicle 32 were 27% above the type-approval value. Shifting from the NEDC (Test 1) to the WLTP (Test 8) recorded a 19% CO_2 emissions increase on Vehicle 32 and a 9% increase on Vehicle 33.

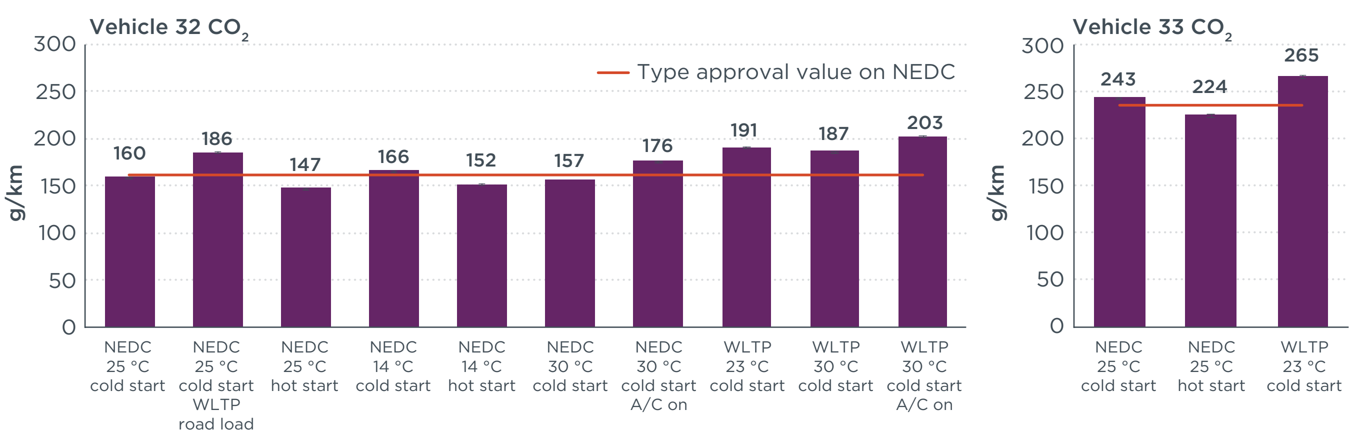

Figure ES-3. Overview of laboratory CO_2 emissions factors under different laboratory tests (error bars indicate standard deviation)

Analyzing different data sources, this study reaches four findings:

» **Finding 1**: The increasing gap between real-world and type-approval fuel consumption will dilute the practical effects of consumption policies. Based on consumer-reported data, China made little progress in reducing consumption in real-world driving since 2008. If this trend continues, even though conventional vehicles are expected to post greater reduction rates on future official tests, a much smaller portion of those reductions would be reflected in real-world driving.

» **Finding 2**: The mismatch between real-world and type-approval fuel consumption will reduce consumers' faith in data on labels and government certification. Although the current average consumer-reported consumption is close to the official rates on the city cycle, real-world consumption might exceed city-cycle fuel usage on type-approval testing in a few years if the gap between real-world and type-approval consumption keeps widening.

» **Finding 3**: Different driving conditions including road load, driving cycle, and A/C application significantly influence the test results for CO_2 emissions and fuel consumption. As illustrated by Figure ES-4 showing the test results of one vehicle, road load and vehicle test mass have a higher impact on CO_2 emissions than the difference in driving cycle, which is the speed trace that prescribes sequence of accelerations and decelerations. A/C use during hot weather, which is not currently taken into account by test procedures, also has a significant impact in raising CO_2 emissions.

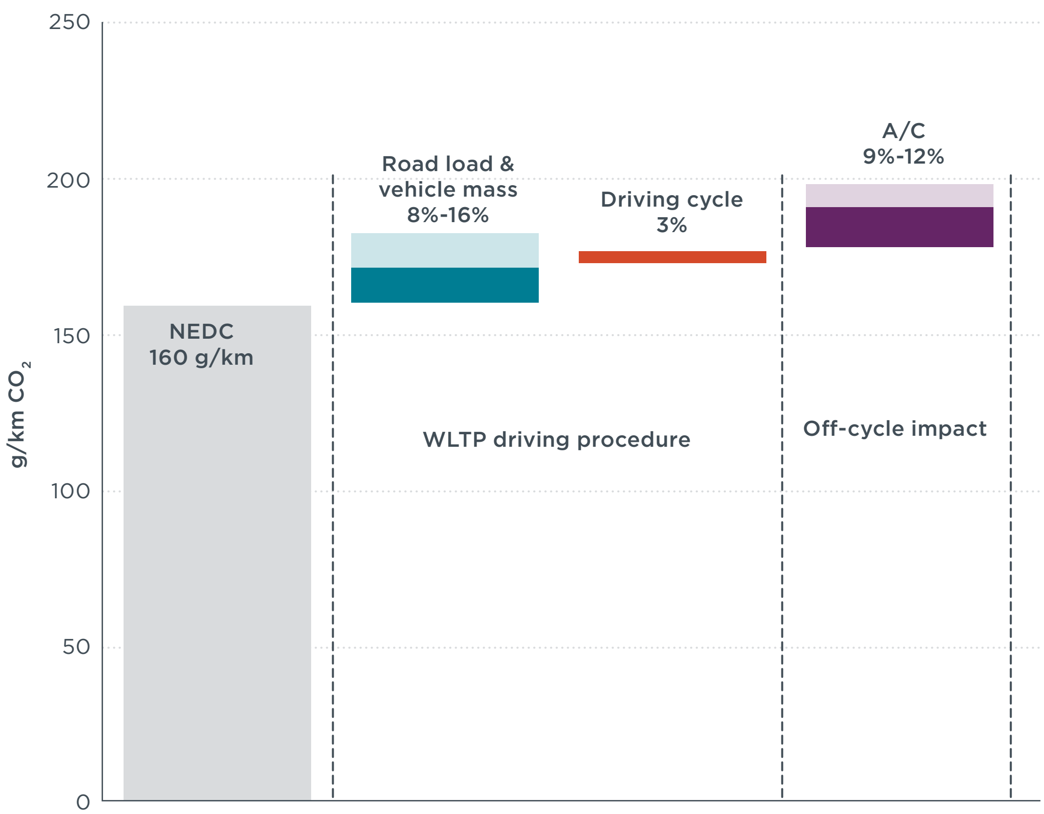

Figure ES-4. Graphical illustration of estimated CO_2 emissions impact from switching from NEDC to WLTP and turning on A/C

» **Finding 4**: Although the WLTP covers a wider range of driving conditions than the NEDC, the RDE test better represents actual on-road driving behaviors. Comparing the instantaneous driving points of the RDE, WLTP, and NEDC test cycles shows that the RDE covers the widest range of operation points and better represents actual on-road driving behaviors (Figure ES-5).

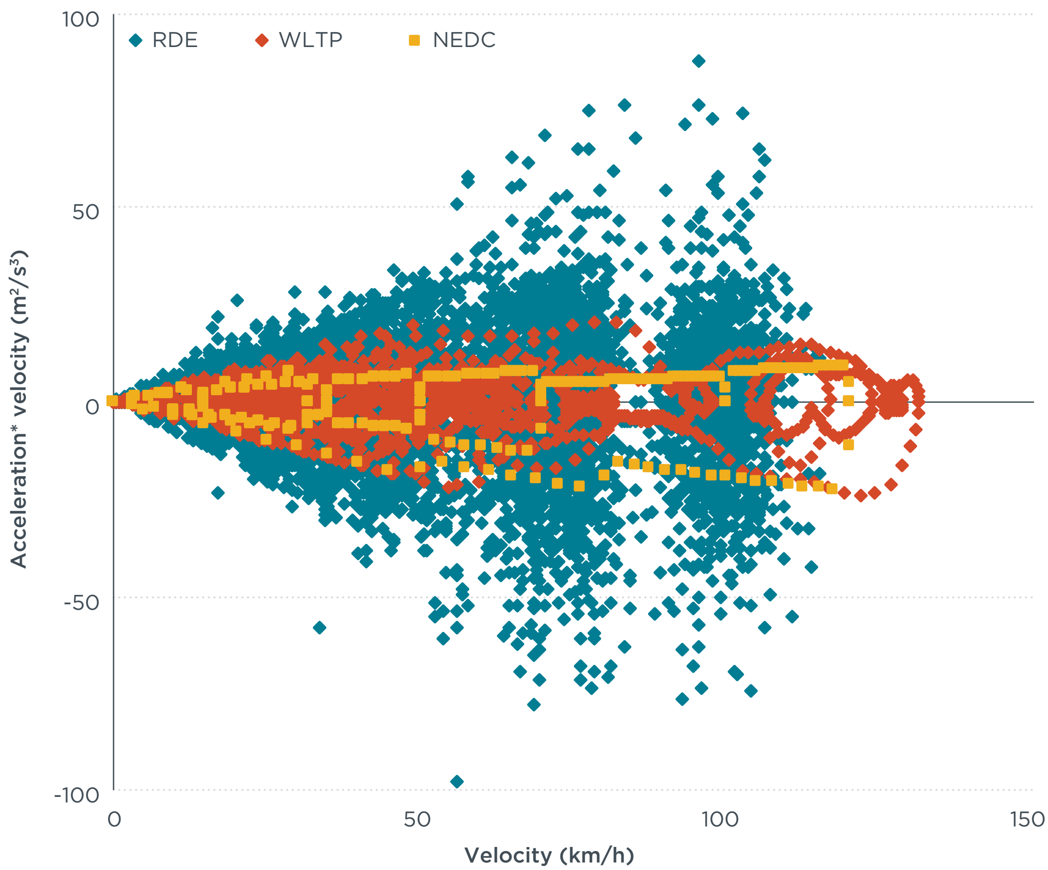

Figure ES-5. Instantaneous velocity and acceleration times velocity of RDE-valid 1 of Vehicle 32, WLTP and NEDC

The findings from the three data sources provide good insights regarding the widening gap between real-world and official fuel consumption in China. The accelerated expansion of the gap clearly indicates the need for regulatory changes to reverse this trend and close the gap. Recommended regulatory innovations are:

» Enhance the "China cycle" with test procedures that are equal to or more stringent than WLTP test procedures.

» Adjust the values on fuel consumption labels to reflect average real-world values.

» Extend RDE testing to fuel consumption standards, especially for in-use conformity testing, and define a compliance factor.

» Require application of On Board Diagnostics package three (OBD3) to monitor fuel consumption and establish official procedures to collect and publish fuel consumption information from in-use OBD3 systems.

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1. BACKGROUND

There is growing evidence globally and in China of the gap between laboratory test findings and real-world carbon dioxide (CO_2) emissions and fuel consumption (Tietge et al., 2017). In China, this observation was primarily supported by self-reported consumer experience data. While valuable for evaluating trends over time, consumer experience data are not sufficient for developing policy solutions. More rigorous experimental data are needed.

Building on previous work, this project uses different sources of real-world CO_2 emissions and fuel consumption data for light-duty vehicles (LDVs) to conduct in-depth analysis of real-world patterns that are crucial to support regulatory program development.

The study starts with an updated summary of consumer experience data that are representative of fleet trends. Then, new analyses are conducted using detailed vehicle fuel consumption testing data collected from two testing measures—real-world testing with portable emission measurement system (PEMS) and chassis dynamometer tests in the laboratory. The objective of this research is to explore policy approaches that can improve real-world fuel consumption performance, especially for compliance with 2015-2020 fuel consumption standards and the development of longer-term, 2025-2030 standards.

The paper is organized as follows: Section 2 explains the data sources and methodologies used for analysis. Section 3 conducts in-depth analysis of the three data sources. Section 4 summarizes findings based on the analysis. Section 5 outlines policy recommendations.

2. METHODOLOGY

Real-world fuel consumption performance was evaluated based on three data sources to balance the representativeness and accuracy of the information (Table 1). Each data source adds value to the research.

Table 1. Overview of data sources of the research

	Pros	Cons
Consumer-reported fuel consumption	• Easy to collect • Large sample size	• Potential bias of data sources • Inaccurate fuel efficiency value • Insufficient driving condition information
PEMS or real driving emission (RDE) testing	• More information on driving condition • Accurate fuel efficiency value	• Expensive to collect • Small sample size
Laboratory testing	• Control over driving conditions • Accurate fuel efficiency value	• Expensive to collect • Small sample size

First, fleet average real-world fuel consumption was tracked through consumer-reported data, and analyses were conducted on the gap between real-world and type-approval fuel consumption changes over time and how the gap may vary by technology type or segment. This is an update following the methods and results in the ICCT's 2017 international study (Tietge et al., 2017).

Second, evaluations were conducted using real-world fuel consumption of 33 vehicles with highly accurate PEMS testing. The PEMS testing protocol for the research was relatively consistent from one vehicle to another. Two of the 33 vehicles were tested following the RDE protocol established under China 6 LDV emissions standards. RDE trips are validated by boundary conditions required by the regulations. The analysis of this data source was used to verify and adjust the consumer-reported information.

Third, fuel consumption information from several enhanced laboratory tests designed to track the impact of different testing or driving elements on vehicle consumption were analyzed. The laboratory test conditions were tightly controlled, such as driving cycle, ambient temperature, road load and air conditioning operation, allowing quantification of the impact on vehicle fuel consumption of individual testing elements.

These three analysis aspects enabled evaluation of real-world fuel consumption in China from various perspectives. The following section describes the methodology and analysis results of each of the three data sources.

3. ANALYSIS

3.1 CONSUMER-REPORTED FUEL CONSUMPTION

There are several unofficial platforms that collect real-world fuel consumption information in China, such as Sina auto, Sohu auto, and XiaoXiongYouHao. Sina auto and Sohu auto are two mainstream websites that collect and summarize consumer-reported fuel consumption by vehicle model. XiaoXiongYouHao is a mobile application that allows users to track and compare their fuel consumption.[1]

We use XiaoXiongYouHao information for this part to summarize consumer-based fuel consumption, as the proprietor of XiaoXiongYouHao graciously provided the data set for this study. The mobile application of XiaoXiongYouHao was launched in 2010 and by the end of 2017 had data on more than 1 million individual vehicles. The data set includes information on more than 10,000 vehicle model variants with model years ranging from 2002 to 2017. The number of users and vehicles has increased dramatically in recent years because of the growing vehicle market and expanding use of smartphones.

3.1.1. Methodology

Most fuel volume and odometer readings logged in the application are assumed to be real information because users' goal is to track and compare their fuel consumption and the app does not reward any data login or fuel consumption ranking, which might give users an incentive to enter fake data.

The data proprietor removed outliers using reasonable ranges based on statistical analysis. For individual vehicles with more than five reported fuel consumption records, the average fuel consumption is considered normal if it lies within 2.5 standard deviations left from the mean and 4.5 standard deviations right from the mean of all data from the same vehicle variant.[2] For individual vehicles with five or fewer reported fuel consumption records, the average fuel consumption value is considered normal if it lies within two standard deviations from the mean of all data on the same vehicle variant.

For each vehicle model variant, the data set included information on the model year, engine type whether naturally aspirated or turbocharged, transmission type, vehicle segment, average on-road fuel consumption, official fuel consumption rating, and number of vehicles in the sample. After filtering the data for missing values and removing model years 2003 to 2006 as they included fewer than 5,000 samples per year, about 902,000 individual vehicles of more than 7,000 vehicle model variants remained, with model years ranging from 2007 to 2017. Outlier removal was not deemed necessary as no erroneous data points were identified using Peirce's criterion.

1 http://www.xiaoxiongyouhao.com

2 The distribution of the sample fuel economy is somewhat skewed, since there is more scatter in the fuel consumption records that are higher than the average value. (It is normal for vehicles to have higher fuel consumption in real driving.) The fuel consumption records that are lower than the average value are more concentrated. Therefore, the data proprietor chose different variance intervals to determine outliers on different sides of the mean value.

3.1.2. Results and discussion

Figure 1 plots the trend in the average divergence between consumer-reported and official fuel consumption values[3] by transmission type. All model years have reported information from more than 20,000 individual vehicles, except for 9,000 in 2007.

As shown in Figure 1, the average divergence between real-world and type-approval fuel consumption increased by around 21 percentage points between MY 2007 and MY 2017, reaching 34% in MY 2017. The annual increase in the gap also accelerated from one percentage point from 2013 to 2014 to five percentage points from 2016 to 2017. The divergence increased for both automatic and manual transmission cars, although vehicles with automatic transmissions consistently exhibited a higher divergence than vehicles with manual transmissions. Vehicles with automatic transmissions have outnumbered those with manual transmission since MY 2011, and their share of the sample fleet increased to 80% in MY 2017.

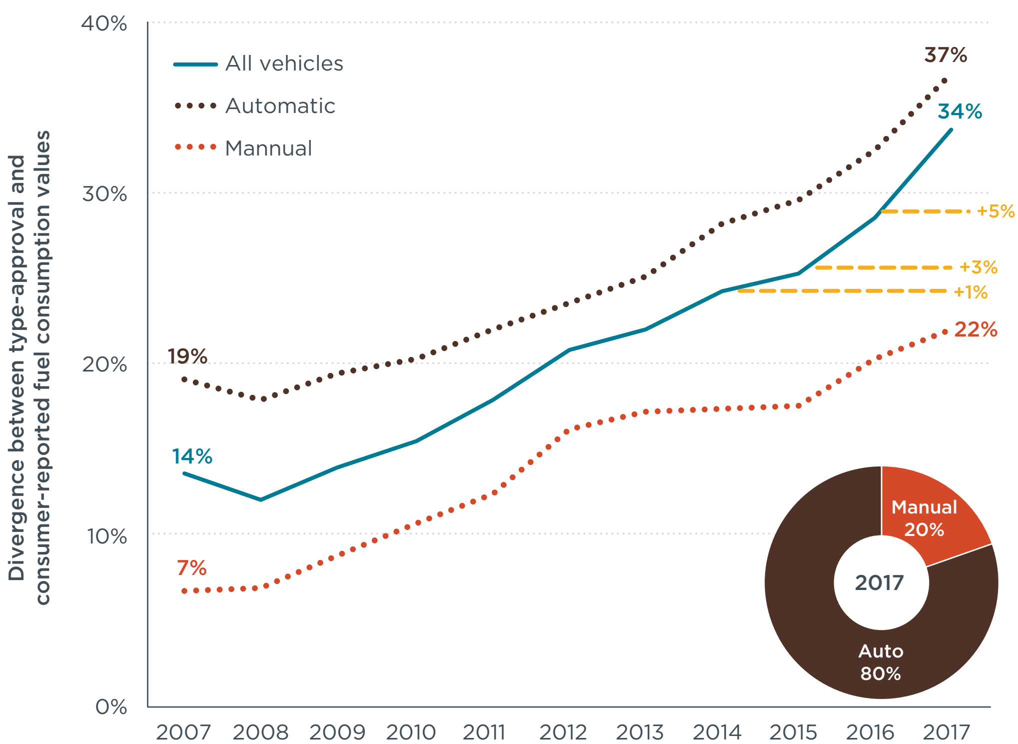

Figure 1. Divergence between consumer-reported and official fuel consumption by transmission type

As Figure 2 illustrates, automatic transmission vehicles with turbocharged engines consistently exhibited a higher divergence than vehicles with naturally aspirated engines. One possible explanation for the large gap for turbocharged vehicles is that consumers may use the higher torque to accelerate faster in the real world, reducing real-world fuel consumption compared with that on the lower load type-approval driving cycle. Therefore, the fuel benefits from turbocharged engines may not be fully realized in real-world driving.

3 Divergence is calculated as dividing the gap between real-world and official fuel consumption values by official fuel consumption values.

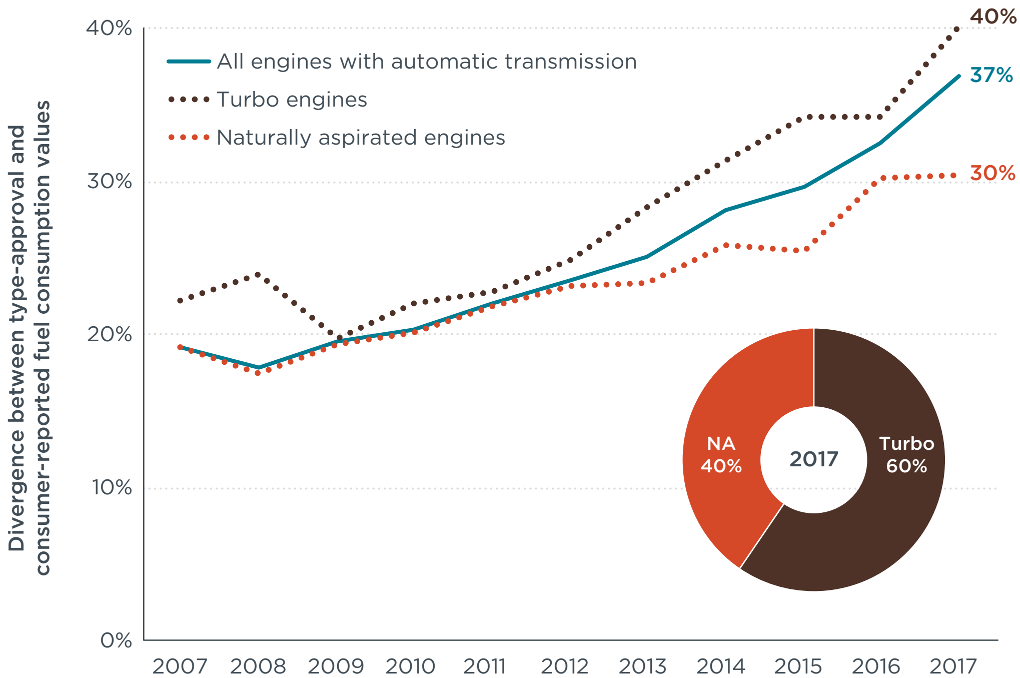

Figure 2. Divergence between consumer-reported and official fuel consumption of vehicles with automatic transmissions by engine type

Results presented in this report differ slightly from the older 2007 to 2016 results published by Tietge et al. in 2017, as existing users continuously add fuel consumption data to the database and as new users sign up. Figure 3 shows the development of the average divergence by the year of data analysis. The results are similar, although the previous study may have slightly overestimated the gap from 2010 to 2015. The previous study gap for 2012 was more than 2 percentage points higher than the gap for the same model year in this study.

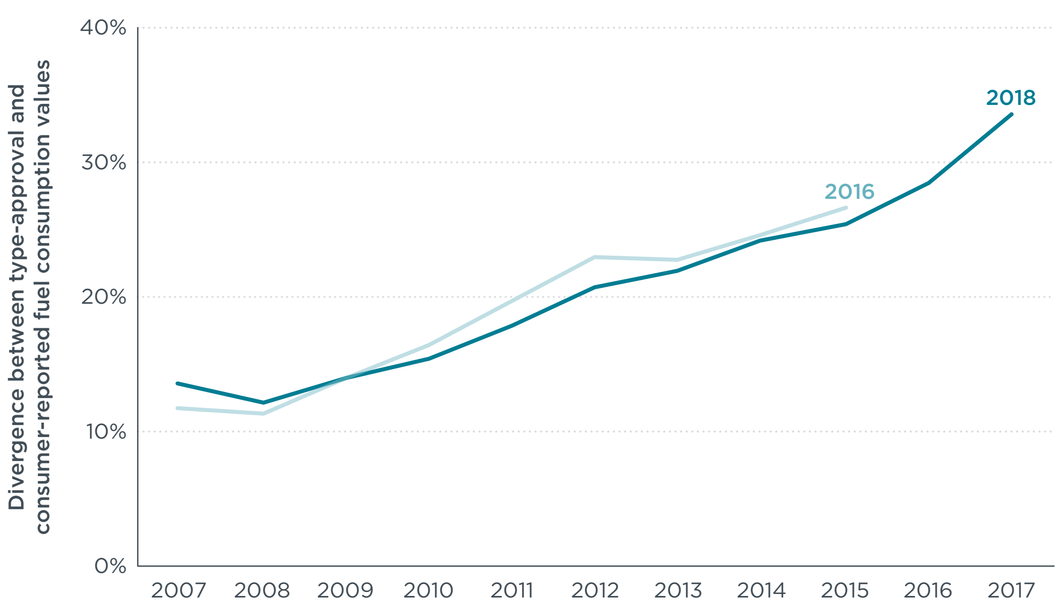

Figure 3. Divergence between XiaoXiongYouHao and official fuel consumption by year of

3.1.3. data analysis

The composition of samples by segment has changed over time (Figure 4). SUVs account for an increasing portion of the total sample while the shares of mini and small cars are decreasing, in line with changes in the overall passenger car market. However, changes in market structure do not explain the increase in the average fuel consumption divergence over time. As Figure 5 shows, the divergence between consumer-reported and official fuel consumption increased across all segments. SUVs exhibited a divergence similar to the average for all segments. The medium, upper medium, and large segments consistently showed a higher divergence than the other segments, but the market share of these segments has been relatively consistent over time and consequently these vehicles do not contribute to the widening divergence for the entire fleet over time.

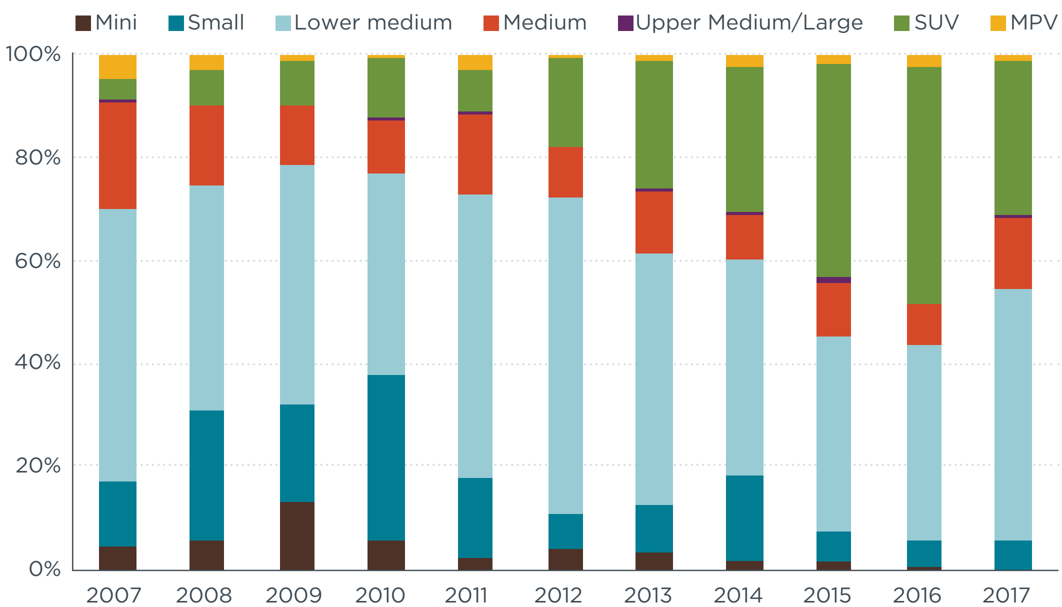

Figure 4. Sample size by segment

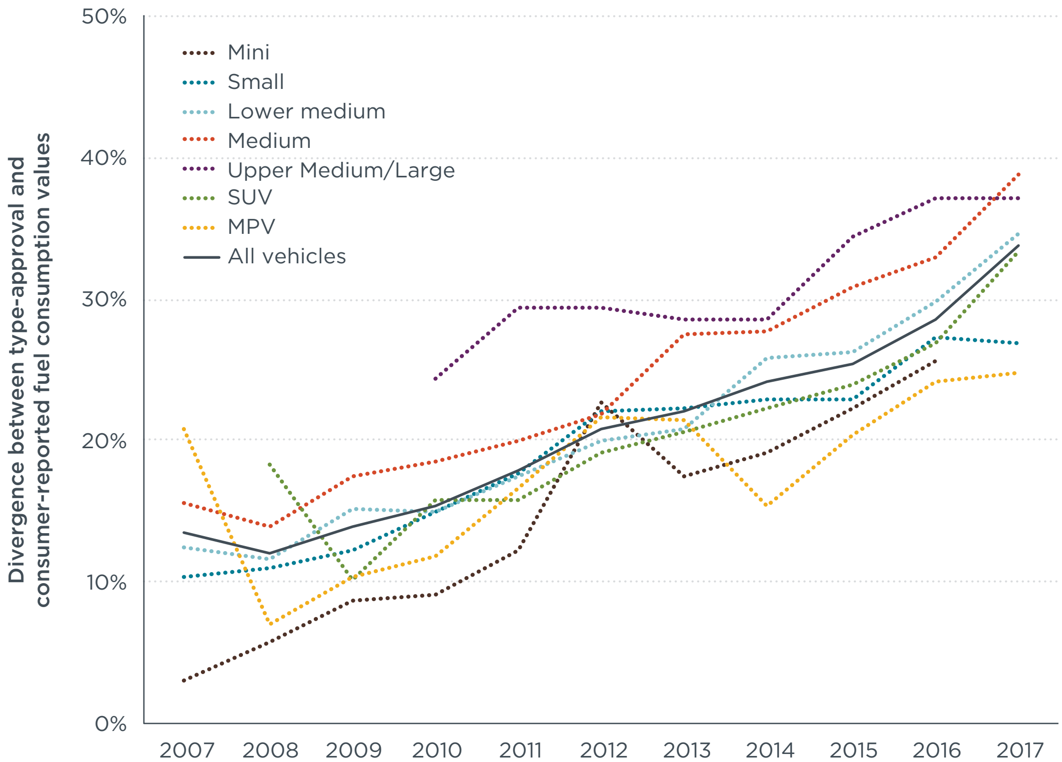

Figure 5. Divergence between consumer-reported and official fuel consumption by segment

3.2 ON-ROAD TESTING WITH PEMS

3.2.1. Methodology

In a previous ICCT PEMS meta-study (Yang, 2018), PEMS testing data on 55 LDVs from multiple sources in China were collected and analyzed. The PEMS data include second-by-second exhaust emissions and CO_2 emissions rates. GPS data on instantaneous velocity and acceleration were also available to provide precise information on driving conditions. Of the 55 LDVs, the official type-approval fuel consumption data was identified for 33 vehicles. An analysis of the gap between real-world CO_2 and type-approval values was performed for these 33 vehicles.

The vehicle sample covers a wide range of model years from 2009 to 2016 and includes private LDVs and taxis. Taxis were analyzed separately because they mostly have manual transmissions and are usually operated much more extensively than private cars. Table 2 provides an overview of the LDVs included in this study.

Each vehicle was tested over one PEMS trip. Two China 5 private cars—Nos. 32 and 33—were tested three times. The vehicles were driven in normal, real-world conditions following actual traffic. The tests were conducted from 2009 to 2016 in Beijing and Xiamen by different laboratories. The trip routes were the same for all vehicles tested in Xiamen, while similar trip routes with some differences were chosen in Beijing. The tests were conducted at different times of the year, so the driving conditions varied. Table 2 presents the trip duration, trip distance and average speed. The tests lasted from one hour to two hours and 20 minutes, and the trip distance ranged from 41 km to 83 km. The average speed of each PEMS trip ranged from 25 km/h to 53 km/h, with an average speed for all trips of 40 km/h.

Table 2. Overview of vehicle and trip information for PEMS testing

No.	Category	Model year	Test city	Trip duration (h)	Trip Distance (km)	Average speed (km/h)
1	Taxi	2009	Beijing	2:19	70.3	30.3
2	Taxi	2009	Beijing	1:30	50.4	33.7
3	Taxi	2009	Beijing	1:41	53.2	31.5
4	Taxi	2009	Beijing	1:15	52.8	42.2
5	Taxi	2009	Beijing	1:19	53.8	40.6
6	Taxi	2009	Beijing	1:10	52.8	45.0
7	Taxi	2009	Beijing	1:18	52.8	40.9
8	Taxi	2009	Beijing	1:18	53.1	40.6
9	Taxi	2009	Beijing	1:14	45.6	36.9
10	Taxi	2009	Beijing	1:14	45.6	36.9
11	Taxi	2009	Beijing	1:4	49.0	45.9
12	Taxi	2009	Beijing	1:15	52.8	42.4
13	Taxi	2009	Beijing	1:1	41.3	40.6
14	Taxi	2009	Beijing	1:1	41.3	40.6
15	Taxi	2009	Beijing	1:20	52.8	39.7
16	Taxi	2009	Beijing	1:20	52.8	39.7
17	Taxi	2009	Beijing	1:19	43.7	33.4
18	Taxi	2009	Beijing	1:19	43.7	33.4
19	Taxi	2010	Beijing	1:31	52.2	34.5
20	Taxi	2011	Beijing	1:22	52.3	38.1
21	Taxi	2011	Beijing	1:42	54.9	32.2
22	PC	2011	Beijing	1:17	52.9	41.1
23	Taxi	2011	Beijing	1:18	48.2	36.9
24	PC	2012	Beijing	1:41	52.5	31.3
25	Taxi	2012	Beijing	1:16	47.8	37.5
26	Taxi	2013	Beijing	2:9	55.1	25.6
27	Taxi	2013	Beijing	1:46	53.8	30.4
28	PC	2013	Beijing	1:12	48.3	40.3
29	PC	2013	Beijing	1:26	52.3	36.4
30	Taxi	2013	Beijing	1:23	50.2	36.5
31	PC	2014	Beijing	1:3	44.0	42.2
32a	PC	2016	Xiamen	1:39	82.9	50.2
32b	PC	2016	Xiamen	1:40	82.5	49.6
32c	PC	2016	Xiamen	1:38	82.1	50.3
33a	PC	2016	Xiamen	1:37	82.9	51.2
33b	PC	2016	Xiamen	1:34	82.4	52.4
33c	PC	2016	Xiamen	1:35	82.6	52.2

Testing on vehicles 32 and 33 was conducted by the Xiamen Environment Protection Vehicle Emission Control Technology Center in 2016. The testing conditions and trip routes meet all the provisions of the China 6 RDE regulation. AVL M.O.V.E. PEMS system was employed for RDE tests.

Figure 6 shows the PEMS installation on a sample vehicle. A driver and one technician sit in the car for each test. As cold start is excluded in the China 6 RDE regulation, the fuel consumption during cold start was not recorded in the test.

Figure 6. PEMS installation dynamometer

Figure 7. PEMS verification on chassis

To ensure the accuracy of the PEMS system, verification tests were carried out in a laboratory on a chassis dynamometer (Figure 7). Vehicle emissions were measured by PEMS and Constant Volume Sampling (CVS) systems at the same time over the WLTP test cycle. As shown in Table 3, the relative deviations between the two systems for all tests were well within the China 6 regulated limits.

Table 3. PEMS Verification test results

Vehicle	Test	Equipment	CO_2 (G/KM)
32	WLTP 23°C cold start	CVS	189.2
		AVL MOVE	195.3
		Relative deviation	**3%**
32	WLTP 23°C cold start	CVS	190.0
		AVL MOVE	200.6
		Relative deviation	**6%**
33	WLTP 23°C cold start	CVS	270.9
		AVL MOVE	286.3
		Relative deviation	**6%**
Relative deviation limit in China 6			10%

The RDE test route was selected in Xiamen according to the requirements in the China 6 standard. Figure 8 shows the map of the testing route. It consists of three parts—urban, rural, and motorway. The overall distance was about 80 km and the altitude was lower than 100 m.

Figure 8. RDE test route

Instantaneous CO_2 emissions rates in gram per second were measured by the PEMS equipment. The final CO_2 emissions factors (in g/km) were calculated by dividing the cumulative CO_2 mass emissions by the total distance. The type-approval fuel consumption was converted to CO_2 emissions by assuming an average conversion factor of 1L gasoline/100 km to 23.4g CO_2/km (Kühlwein et al., 2014).

3.2.2. Results and discussion

This section first discusses the results of all 37 PEMS tests and then performs an in-depth analysis of the six RDE trips (Trips 32a to 33c).

All PEMS trips

Figure 9 gives an overview of the gap between type-approval and real-world CO_2 emissions for all PEMS trips. The divergence between type-approval and real-world CO_2 ranged from -3% to 55% for different models and trips. According to the China 6 RDE regulation, the results for Vehicles 32a and 33a are considered mild trips. Excluding these two trips, the average gap was 22% for all vehicles tested (MY 2009 to 2016).[4] For taxis, the average gap was 17% and for private cars, 36%, excluding Vehicles 32a and 33a. Figure 10 presents the CO_2 divergence by vehicle model year. No clear trend was observed as model year increased, because the sample size is limited for each model year category. For example, there are 18 samples for 2009 and only two samples for 2012.

4 The average number was calculated as the average of the individual divergences.

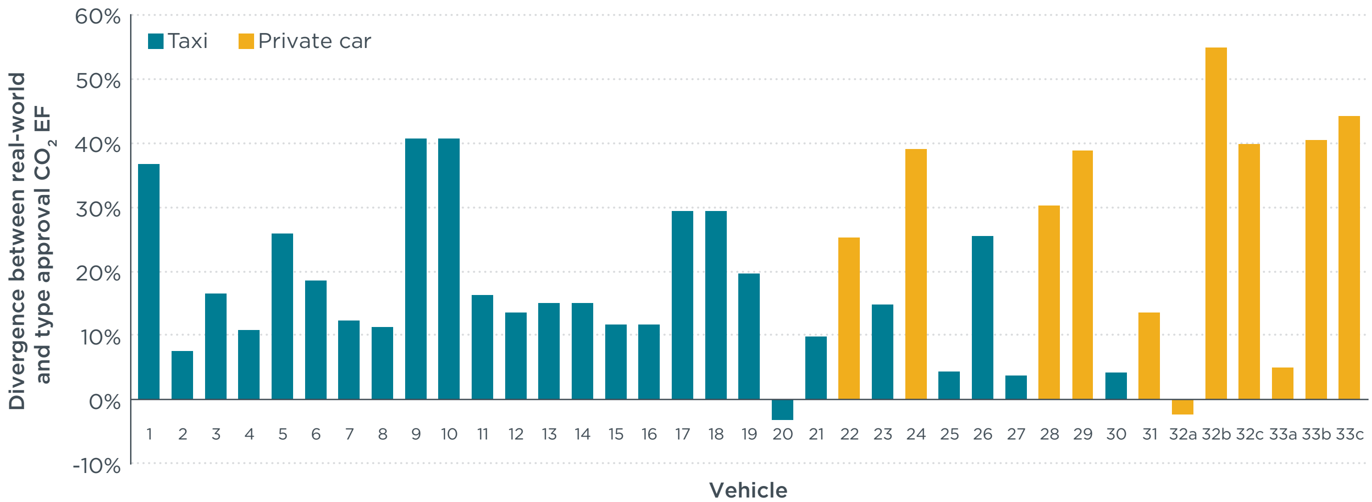

Figure 9. Divergence between type approval and PEMS CO_2 emissions, by vehicle

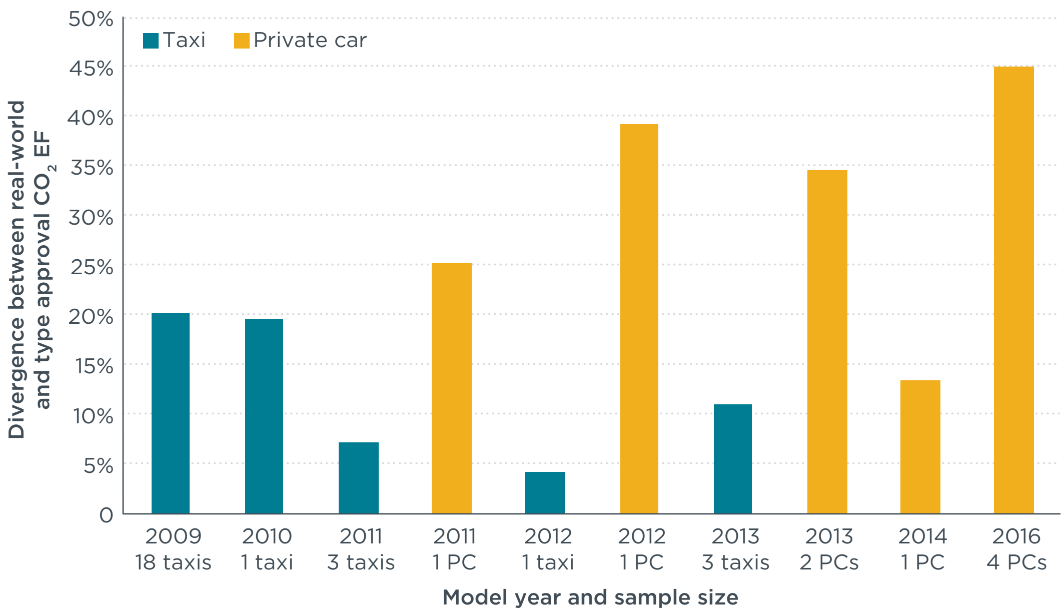

Figure 10. Divergence between type approval and PEMS CO_2 emissions, by model year and vehicle category

Among the 26 taxis, 18 were the same vehicle model—the Beijing Hyundai Elantra—from the same manufacturer and produced in the same year, 2009. Figure 11 shows the CO_2 emissions of these 18 taxis from the lowest to the highest. The type-approval value is the same for all vehicles, so this is represented by a line in FIgure 11. The highest CO_2 emissions from PEMS was 30% higher than the lowest CO_2 emissions. PEMS testing resulted in 7% to 41% higher CO_2 emission from these vehicles compared with their certified value, with an average of 20%.

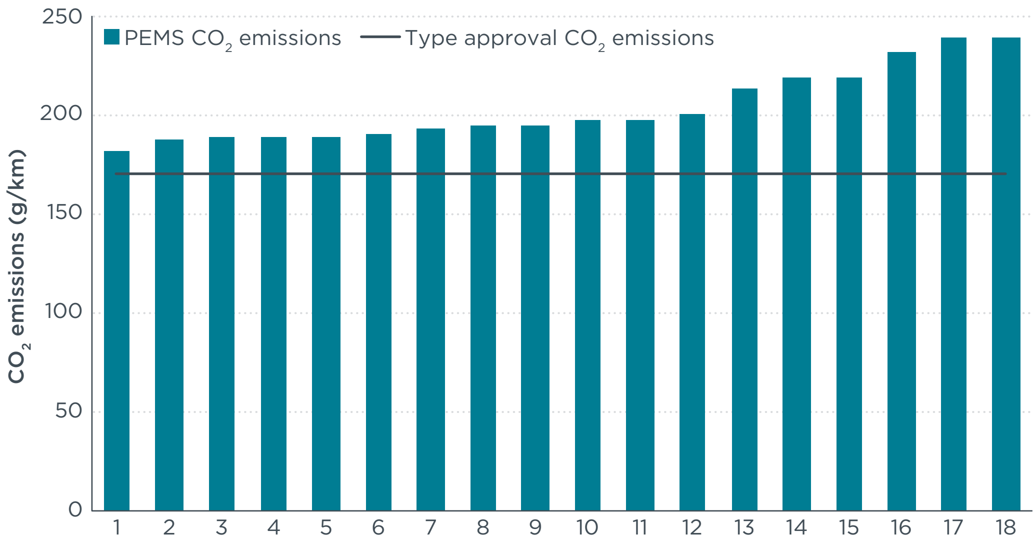

Figure 11. PEMS CO_2 emissions factors for 18 2009 Elantra taxis

This difference in real-world CO_2 emissions as measured by PEMS for the same model may be reasonable. For example, trips 32a, 32b, and 32c were conducted on the same vehicle over the same route, but the CO_2 gaps varied from -2% to 55%. Similar results can be observed for trips 33a to 33c. This is mainly because the driving behaviors of trips 32a and 33a were considered to be too mild according to the China 6 RDE regulation. A detailed analysis of the driving behaviors of Trips 32 and 33 is provided in the following section.

Trips 32 and 33 (RDE trips)

The RDE test uses PEMS to measure CO_2 emissions/fuel consumption while driven on the road. Different from random PEMS testing, the RDE test accepts only results from valid trips and rejects trips that are too smooth or too aggressive. It also mandates an urban section following by rural and motorway sections. In the China 6 and EU RDE regulations, relative positive acceleration (RPA) and the 95th percentile of the product of vehicle speed and positive acceleration ($v*a_{pos[95]}$) are used to determine the overall aggressiveness or mildness of a trip.[5] The 95th percentile of $v*a_{pos}$ is used to determine the upper limit, and RPA is used for the lower limit. To be valid, the $v*a_{pos[95]}$ and RPA of urban, rural, and motorway section of an RDE trip shall be below the $v*a_{pos[95]}$ upper limit and above the RPA lower limit.

In this study, Vehicles 32 and 33 were tested using PEMS according to the China 6 RDE regulation. In addition, both vehicles were tested on a laboratory chassis dynamometer over NEDC and WLTP test procedures.[6] Figure 12 presents the trip dynamics results of three RDE trips for Vehicles 32 and 33. For both vehicles, the RPA for urban driving of the first RDE trip is below the lower limit of the dynamic boundary condition, so RDE trip 1 of both vehicles is too passive and is considered to be an invalid trip. The trip

5 RPA is defined as the integral of vehicle speed multiplied with the time interval and the positive acceleration, divided by the total distance of each speed segment. $v*a_{pos[95]}$ is defined as the 95th percentile of the instantaneous vehicle speed multiplied with the positive acceleration above 0.1 m/s^2.

6 NEDC is the current type-approval fuel consumption test procedure in China. WLTP is the current type-approval fuel consumption test procedure in EU.

dynamics of RDE Trip 2 and Trip 3 for both vehicles fall within the dynamics boundary conditions, so they are considered valid.

In the following discussion, RDE Trip 1 is referred to as RDE-mild, and RDE Trips 2 and 3 are referred to as RDE-valid 1 and RDE-valid 2.

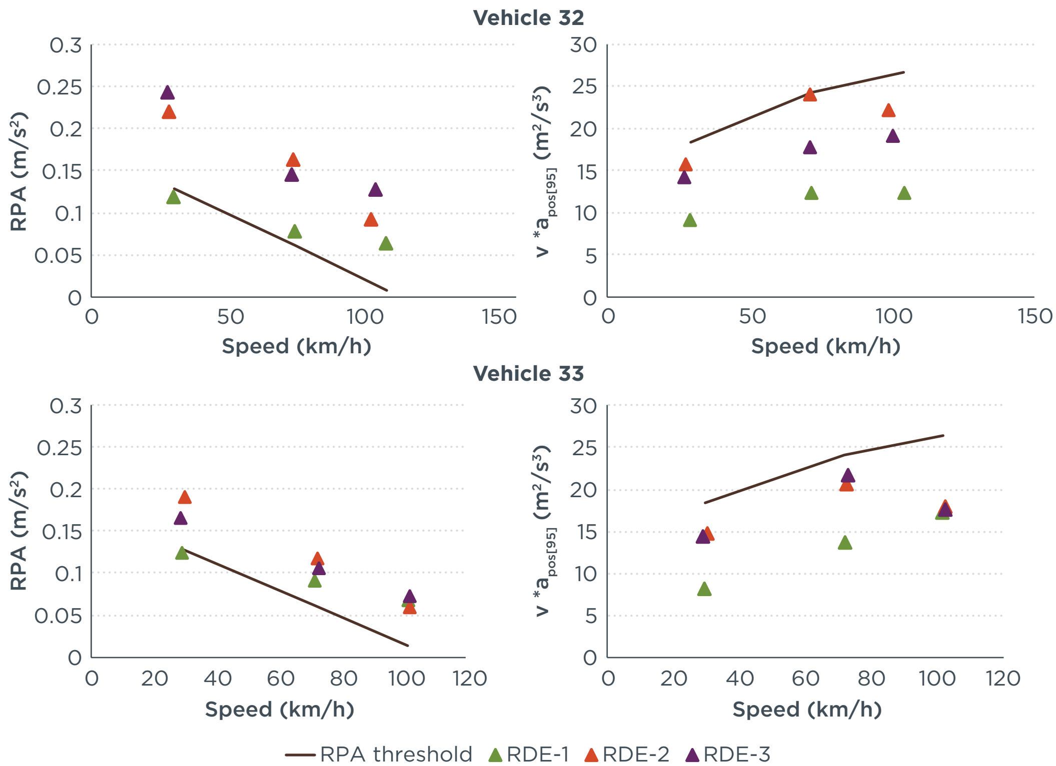

Figure 12. Trip dynamics of three RDE trips for Vehicles 32 and 33

Figure 13 provides RDE test results for the two vehicles. The CO_2 emissions during the urban phase were the highest of the three driving segments. For the first RDE trips of both vehicles, the overall on-road CO_2 emissions were equal to or less than type-approval values over the NEDC, indicating that both trips were as mild as the NEDC. The average CO_2 emissions of valid RDE tests were 50% higher than the NEDC test result and 31% higher than the WLTP test result. This gap is consistent with findings from consumers reported in Section 3.1.

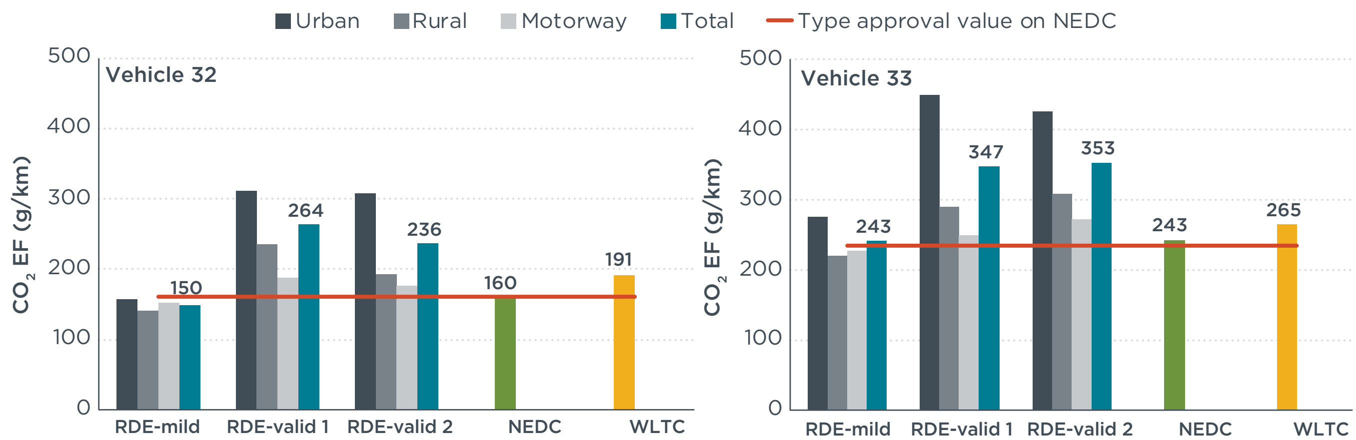

Figure 13. RDE and laboratory CO_2 emissions for vehicles 32 and 33.

3.3 LABORATORY TESTING ON CHASSIS DYNAMOMETER

Laboratory testing uses a chassis dynamometer that allows vehicles to be "driven" in place while exhaust is captured and analyzed and fuel consumption is measured. This is the method used for type-approval testing to certify vehicles' reported fuel consumption as a precondition for sales.

The fuel consumption information collected from car owners or PEMS testing in Sections 3.1 and 3.2 reflects vehicle fuel usage under a wide variety of real-world driving conditions. In comparison, laboratory testing controls test procedures and restricts the driving pattern under which the data is collected. Laboratory testing is used here to quantify impacts on fuel consumption of changes in driving conditions on the same vehicle.

3.3.1. Methodology

Vehicle selection

This study conducts chassis dynamometer tests on two gasoline vehicles, which are the same vehicle 32 and 33 for the PEMS testing in Section 3.2. Table 4 summarizes the specifications of the two vehicles. Both vehicles were rented from a car rental company. Vehicle 32 and Vehicle 33 are both classified as M1 vehicles, or passenger cars.[7] A gasoline particle filter was not deployed on either car for particle emissions control.

The sample vehicles were carefully inspected before testing. The main inspections included vehicle condition, configuration of key emissions control components, maintenance records, and an on-board diagnostics check. The powertrain, the intake and exhaust system, and the canister purge system were checked to ensure they were operating properly. All key components of the two cars complied with each vehicle's type-approval declaration. The maintenance records showed that both vehicles were well maintained as required by the operation manuals. There were no online or permanent fault codes in the OBD checks. The same batch of China 5 reference gasoline was used for all dynamometer testing.

7 M1: Vehicle with no more than nine passengers including driver, and gross vehicle weight of no more than 3.5 tons.

Table 4. Chassis dynamometer test vehicles specifications

	Vehicle 32 (Small sedan)	Vehicle 33 (Multi-Purpose Vehicle)
Model year	2016	2016
Fuel injection	PFI	GDI
Mileage at test start/km	1,290	7,262
Curb weight/kg	1,265	1,860
Gross vehicle weight rating/kg	1,775	2,470
Test Fuel	China 5 reference gasoline	China 5 reference gasoline
Engine displacement/L	1.6	2.4
Engine aspiration	Natural	Natural
Max. engine power/kW	81	137
Max. engine torque/Nm	155	240
Emissions after-treatment	TWC	TWC
Drive train	2W front	2W front
Transmission	6-Automatic Transmission	6-Automatic Transmission
MIIT Fuel consumption /L/100km	6.9	10.0

Note: MIIT is China's Ministry of Industry and Information Technology.

Test matrix

Table 5 lists the 10 test procedures run on each vehicle. Test No. 1 was a standard NEDC type-approval test. Test Nos. 2 to 10 were enhanced laboratory tests—we slightly changed the test conditions and procedures for each test to quantitatively identify the impacts of WLTP road load determination,[8] cold start, ambient temperature, air conditioning operation, and WLTP test procedure. For Vehicle 32, all 10 laboratory test items were conducted in the laboratory. For Vehicle 33, only Test Nos. 1, 3, and 8 were performed in the laboratory because of funding limitations. Except for Test No. 5, two repeated tests were conducted to reduce uncertainty of the results.

Table 5. Dynamometer testing matrix and number of tests

Test No.	Test type	Start	Ambient temperature	A/C	Road load	Number of tests for Vehicle 32	Number of tests for Vehicle 33
1	NEDC	Cold	25°C	Off	NEDC	2	2
2	NEDC	Cold	25°C	Off	WLTP	2	0
3	NEDC	Hot	25°C	Off	NEDC	2	2
4	NEDC	Cold	14°C	Off	NEDC	2	0
5	NEDC	Hot	14°C	Off	NEDC	1	0
6	NEDC	Cold	30°C	Off	NEDC	2	0
7	NEDC	Cold	30°C	On	NEDC	2	0
8	WLTP	Cold	23°C	Off	WLTP	2	2
9	WLTP	Cold	30°C	Off	WLTP	2	0
10	WLTP	Cold	30°C	On	WLTP	2	0

Note: WLTP road load was calculated according to China 6 standard.
The hot-start tests were performed 50 minutes after conducting NEDC precondition.
Test No. 5 was conducted only once because of funding limitation.

8 The WLTP road load determination includes more accurate determination of the vehicle's aerodynamic drag and rolling resistance, as well as a revised method of determining vehicle mass for test purposes that increases the mass used for testing.

Laboratory test

All tests were conducted by the Xiamen Environment Protection Vehicle Emission Control Technology Center (VETC, see Figure 14). This laboratory was equipped with an Imtech climatic chamber, AVL 4WD chassis dynamometer, AVL i60 series exhaust sampling and analysis system, and TSI particle counting system. The equipment was calibrated and checked according to VETC's quality assurance system, which is stricter than the China 5 requirements.

Figure 14. LDV emission test lab of VETC

The benchmark tests were standard NEDC (Test 1) or WLTP (Test 8) tests compliant with China 5 or 6 standards. For all cold start tests, the vehicle was preconditioned in a soak area at constant ambient test temperature for 12 hours before the actual measurements took place. Hot start tests refer to tests carried out within 50 minutes of finishing an NEDC or WLTC test, when the engine block, coolant, and aftertreatment control systems were well above the temperatures corresponding to cold start tests. This testing project also covered tests under low (14°C) and high (30°C) temperatures.

Two methods for determination of vehicle road load setting were used in this project. The NEDC (China 5) road load was declared by the vehicle manufacturers in type approval. The VETC lab didn't have the capacity to conduct vehicle coast-down tests, so the WLTP (China 6) road load was calculated using the equations by frontal area and curb weight in the China 6 standard, which is identical to the WLTP regulation. Figure 15 illustrates the road load difference between the two methods for vehicles A and B. Note that the declared road load by the vehicle manufacturers following the NEDC requirement is much lower than the calculated road load as shown with dashed lines. Therefore, we expect that the declared road load following the WLTP requirement, if it comes into effect, would be lower than the calculated road load shown in the figure. So in terms of compliance, the difference between road load under WLTP and NEDC procedures should be smaller than the gap illustrated in the figure.

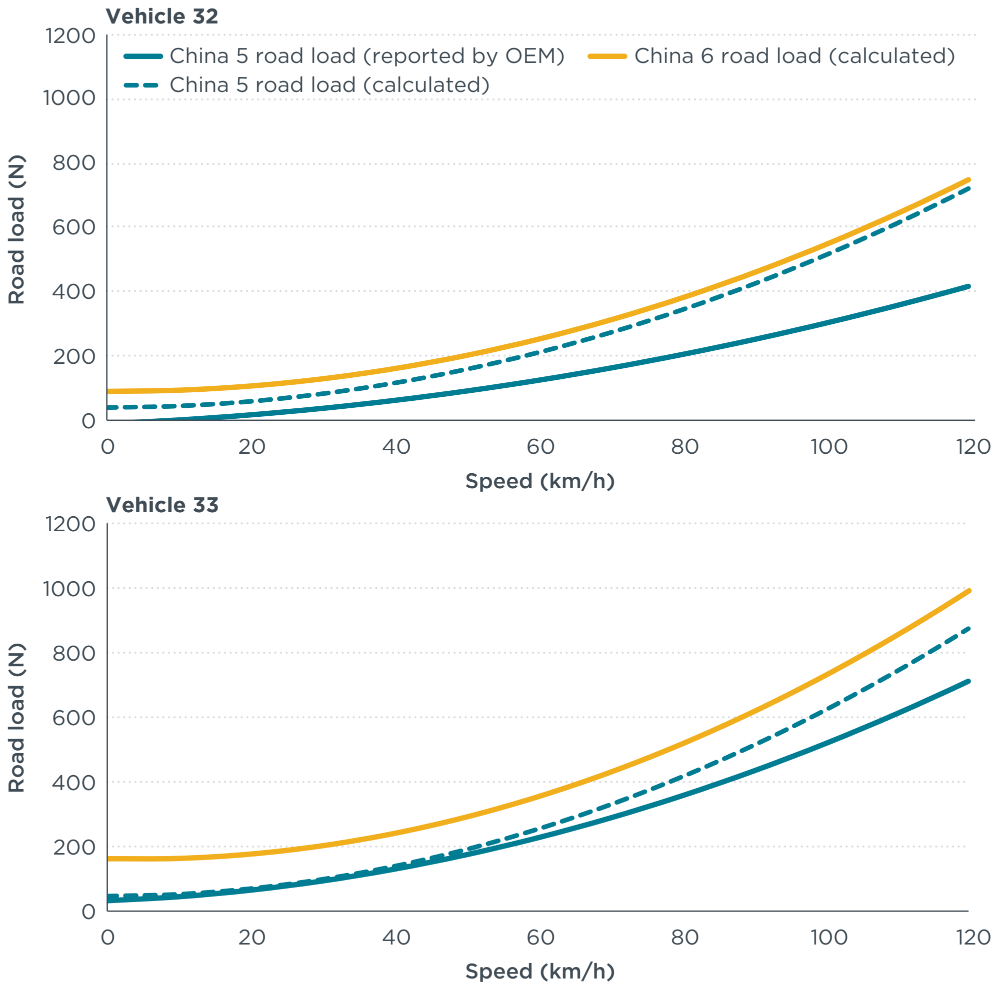

Figure 15. Road load setting for Vehicle 32 and Vehicle 33 using NEDC (China 5) and WLTP (China 6) methods

The air conditioning test was conducted only on Vehicle 32. The ambient temperature was set at 30°C. The A/C was turned on after engine ignition with the A/C set to full cold and recirculation mode, the flowrate of fan set to half, and the windows closed during the whole test.

3.3.2. Results and discussion

Figure 16 presents an overview of the laboratory test results of the two vehicles. CO_2 emissions over the standard NEDC test cycle (Test 1) of both vehicles were very close to the type-approval values, confirming that the vehicles were representative and working properly.

Road load parameters, test cycles, and usage of A/C have significant impacts on CO_2 emissions. The highest CO_2 emissions of Vehicle 32 were 27% higher than the type-approval value. Shifting from NEDC (Test 1) to WLTP (Test 8) brought a 19% CO_2 emissions increase on Vehicle 32 and a 9% increase on Vehicle 33.

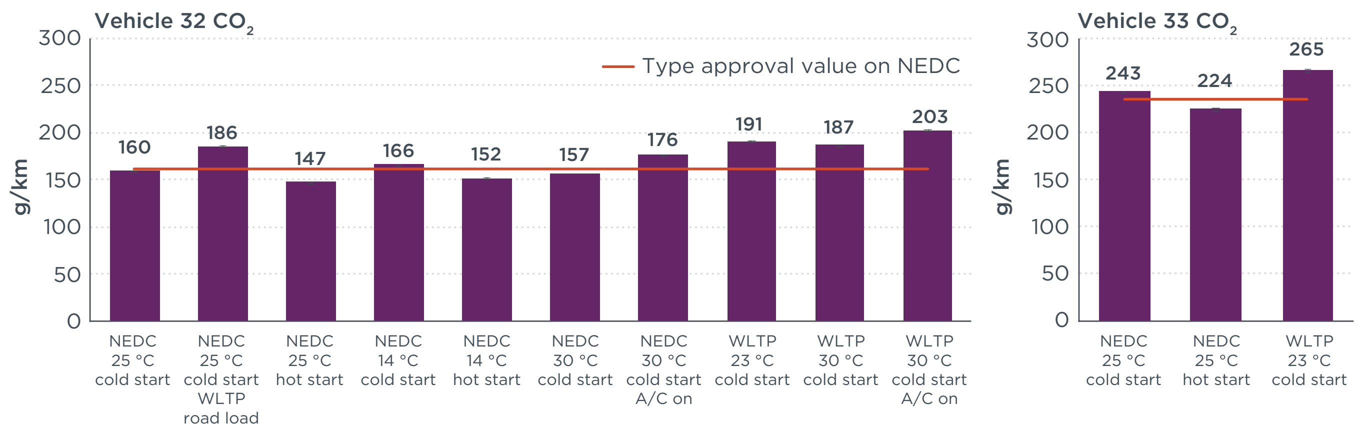

Figure 16. Overview of laboratory CO_2 emissions factors under different laboratory tests (error bars indicate standard deviation)

Impact of road load

Over the same NEDC test cycle, using the WLTP road load parameters (Test 2) increased CO_2 emissions of Vehicle 32 by 16% above the value using the NEDC road load (Test 1). Figure 17 presents the instantaneous CO_2 emissions rates under NEDC road load and WLTP road load. For CO_2, the discrepancies between NEDC road load and WLTP road load were very small during the first 800 seconds of NEDC when the speed was lower than 60 km/h. But the road load change had a much larger impact on CO_2 emissions during the high-speed phase of NEDC, especially when the vehicle speed was above 90 km/h. The higher CO_2 emissions during the high-speed phase correspond to the higher calculated engine load during the same period (Figure 18).

Observation: ***If a vehicle encounters higher resistance in real-world driving than the road load setting in the lab, it will have higher fuel consumption in the real world, especially at high speed.***

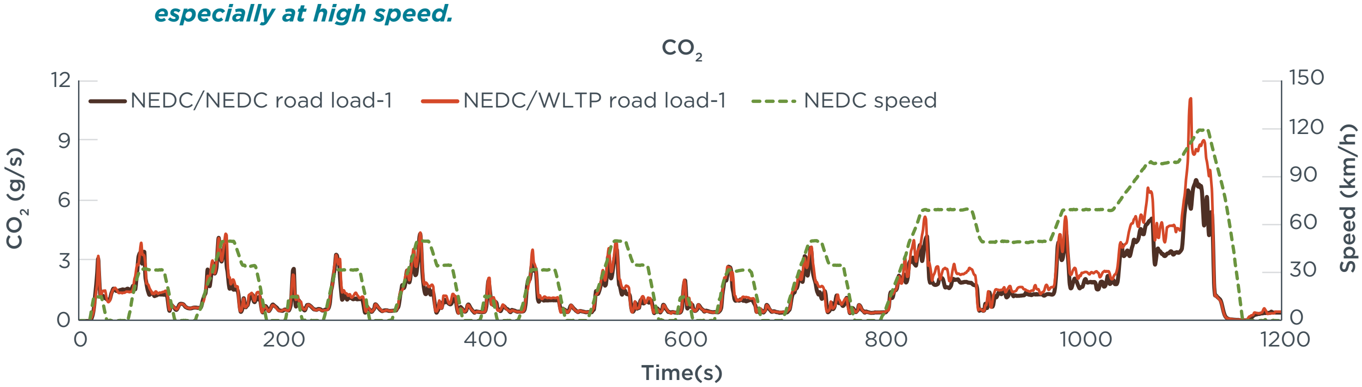

Figure 17. Instantaneous CO_2 emissions rates of Vehicle 32 under the NEDC road load and WLTP road load

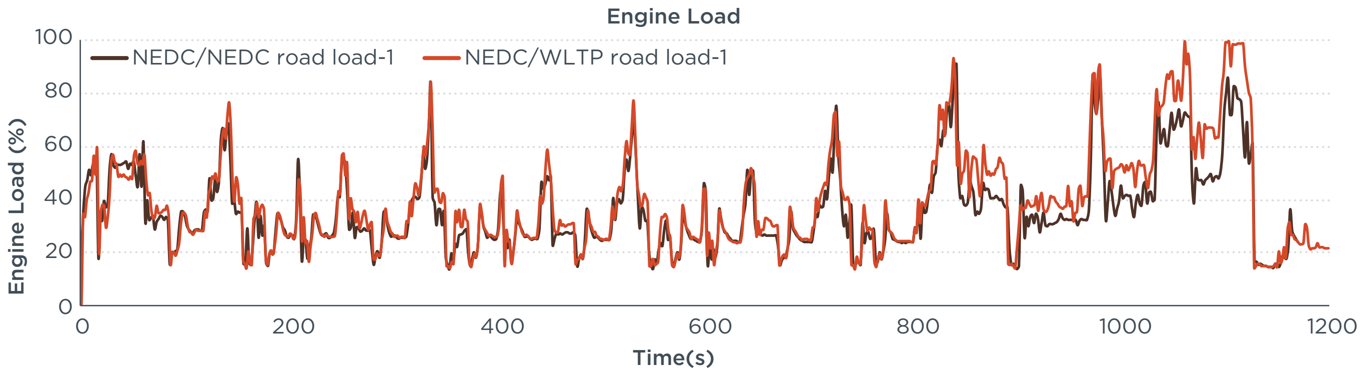

Figure 18. Instantaneous calculated engine load of Vehicle 32 under the NEDC road load and WLTP road load

Impact of ambient temperature

The tests change ambient temperature for both cold start and hot start testing. Vehicle 32 was tested over NEDC cold start at different ambient temperatures of 14°C (Test 4), 25°C (Test 1) and 30°C (Test 6). The CO_2 emissions at 14°C were 4% higher than the value at 25°C and 6% higher than the value at 30°C. Vehicle 32 was also tested with a cold start over the WLTP at two ambient temperatures, 23°C (Test 8) and 30°C (Test 9). CO_2 emissions at 23°C were 2% higher than the value at 30°C, consistent with impacts of temperature on the NEDC.

For cold start testing, the vehicle was preconditioned in a soak area at the constant ambient test temperature for 12 hours before the actual measurements took place. This test was to simulate driving a vehicle after hours of parking. Since the start-engine temperature was close to the ambient temperature, the lower the ambient temperature is, the longer it will take for the engine to heat up and reach the typical operation temperatures of 90-110°C for engine coolant and lubricants. Therefore, the friction losses and fluid viscosities during the warm-up period are higher than during normal operation and heat losses to the cylinder walls are also slightly higher.

As Figure 19 shows, CO_2 emissions of cold start under 14°C and 25°C of Vehicle 32 on the NEDC are higher during the warm-up period, especially when vehicle accelerates in the beginning of the trip.

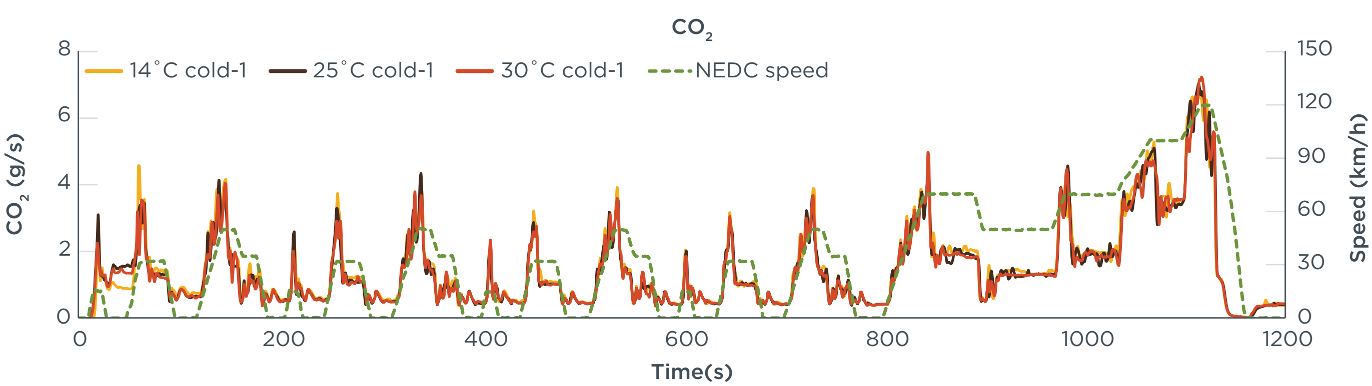

Figure 19. Instantaneous CO_2 emissions rates of Vehicle 32 over NEDC at 14°C, 25°C, and 30°C cold starts

Vehicle 32 was also tested over the NEDC with a hot start at different ambient temperatures, 14°C (Test 5) and 25°C (Test 3). Comparing the hot start tests (Figure 20), the CO_2 emissions at 14°C were 3% higher than the value at 25°C, almost the same as the percentage difference after a cold start.

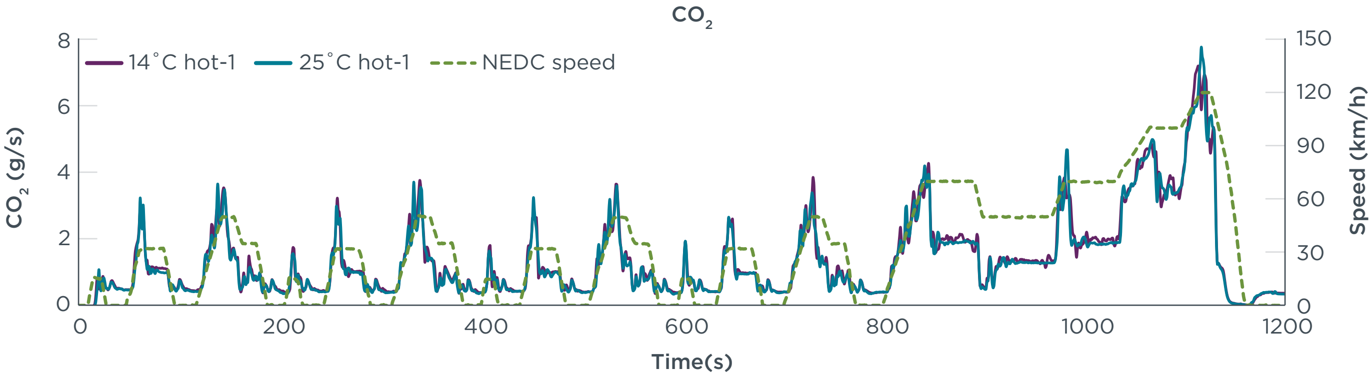

Figure 20. Instantaneous CO_2 emission rates of Vehicle 32 over NEDC at 14°C and 25°C hot starts

Observation: ***If a vehicle is driven at an ambient temperature lower than the temperature range specified for the type-approval test procedure, it will consume more fuel in real-world driving.***

Impact of cold starts

Vehicle 32 was tested over the NEDC with a hot start at 14°C (Test 5) and 25°C (Test 3). The CO_2 emissions of Vehicle 32 during hot-start tests were 8% lower than CO_2 emissions during the NEDC cold tart tests under both ambient temperature levels.

Vehicle 33 was also tested over the NEDC at the same ambient temperature (25°C) with a hot-start (Test 2) and a cold-start (Test 1). The hot-start CO_2 emissions were also 8% lower than on the cold start, showing excellent agreement with Vehicle 32.

Hot start testing was not conducted on the WLTP, so the impact of cold starts over the WLTP cannot be calculated. However, the cold start impact on fuel consumption over the WLTP will decrease compared with the NEDC, as the additional fuel consumption is diluted by the 50% longer distance of the WLTP test cycle.

Observation: ***Real-world and RDE tests that are conducted on a warmed-up engine will understate fuel consumption and CO_2 emissions***

Impact of testing procedure

Overall CO_2 emissions under the WLTP were 19% higher than the value under NEDC for Vehicle 32 and 9% higher than for Vehicle 33. Switching testing procedure from NEDC to WLTP, including changes in test cycle, road load determination, vehicle test mass determination, and ambient temperature, would have a significant influence on CO_2 emissions (Mock, Kühlwein, Tietge, Franco, Bandivadekar, and German, 2014). Figure 21 and Figure 22 compare engine operating points[9] between NEDC and WLTP for Vehicle 32 and Vehicle 33. It is obvious that WLTP covers a wider range of both engine speed and engine load with possible full load operation.

9 Engine speed and engine load were determined from OBD outputs.

Figure 21. Engine operating points of Vehicle 32 over NEDC and WLTP

Figure 22. Engine operating points of Vehicle 33 over NEDC and WLTP

Figure 23 and Figure 24 present the instantaneous CO_2 emission rates over standard WLTP and NEDC tests of Vehicle 32 and Vehicle 33. High CO_2 emissions mainly occurred during the extra high-speed phase of WLTP and hard accelerations.

Observation: ***If a vehicle is verified under WLTP, its type-approved CO_2 emissions (fuel consumption on the label) will be higher than the value tested under NEDC.***

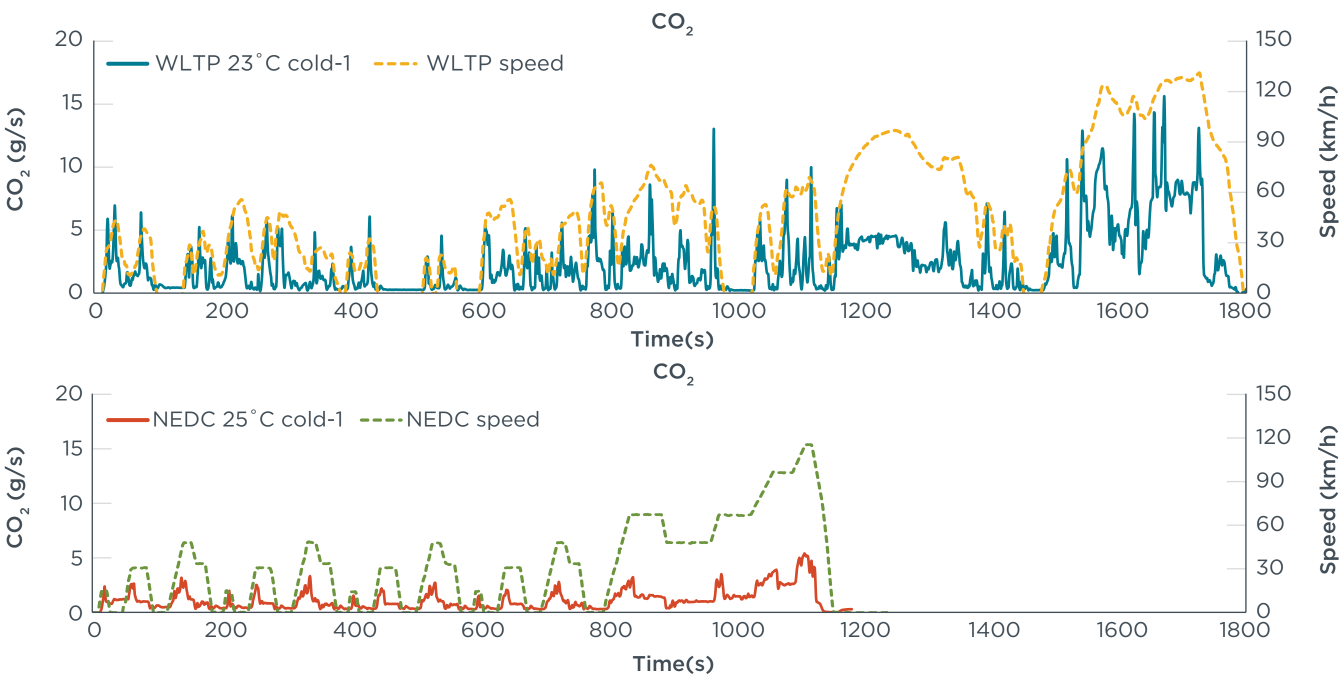

Figure 23. Instantaneous CO_2 emission rates of Vehicle 32 over standard WLTP (Test 8) and NEDC (Test 1)

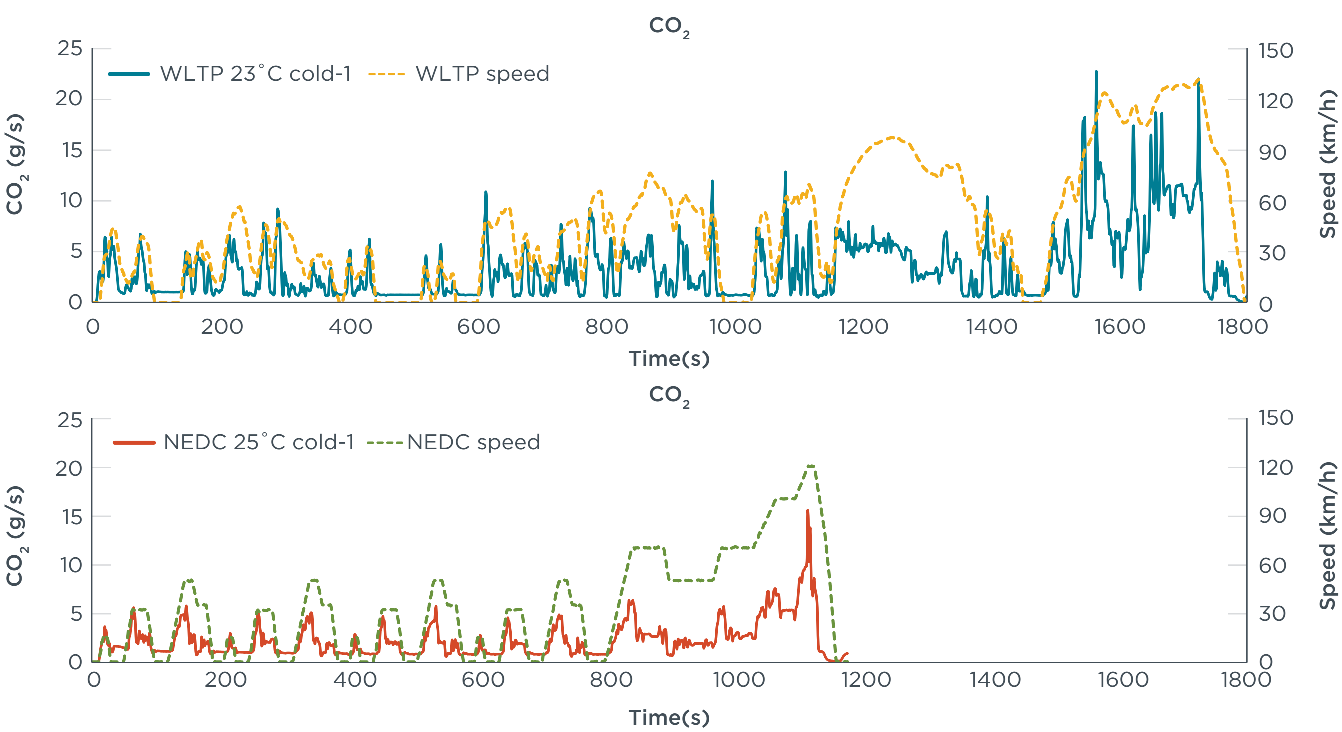

Figure 24. Instantaneous CO_2 emission rates of Vehicle 33 over standard WLTP (Test 3) and NEDC test (Test 1)

3.3.3. A/C operation

Testing vehicles with A/C turned on simulates CO_2 emissions in hot weather. Figure 25 shows the impact of A/C operation on CO_2 emission rates of Vehicle 32 over a cold start NEDC test at 30°C (Test 7), and Figure 26, a cold start WLTP test, also at 30°C (Test 10). The CO_2 emissions increased by 12% on the NEDC and 9% on the WLTP when A/C was turned on at 30°C. By looking at the instantaneous engine load profiles over NEDC (Figure 27), it can be observed that the engine load with A/C on was always higher than with A/C off, which is consistent with the higher CO_2 emissions in Figures 25 and 26. This is attributed to the fact that the engine needs to expend more energy to operate the A/C system.

Observation: ***If a driver turns on A/C while driving in hot weather, the vehicle will consume more fuel in real-world driving.***

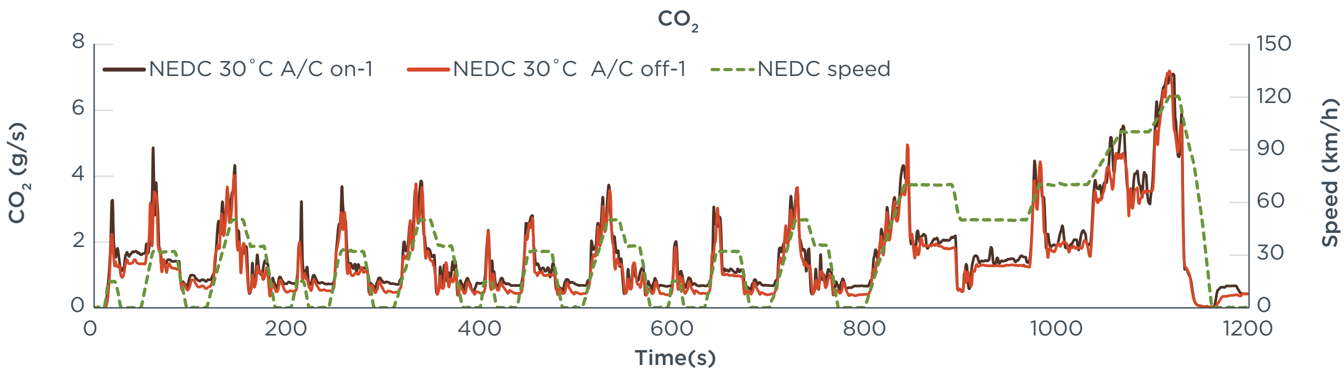

Figure 25. Instantaneous CO_2 emission rates of Vehicle 32 over NEDC at 30°C with A/C on and off

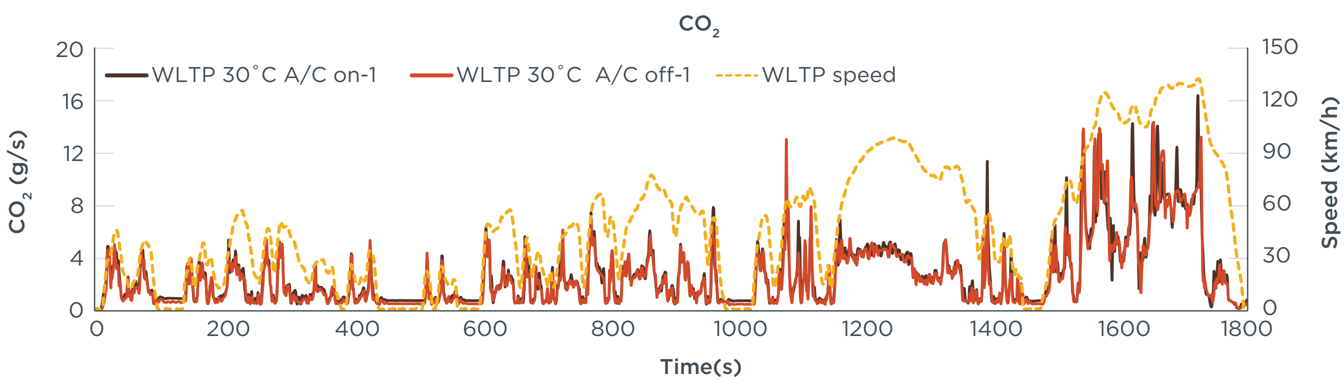

Figure 26. Instantaneous CO_2 emission rates of Vehicle 32 over WLTP at 30°C with A/C on and off

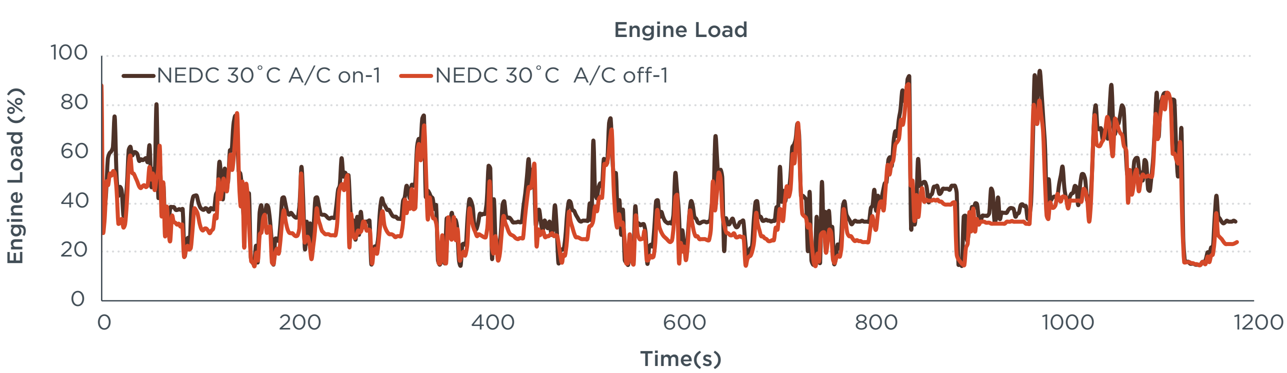

Figure 27. Instantaneous engine load of Vehicle 32 over NEDC at 30°C with A/C on and off

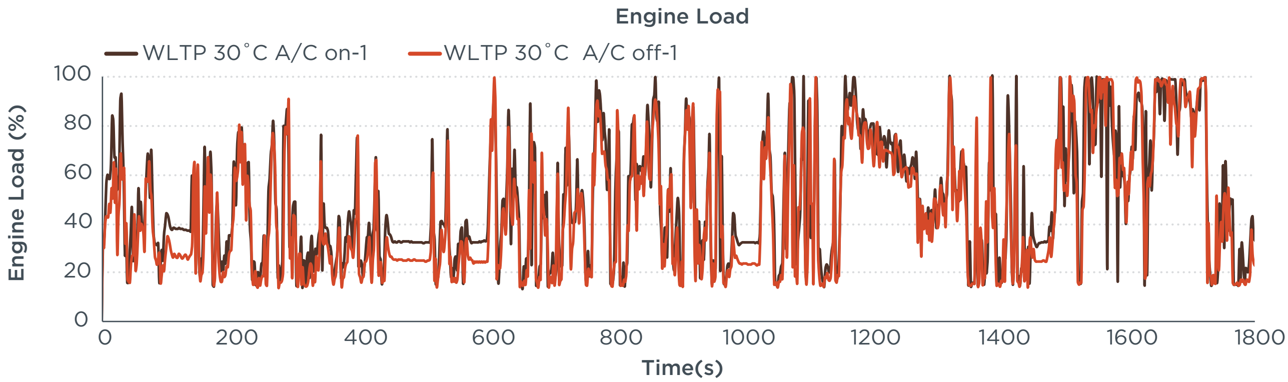

Figure 28. Instantaneous engine load of Vehicle 32 over WLTP at 30°C with A/C on and off

4. FINDINGS AND ANALYSIS OF RESULTS

Finding 1: *The increasing gap between real-world and type-approval fuel consumption will dilute the impact of fuel consumption policies.*

The divergence between real-world and type-approval fuel consumption increased almost 4 percentage points in 2016 and 5 percentage points in 2017, much higher than the average increase of 1.5 percentage points from 2007 to 2015. This trend, if it continues, will offset the benefits from technological improvement of conventional vehicles. The fuel saving or CO_2 emissions estimated by the reduction of type-approval fleet average fuel consumption will not be fully realized in the real world.

Figure 29 illustrates average official and estimated real-world fuel consumption of passenger cars in China from 2008 to 2016 based on the consumer-reported versus type-approval fuel consumption ratio summarized in Section 3.1. It shows that China made little progress in reducing fuel consumption in real-world driving since 2008. If the fuel consumption gap between real-world driving and type-approval results keeps widening, even though conventional vehicles are expected to have higher reduction rates in the future on the official tests, a much smaller portion of those reductions would be reflected in real-world driving.

Unless regulators solve the issue of growing divergence appropriately, the gap will continue to dilute fuel consumption policies and lessen the incentives for manufacturers to improve technologies of conventional vehicles that work in the real world.

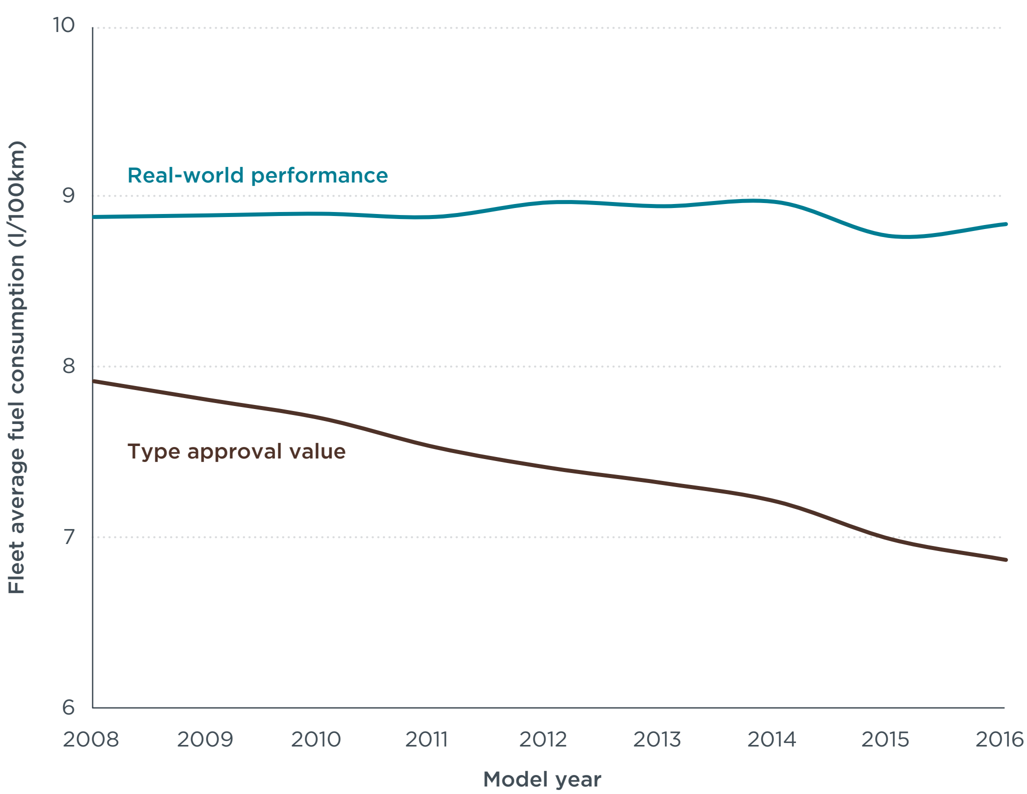

Figure 29. Official and real-world fuel consumption values for new passenger cars in China (2008-2016)

Finding 2: *The mismatch between real-world and type-approval fuel consumption will reduce consumers' faith in fuel consumption labels and government certification.*

Since 2009, vehicle fuel consumption has been disclosed to consumers on labels, usually at the showroom or through manufacturers' websites. The official fuel consumption level shown on the labels includes type-approved values under city, highway, and combined driving cycles.

The current average consumer-reported fuel consumption is close to the official fuel consumption for the city driving cycle—both are around 30% above the combined type-approval level. So in the latest revision of the labeling requirement in 2016, regulators intended to use the city cycle fuel consumption data to better present real-world fuel consumption. However, there are two concerns about whether this change could solve the problem. First, the consumer-reported data may have some bias in the sample, which cannot accurately reflect the real-world fuel consumption. Second, although not perfectly accurate, the consumer-reported data reflects the trend of a widening gap between real-world and type-approval fuel consumption. This means that the real-world consumption might exceed the city cycle consumption as measured in type-approval testing in a few years.

Therefore, the mismatch between real-world driving experience and the fuel consumption value on the label will cause consumers to lose faith in the label and the validity of the type-approval fuel consumption certified by the government.

Finding 3: *Different driving conditions—including road load, driving cycle, and A/C application—significantly influences CO_2 emissions and fuel consumption.*

There is common agreement in China that a revision of the vehicle test procedures is needed to better reflect real-world driving, especially as the next phase of vehicle emissions standards will also involve a switch in testing procedure from NEDC to WLTP. The WLTP improves on the current NEDC in certain respects, including test cycle, road load determination, test temperatures, vehicle mass, and testing altitude. There are also conditions that are not covered by either NEDC or WLTP, such as application of A/C during driving in hot weather, colder ambient temperatures, and more-aggressive driving.

Figure 30 illustrates the impact of road load, driving cycle, and A/C application on CO_2 emissions for Vehicle 32, based upon the laboratory testing results.

The revised methodology for determining road load under WLTP, including the method to calculate vehicle inertia mass, increases measured CO_2 emissions by 16% based on the testing results of Vehicle 32. This may be overstated, as the road load difference compares the manufacturer-reported road load factors under the NEDC regulation with the calculated road load factors in the WLTP regulation. Manufacturers usually conduct coast-down tests for better, or lower, self-reported road load factors. Thus, the real impact of road load factor on CO_2 emissions in laboratory testing could be lower, especially if the regulations give manufacturers leeway in determining the vehicle's road load using the coast-down test. Also note that the combined difference in road load and WLTP speed trace reduced CO_2 emissions of Vehicle 33 by only 9%, also suggesting that the 16% seen on Vehicle 32 for road load and test mass changes alone may be overstated.

The difference in speed trace and other elements contributes to an additional 3% of measured CO_2 emissions. The WLTP has a more dynamic driving trace and therefore results in higher fuel consumption. The WLTP also requires a slightly lower engine temperature at test start, which results in higher fuel consumption. However, the cold start impact on fuel consumption decreases in the total fuel consumption results because it is diluted by the 50% longer distance of the WLTP test cycle.

A/C use during hot weather adds a parasitic load on the engine, therefore increasing fuel consumption. Driving vehicles with A/C on is not covered by either the NEDC or the WLTP, but it results in an increase of about 10% in CO_2 emissions in the laboratory testing over the WLTP cycle. Note that the A/C impact on fuel consumption varies widely depending on vehicle speed, with a much greater effect at low speeds, and type of vehicle, with a much higher impact on a low-powered vehicle than a high-powered vehicle.

Be mindful that the emissions impacts evaluated with laboratory testing are primarily based upon a single vehicle. Although the detailed design of the test procedure is sufficient to illustrate the importance of different test elements on the CO_2 emissions test results, the percentage impacts are probably not representative of the expected impacts on CO_2 emissions of the entire fleet. For example, for Vehicle 33, the increase of CO_2 emissions under the WLTP is 9% higher than under the NEDC, compared with a 19% gap for Vehicle 32 through the same test procedures. To fully compare the difference in CO_2 emissions under the NEDC and the WLTP, more vehicles need to be tested to make the results representative of passenger cars in China.

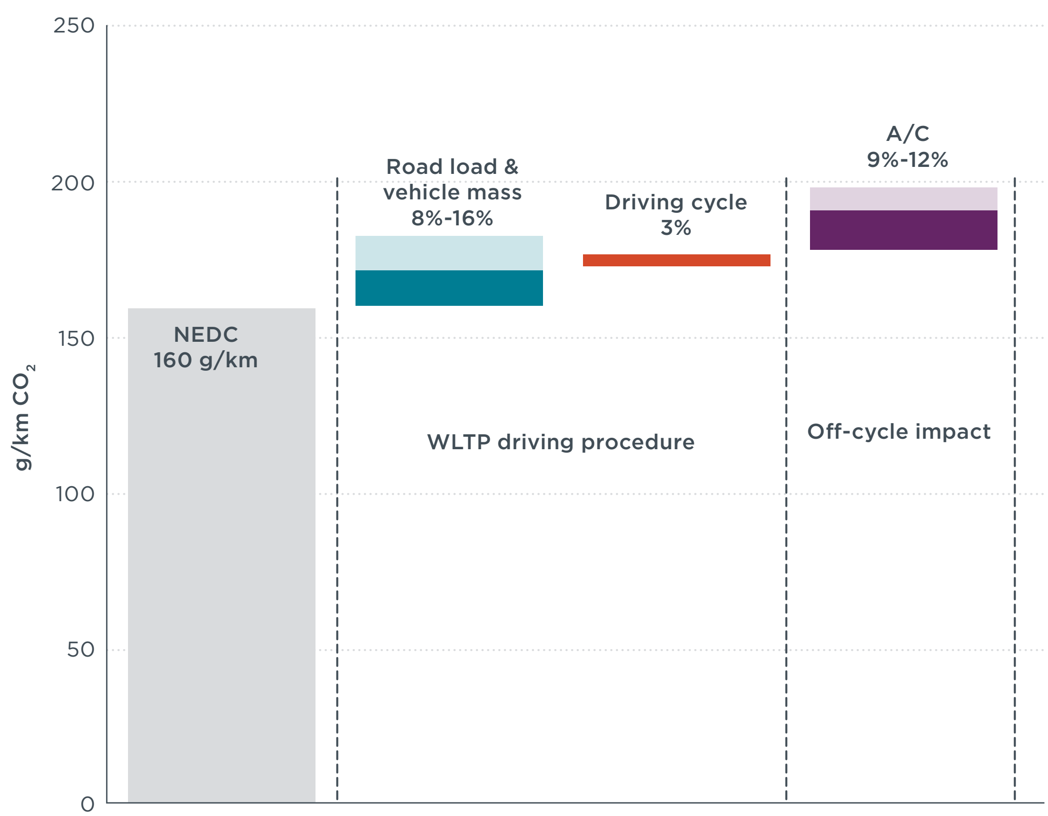

Figure 30. Graphic illustration of estimated CO_2 emissions impact from switching from NEDC to WLTP and turning on A/C

Finding 4: *Although the WLTP covers a wider range of driving conditions than the NEDC, the RDE test better represents actual on-road driving behaviors.*

Figure 31 presents a comparison of instantaneous driving points of a valid RDE test, the WLTP, and the NEDC. The figure clearly indicates that the NEDC is a very mild driving cycle with primarily steady-state speed operation and, thus, does not realistically represent real-world driving conditions. The WLTP covers a wider range than the NEDC and adds far more speed transients, but it is still a relatively mild cycle. Even with the driving cap that excludes more aggressive driving with the largest emissions impacts, the RDE covers the widest range of operation points and better represents actual on-road driving behaviors.

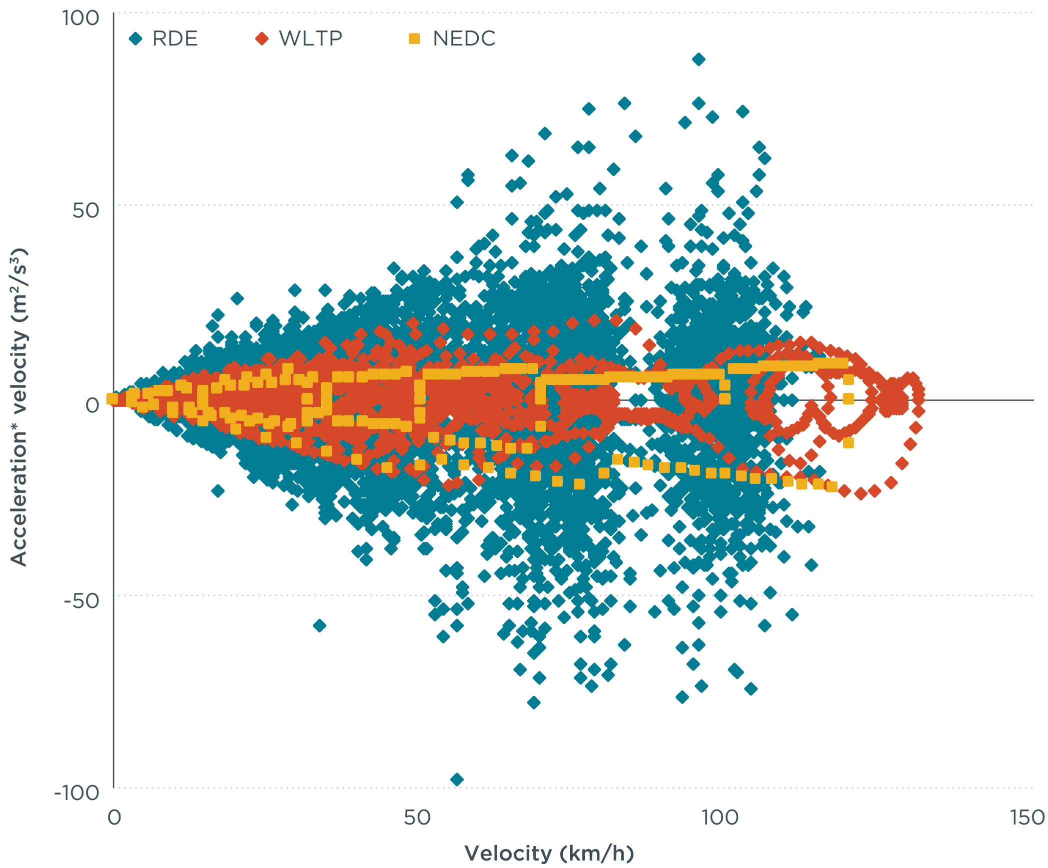

Figure 31. Instantaneous velocity and acceleration times velocity of RDE-valid 1 of Vehicle 32, WLTP and NEDC

Table 6 summarizes the results in Section 3.2.2 by listing the final RDE emissions conformity factors relative to NEDC and WLTP of vehicles 32 and 33. The conformity factors of CO_2 to NEDC were calculated as the ratio of on-road CO_2 emissions to the type-approval values published by China's Ministry of Industry and Information Technology (MIIT). The conformity factors to WLTP were calculated based on the laboratory test results under WLTP. It should be noted that cold starts were excluded in the data processing. The real-world CO_2 with cold starts would be more than 50% above the NEDC findings for these two cars.

Table 6. Conformity factors of CO_2 emissions of three RDE tests for Vehicle 32 and Vehicle 33

Vehicle No.	Test No.	Conformity factor to NEDC	Conformity factor to WLTP
Vehicle 32	RDE-mild	0.9	0.8
	RDE-valid 1	**1.6**	**1.4**
	RDE-valid 2	**1.5**	**1.2**
Vehicle 33	RDE-mild	1.0	0.9
	RDE-valid 1	**1.5**	**1.3**
	RDE-valid 2	**1.5**	**1.3**

Results from the PEMS testing of 33 vehicles in Section 3.2.2 prove the feasibility of using the RDE test to stimulate on-road CO_2 emissions of vehicles, although if the on-road testing is to be used for enforcement, the data suggests the need for boundary conditions. The testing conditions can be defined while maintaining flexibility to check a vehicle's real fuel consumption performance. The principles for determining the mildness and aggressiveness of the RDE trip are effective enough to filter out irregular trips, therefore providing a level playing field for manufacturers. The test results are also well aligned with the real-world fuel consumption trend collected through consumer reports.

5. POLICY RECOMMENDATIONS

The findings from the three data sources provide good insights regarding the widening gap between real-world and official fuel consumption in China. The accelerated expansion of the gap clearly indicates the need for regulatory changes to reverse the trend and close the gap. Recommended regulatory innovations are:

- **Enhance the "China cycle" with test procedures that are equal to or more stringent than WLTP test procedures.**
    - The existing NEDC test cycle is too mild to represent real-world driving conditions. China should switch to the WLTC or the "China cycle" that is under development to make the test cycle more representative of real-world driving.
    - The test cycle that determines the vehicle speed trace is a relatively small part of the factors influencing fuel consumption test results. Regulators must also pay attention to test procedures, such as inertia weight determination, road load calculation or coast-down test, and A/C usage to ensure they are representative of on-road conditions. It is more important to define all the details in the test procedure to reduce the opportunity for manufacturers to game the system than to adopt a more representative test cycle. The WLTP test procedure is a good benchmark.
    - The regulatory agency should verify the effectiveness of test-procedure changes by estimating the influence of each parameter change in the new test procedure.
- **Adjust the values on fuel consumption labels to reflect average real-world consumption.[10]**
    - Started January 1, 2018, MIIT required vehicles to apply a revised label design emphasizing the city-driving fuel consumption value more than the combination of city and highway driving. The goal of this revision was to get the main fuel consumption value closer to the average consumer's driving experience. As of March 31, 2018, we have not seen the switch to the newly designed label on MIIT's website. It is critical to ensure the new fuel consumption label format is being adopted as soon as possible.
    - Regulators should establish an adjustment method to get the fuel consumption value close to the average real-world performance. The revised fuel consumption label design is an improvement, but it does not address the fundamental difference between the type-approval value and average real-world fuel consumption. Most cars are not driven only in the city; thus, the city cycle fuel consumption is not representative of most real-world driving situations. The United States has set precedents for adjusting fuel consumption values on the label, first with a simplistic percentage adjustment applied to all vehicles in 1984, then with an update in 2007 for a more accurate adjustment based upon a five-cycle test method to simulate varied driving situations. A previous study (Tietge et al., 2017) verified that this adjustment is effective in bringing the label fuel consumption values much closer to the average real-world consumption.

10 Real-world fuel consumption varies widely, based on driving conditions, vehicle speed, and driver behavior, so the goal should be to match average real-world fuel consumption.

- **Extend RDE test to fuel consumption standards, especially for in-use conformity testing, and define compliance factor.**
  - Regulators should introduce the RDE test to complement the laboratory test procedure and better represent the range of real-world driving conditions. The laboratory testing results presented in Section 3.3 indicate that the laboratory test procedures do not properly reflect the range of real-world driving and that vehicles in China are specially designed to optimize fuel consumption on the NEDC test. Switching to the WLTP or a China-specific testing procedure will increase the coverage of driving conditions, but chassis dynamometer tests will always be conducted under well-defined conditions. The RDE test better reflects the wide range of driving and conditions of real-world driving. This would push manufacturers to make their systems more robust and reduce fuel consumption over a wider range of driving behaviors and conditions.
  - Fuel consumption standards should add in-use conformity testing requirements to check compliance against standards throughout the useful life of the vehicle. The RDE test should be required for in-use conformity testing, the same as the RDE test requirement in China 6 emissions standards.
  - Regulators need to conduct more RDE tests to determine the proper conformity factor to be applied in RDE tests for fuel consumption. The conformity factor could be a little more lenient when the RDE test procedure is first introduced and then be tightened over time.
- **Require application of On Board Diagnostics package 3 (OBD3) to monitor fuel consumption and establish official procedures to collect and publish fuel consumption information from in-use OBD3 systems.**
  - New cars in China should be required to install OBD3 systems that can monitor vehicle fuel consumption. These requirements should include both on-board summaries of accumulated fuel consumption and OBD channels streaming fuel consumption and other relevant information to an off-board data logger. Regulators should determine the method for calculating fuel consumption from the OBD data and require manufacturers to provided average fuel consumption information for each model annually. Regulators should publish the real-world fuel consumption information to provide information on how accurate the label values are by manufacturer and vehicle and to enable third-party supervision.
  - Develop a national website similar to the My MPG service, a national platform established by the U.S. Environmental Protection Agency and U.S. Department of Energy to collect real-world fuel consumption information from vehicle owners. This consumer-reported information should be used to verify the real-world fuel consumption collected from OBD systems.

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