POLICY UPDATE

JULY 2013

SUPPLEMENTAL NO_X STANDARDS FOR EURO IV AND V HEAVY-DUTY VEHICLES IN BEIJING

ICCT **POLICY UPDATES** SUMMARIZE REGULATORY AND OTHER DEVELOPMENTS RELATED TO CLEAN TRANSPORTATION WORLDWIDE.

It has been widely demonstrated in Europe and Beijing that some heavy-duty diesel vehicles (HDDVs) certified to the Euro IV and V standards emit excess NO_X emissions when operating in low-speed, urban driving conditions.[1] In some cases, real-world NO_X emissions from these vehicles even exceed those of Euro III vehicles. In February 2013, the Beijing Municipal Environmental Protection Bureau (EPB) released two new local standards specifically designed to prevent these excess NO_X emissions.[2] In doing so, Beijing has become the first region in the world to attempt to solve a known deficiency in the Euro IV and V standards by requiring additional environmental testing (including both supplemental testing beyond the type approval stage as well as in-use compliance testing).

The two Beijing standards, which are supplements to the existing national China IV and V standards (prescribed in GB17691-2005[3] and comparable to Euro IV and V), apply to China IV and V vehicles with Gross Vehicle Weight above 3,500kg and registered in Beijing. The two standards are as follows:

- DB11/964-2013,[4] "Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles (Bench mode methods)." It requires China IV and V engines to be tested over the World Harmonized Transient Cycle (WHTC) in addition to the currently required European Transient Cycle (ETC). In Europe, testing over the WHTC is not required until the Euro VI stage. Both cold-start and hot-start testing are required, with results weighted 14% and 86%, respectively.
- DB11/965-2013,[5] "Limits and measurement method of emissions from heavy duty vehicle (PEMS method)." This second standard establishes in-use, complete vehicle Portable Emission Measurement System (PEMS) testing requirements for manufacturers to prove that real-world emissions do not overly exceed certification limit values.

1 A detailed description of the problem and proposed solutions may be found in the 2012 ICCT publication, "Urban off-cycle NO_X emissions from Euro IV/V trucks and buses," available online at http://www.theicct.org/urban-cycle-nox-emissions-euro-ivv-trucks-and-buses.

2 Beijing EPB announcement about the two standards: http://www.bjepb.gov.cn/portal0/tab189/info9924.htm.

3 GB17691-2005 - Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles (III, IV, V).

4 Full standard available online at: http://www.bjepb.gov.cn/Portals/0/fujian/zwgk/kjbz/964车用压燃式、气体燃料点燃式发动机与汽车排气污染物限值及测量方法（台架工况法）.pdf

5 Full standard available online at: http://www.bjepb.gov.cn/Portals/0/fujian/zwgk/kjbz/965重型汽车排气污染物排放限值及测量方法（车载法）.pdf

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

It should be noted that the two supplemental standards do not change the existing national type approval process as described in GB17691-2005. Rather, these standards represent new "environmental protection approval" requirements that must be met for applicable HDVs and their engines to be registered in Beijing.

The two standards were implemented on March 1, 2013, and July 1, 2013, respectively. Together, the standards are designed to force manufacturers to employ NO_X reductions strategies that function across a broader range of exhaust temperatures and therefore vehicle operating conditions.

The Beijing EPB estimates that implementation of these standards may reduce NO_X emissions from applicable China IV/V diesel vehicles by up to 60% during urban operation.[2] The Beijing EPB has even announced their intention to retrofit the approximately 9,000 existing China IV and V heavy-duty vehicles sold in Beijing prior to implementation of the new standards.

BACKGROUND

Real-world emissions testing in both Europe and China has demonstrated that some Euro IV and V HDVs emit excess NO_X emissions during low-load or low-speed operations.

For example, Figure 1 shows real-world NO_X emissions of 22 China IV buses tested in Beijing using a Portable Emissions Measurement System (PEMS).[6] The buses operate at low average speeds due to congestion in the city. Only three buses show emissions levels below the limit, while most of the buses show emissions two or three times the limit.

Even more widespread testing of over a hundred trucks and buses by researchers in Beijing from 2008 to 2010 showed that there was no significant difference in NO_X emissions between the Euro III and IV buses.[7] This confirmed results that have been previously demonstrated on European trucks and buses. Figure 2 illustrates different levels of NO_X emissions of Euro IV and Euro V trucks tested on German roads using PEMS.[8] Both truck types were equipped with the Selective Catalytic Reduction (SCR) system. The figure shows that NO_X emissions were significantly higher at average speeds below 30 km/h than at higher average speeds. The ETC limit is shown as a straight line. It is noted that emissions from none of the tests at low average speeds met the ETC limit.

6 Source: CATARC, "Emission limits and test procedure for heavy-duty vehicles," standard project for Beijing; 车用压燃式、气体燃料点燃式发动机与汽车冷启动排气污染物排放限值及测量方法》(征求意见稿)编制说明, July 2012.

7 Wu, Y., et al., "The challenge to NO_X Emission Control for Heavy-duty Diesel Vehicles in China," Atmos. Chem. Phys., 12, 9365-9379, doi:10.5194/acp-12-9365-2012, 2012.

8 Source: Kleinebrahm, M., et al., "On-Board Measurements of Euro IV / V Trucks, Final Report", a research project of the Federal Environmental Agency (FKZ: 204 45 144). Germany: TUV NORD Mobilität, 2008.

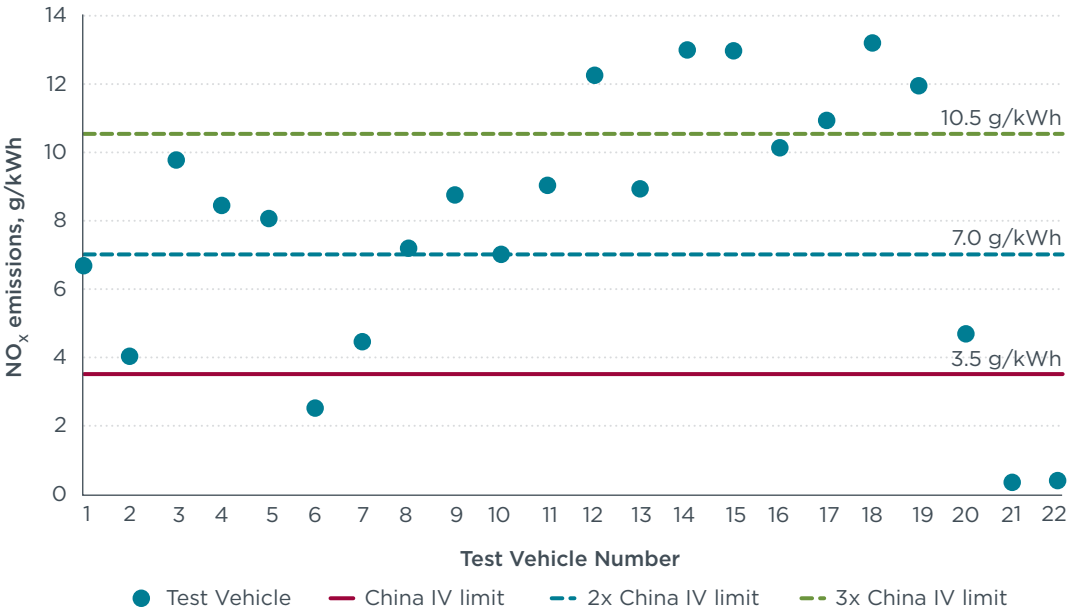

Figure 1 Real-world NO_x emissions of 22 China IV buses[9]

This phenomenon is attributed to the low efficiency performance of some SCR after-treatment systems when exhaust temperatures are low. SCR after-treatment technology can be very effective and has been adopted by many vehicle manufacturers for meeting emission standards at the Euro IV level and above. However, one of the main downsides of some SCR systems is that they are not designed to effectively reduce NO_x emissions under operating conditions with lower temperature exhaust such as cold-start and low-speed urban driving modes.

The fundamental problem is that the Euro IV/V type approval process does not require testing over such low-load conditions; therefore, it does not adequately address real-world emissions over a full range of driving cycles. In 2012, the ICCT published a white paper highlighting this problem and providing recommendations to address the issue of high real-world NO_x emissions from Euro IV/V HDVs.[10] These recommendations included adding testing procedures that include cold-start testing as well as testing over the World Harmonized Transient Cycle (WHTC), plus adding not-to-exceed (NTE) limits and in-use compliance testing. Compared to the European Transient Cycle (ETC), the WHTC includes more percentage time for low-speed and low-load driving and is more representative of real-world driving characteristics. This issue is relevant across all developing countries that follow the European HDV emissions standards; implementation of supplemental regulations is an effective means of controlling this problem.

9 Source: CATARC, "Emission limits and test procedure for heavy-duty vehicles," standard project for Beijing; 车用压燃式、气体燃料点燃式发动机与汽车冷启动排气污染物排放限值及测量方法》(征求意见稿)编制说明, July 2012.

10 "Urban off-cycle NO_x emissions from Euro IV/V trucks and buses," the ICCT, 2012

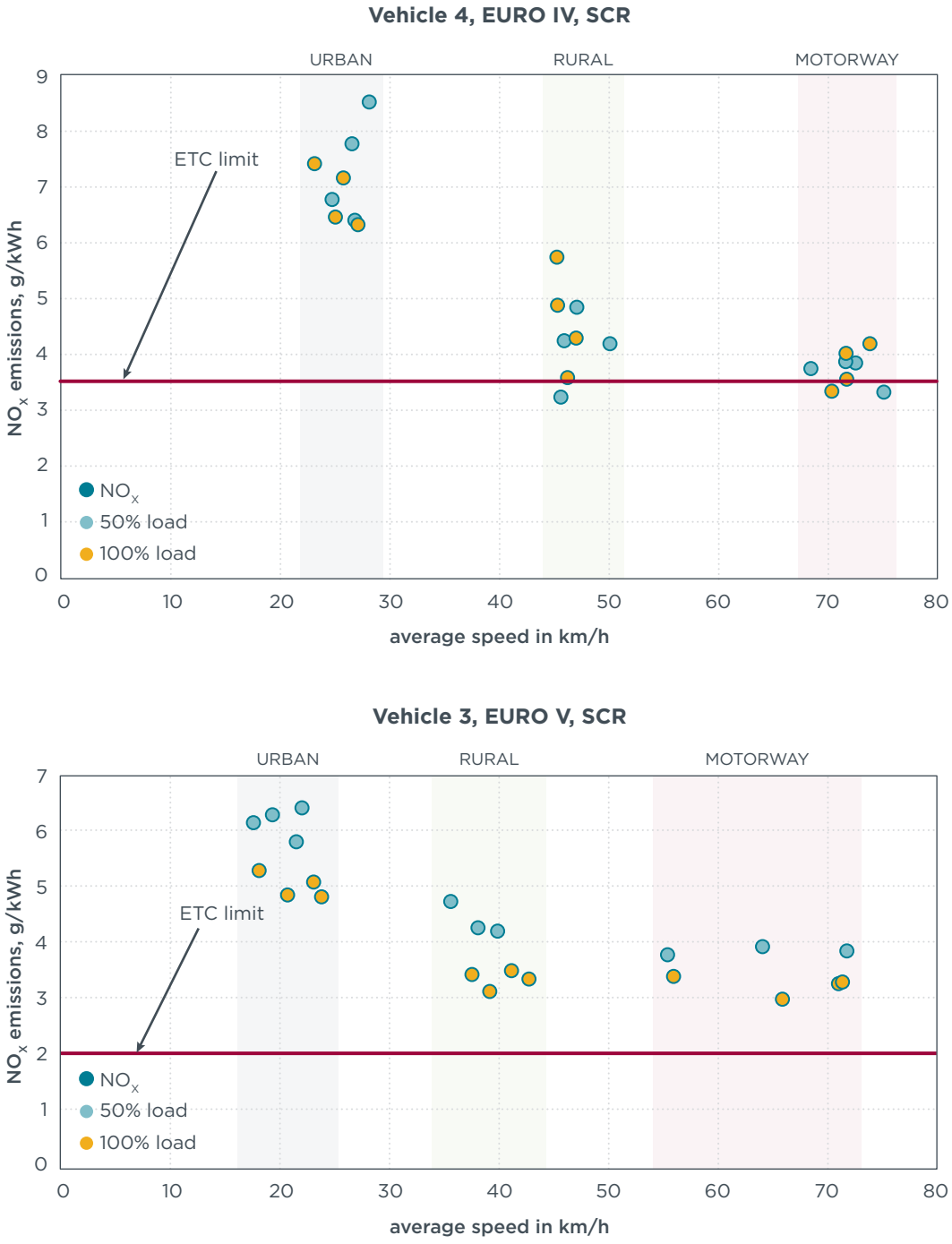

Figure 2 NO_x emissions of 18,000 kg Euro IV and V trucks tested on German roads using PEMS[11]

11 Source: Kleinebrahm, M., et al., "On-Board Measurements of Euro IV / V Trucks, Final Report", a research project of the Federal Environmental Agency (FKZ: 204 45 144). Germany: TUV NORD Mobilität, 2008.

THE NEW BEIJING STANDARDS

Within China, Beijing frequently takes the lead in advanced implementation of stringent fuel quality and vehicle emission standards. In 2008, Beijing became the first region in mainland China to require diesel fuel with a maximum sulfur content of 50ppm, and the first region to implement the China IV (Euro IV) tailpipe emission standards. Both milestones were achieved years before the rest of the nation. Continuing this tradition of early, aggressive action, the Beijing EPB developed two supplemental standards to address the excess urban NO_X issue. This section provides more details for each of the new standards.

Both standards apply to M_2, M_3, N_2 and N_3 vehicles with design speed above 25 km/h as well as their engines. They also apply to M_1 category vehicles with Gross Vehicle Weight (GVW) above 3,500 kg and their engines. (M categories refer to vehicles carrying passengers, while N categories refer to vehicles carrying goods. M_1 category refers to vehicles with no more than nine seats (including the driver). M_2 and M_3 refer to vehicles with more than nine seats (including the driver). M_2 has GVW less than 5,000 kg, while M_3 has GVW more than 5,000 kg. N_2 has GVW more than 3,500 kg but less than 12,000 kg, while N_3 has GVW more than 12,000 kg.[12])

Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles (Bench mode methods) (DB11/964-2013)

This regional standard is a supplement to the existing national standard GB17691-2005[13] and its amendments. Compared with GB17691-2005, the new standard includes three main changes:

1. Addition of a requirement to test over the World Harmonized Transient Cycle (WHTC);
2. Addition of a cold-start testing requirement;
3. Future expected requirements of the China VI stage.

China IV/V HDVs are required to meet this standard during normal usage over their useful life. In addition to the limits set for the European Stationary Cycle (ESC), European Transient Cylce (ETC), and European Load Response (ELR) tests as provided in GB17691-2005, vehicles are required to meet the limit values from engine dynamometer testing over the WHTC[14] before receiving "environmental protection approval." This "environmental protection approval" is granted exclusively by the Beijing EPB for vehicles registered in Beijing. It is separate from the national type approval certification granted by the Ministry of Environmental Protection.

Both cold-start and hot-start tests are required to be performed over the WHTC, and overall test results combine weighted results from both tests. The standard sets weighting factors of 0.14 and 0.86 for cold-start and hot-start tests, respectively.

Table 1 provides the WHTC cycle limits for the China IV and V stages. Most of the limit values are equal to the Euro IV/V ETC values except those for NO_X emissions. Due to the

12 GB/T 15089-2001 – Classification of power-driven vehicles and trailers.
13 GB17691-2005 – Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles (III, IV, V).
14 World Harmonized Stationary Cycle (WHSC) testing and limits may also be used in the China VI stage.

cold-start test, NO_x limits were set higher than Euro IV/V values (shown in parentheses) by 5.7% and 40% for China IV and V stages, respectively.

Table 2 provides the limits for the future China VI stage. These values equal those of Euro VI. It is noteworthy that the supplemental standard already provides future Euro VI-equivalent limit values, even though Euro VI has not been formally drafted or adopted by any region in China. This shows Beijing's intention for future expected requirement of environmental protection approval.

Table 1 Emission limits of WHTC cycle for China IV and V. All values are identical to Euro IV/V ETC cycle limits except the NO_x values (original ETC NO_x emission limits shown in parentheses).

Stage	CO (g/kWh)	NMHC (g/kWh)	CH_4 (1) (g/kWh)	NO_x (g/kWh)	PM(2) (g/kWh)
China IV	4.0	0.55	1.1	3.7 (3.5)	0.03
China V	4.0	0.55	1.1	2.8 (2.0)	0.03

(1) Only gas engines
(2) Not applicable to gas engines

Table 2 Emission limits of WHSC and WHTC cycles for future China VI

	CO (g/kWh)	NMHC (g/kWh)	CH_4 (1) (g/kWh)	NO_x (g/kWh)	PM(2) (g/kWh)
WHSC	1.5	0.13	-	0.40	0.01
WHTC	4.0	0.16	0.5	0.46	0.01

(1) Only gas engines
(2) Not applicable to gas engines

To demonstrate production consistency, the standard requires three engine samples to be randomly selected from the same engine model (or family) and tested over the WHTC cycle.

Regarding the phase-in of the new standard, the requirements for the China IV stage were implemented on March 1, 2013, for all applicable new types of vehicles and their engines. Emission limits for the China V stage were implemented on July 1, 2013 for new types of buses and municipal sanitation vehicles and their engines. The standard states that the China V emission limits will be implemented for other vehicle types once China III diesel fuel is supplied to the regions outside of Beijing. According to the standard, all applicable new vehicles and engines that fail to meet the standard may not be sold, registered, or utilized in Beijing.

Limits and measurement method of emissions from heavy-duty vehicle (PEMS method) (DB11/965-2013)

This regional standard was developed with consideration of Beijing's specific situation and references the EPA CFR 40 Part 86 (86.1370 - 1372), CFR Part 1065 Subpart J, Commission Regulation (EU) No 582/2011 (revised draft), as well as part of technical

context of HJ439-2008 standard.[15] This standard is a supplement to GB17691-2005, and it requires using Portable Emissions Measurement System (PEMS) for emissions testing of China IV/V in-use HDVs.

The standard is applicable to the same categories of vehicles as described in the above standard, but specifically it only provides limits for NO_x emissions. Some driving characteristics might not be reflected during the engine dynamometer testing, thus this new standard was developed for in-use compliance testing to better represent real-world NO_x emissions from HDVs.

There are two methods to calculate emission values from PEMS testing: the work-based window method and the Not-To-Exceed (NTE) method. Manufacturers can choose either method to meet the limits. The methods are described below.

WORK-BASED WINDOW METHOD

A moving window is determined under the condition that the total work equals that of engine dynamometer testing over the ETC cycle. This work-based window keeps moving to the end of the test. This process generates a series of windows. For each window, continuous emission rates are integrated and then divided by the total window work. In addition, the average window power percent of each window is calculated using average power of the window divided by the engine maximum power.

NTE METHOD

An NTE event is determined if the engine has been continuously operated in the "NTE zone" for at least 30 seconds. An NTE zone is a closed area on the engine map which is defined by several boundaries such as 30% of max torque and power, highest engine speed of 70% of max power, and 15% above the lowest speed of 50% of max power. More details for the NTE test are located in CFR 86.1370-2007.[16]

The brake-specific emission rates (g/kWh) are calculated for each NTE event using the ratio of integrated emission rates to total work within the event. In addition, for each NTE event, a weighted duration is calculated. The passing rate of NTE events is determined based on the ratio of total weighted duration of NTE events below the NO_x limits to that of all NTE events.

LIMITS AND EVALUATION

The limit values and evaluation criteria for both methods are provided in Table 3. Sections B.3.2 and B.3.3 in Appendix B of the new Beijing standard (DB11/965-2013) provide more details on how to calculate and evaluate the results from the two methods.

Although manufacturers can select either method to meet the limits, there are different requirements for each method.

If the NTE method is selected, the standard requires at least five NTE events to occur during the test.

If the work-based window method is selected, the standard requires that the fraction of total windows with average window power percent above 20% be at least 50%.

15 HJ439-2008 standard "Technical requirements of in-use compliance of compression ignition and gas fuelled positive ignition engines of vehicles".

16 Code of Federal Regulations: http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol20/xml/CFR-2012-title40-vol20-sec86-1370-2007.xml

If the number cannot reach 50% of total windows, the 20% requirement for average window power percent can be reduced by 1% each time, but the minimum percentage needs to remain at 15%. This process applies till the applicable window number meets the 50% requirement.

To approve a vehicle model, the standard requires at least three, but no more than ten, vehicles to be tested. Table 4 provides pass/no pass criteria for the evaluation of vehicle models.

Table 3 Limit values of NO_x emissions

Calculation method		Work-based window method	NTE method
NO_x limits (g/kWh)	China IV	<=7.0	<=6.0
	China V	<=5.0	<=4.0
Requirement		The percentage of valid windows within the limits is more than 90%	The percentage of NTE events within the limits is more than 90%

Table 4 Evaluation criteria of vehicle models

Number of test vehicles	Least number of vehicles if pass	Least number of vehicles if no pass
3	3	-
6	5	4
10	7	4

TEST ROUTES OR CYCLES

The PEMS method can be applied to on-road or chassis dynamometer tests. Detailed information regarding test requirements, vehicle preparation, data processing, etc. are provided in Appendix B and C of the Beijing standard (DB11/965-2013).

For on-road tests, Table 5 provides information on how different types of routes are defined as well as how weights are allocated for different routes.

Table 5 Weight allocations for different types of routes

		Urban	Suburban	Highway
Vehicle speed		0 - 60 km/h	60 - 90 km/h	Above 90 km/h
Weight allocation	M_2 and M_3 category*	45%	25%	30%
	Transit buses and municipal sanitation vehicles	70%	30%	-
	N_2 category	45%	25%	30%
	N_3 category	20%	25%	55%

* Except for transit buses, etc., special purpose vehicles

For chassis dynamometer testing, transit buses are tested over the China Typical City Buses Cycle as prescribed in "Test methods for energy consumption of heavy-duty hybrid electric vehicles GB19754-2005."[17] All HDVs other than transit buses are tested over the "China Adapted World Transient Vehicle Cycle (C-WTVC)" as prescribed in "Fuel consumption test methods for medium and heavy-duty commercial vehicles GB/T 27840-2011."[18] According to the standard, test results from the China Typical City Buses Cycle are calculated and evaluated based on the work-based window method, while those from C-WTVC cycle are calculated and evaluated based on the NTE method.[19]

NEXT STEPS

Beijing has taken the lead at the local level to address the issue of excess NO_x emissions from Euro IV/V heavy-duty vehicles. It is unclear if other municipal environmental protection bureaus in China are developing similar regulations.

At the national level, China's Ministry of Environmental Protection in 2012 proposed and solicited comments on a similar—though narrower—supplemental standard for China IV/V heavy-duty vehicles.[20] That standard, "Limits and measurement methods for exhaust pollutants after a cold start from compression ignition and gas fuelled positive ignition engines of vehicles," proposed a WHTC cold-start test requirement for the type approval process and set test limit values for China IV/V stages. The standard would apply nationwide. However, it is unclear when or if a final version of this standard will be released.

As noted earlier, it is very likely that countries around the world which follow the Euro path will experience similar problems with excess NO_x emissions from Euro IV and V vehicles. It will be valuable for other regions in China and around the world to watch Beijing's experience carefully. If the urban NO_x emissions reductions estimated by the Beijing EPB (up to 60%) are actually achieved, other regions may consider similar supplemental standards for their fleets.

17 GB/T 19754-2005: Test methods for energy consumption of heavy-duty hybrid electric vehicles, http://www.spc.net.cn/produce/..%5Cproduce%5Cshowonebook.asp?strid=22897

18 GB/T 27840-2011: Fuel consumption test methods for medium and heavy-duty commercial vehicles, http://www.spc.net.cn/produce/..%5Cproduce%5Cshowonebook.asp?strid=55710

19 Refer to Section C.3.2 in Appendix C of DB11/965-2013.

20 China's Ministry of Environmental Protection calls for comments for the national supplemental standard: http://www.mep.gov.cn/gkml/hbb/bgth/201208/t20120810_234647.htm