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BRIEFING

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Accelerating progress from Euro 4/IV to Euro 6/VI vehicle emissions standards

This brief presents the technical details and benefits of leapfrogging to Euro VI heavy-duty emission standards and Euro 6 light-duty emission standards rather than progressing through Euro 5/V.

INTRODUCTION

As many countries model their vehicle emission standards after those developed for the EU, the lessons learned in the European market should inform policymakers and manufacturers in other markets. This means acknowledging both the successes of these policies in leading to highly efficient control technology, and some of the failings in intermediate policy stages. Since the adoption of Euro 5/V standards across the EU, several shortcomings of the regulation have been revealed. For heavy-duty vehicles, Euro V standards have not achieved hoped-for reductions for NO_x emissions.[1] While Euro 5 standards have resulted in dramatic reductions in PM emissions from light-duty diesels, real-world diesel NO_x emissions have continued to far exceed certification limits.[2] Regulators should weigh these regulatory weaknesses when considering whether to move directly to Euro 6 and VI or to include the intermediate stages.

The type-approval process is critical in ensuring that reductions in limit values translate into reductions in real-world emissions from light- and heavy-duty vehicles. The type-approval

1 Ligterink, N., de Lange, R., Vermeulen, R., & Dekker, H. (2009). On-road NO_x emissions of Euro-V trucks. TNO Science and Industry, Delft. Retrieved from http://www.researchgate.net/publication/235961441_On-road_nox_emissions_of_Euro-V_trucks
2 Carslaw, D., Beevers, S., Tate, J., Westmoreland, E., and Williams, M. (2011) Recent evidence concerning higher NO_x emissions from passenger cars and light duty vehicles. *Atmospheric Environment*, Volume 45, Issue 39, Pages 7053-7063.

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process specified for both Euro IV and V standards does not ensure that NO_x controls operate effectively in urban driving conditions. The issue has been addressed through the move to World Harmonized Test Cycles and efforts to improve real-world conformity to NO_x limits in Euro VI.[3] For light-duty vehicles, the current type-approval procedure (New European Driving Cycle or NEDC) allows certification of vehicles with real-world NO_x emissions far above regulatory limits,[4,5] a problem that will be partly addressed in the Real-World Driving Emissions (RDE) provision of Euro 6c and the transition from the NEDC to the World-Harmonized Light-Duty Test Procedure (WLTP).[6] While Euro 5 standards have forced use of diesel particulate filters (DPFs) for light-duty diesels, only the Euro VI standard introduces a particle number (PN) limit for heavy-duty vehicles, leading to the use of diesel particulate filters (DPFs) for all diesel vehicles. Given the regulatory improvements that Euro 6/VI standards provide, countries following emission standards modeled after European regulations should move directly from Euro 4/IV to Euro 6/VI standards.

EURO VI HEAVY-DUTY VEHICLE STANDARDS

Euro VI is a critical step in heavy-duty emission standards, resulting in significant real-world reductions for both NO_x and PM emissions. Euro VI lowers both NO_x and PM limits and introduces a limit on particle number which leads to the use of a DPF for heavy-duty diesel vehicles. The standard also overhauls the testing procedures to better represent real-world driving conditions, broadens the set of pollutants considered, and strengthens durability and OBD requirements.

In the EU, Euro VI standards were implemented for all new vehicle registrations in January 2014,[7] with some provisions to be phased in by 2017.[8] To allow early introduction of lower-emitting vehicles, Euro VI type approvals were granted starting in August 2009. EU member states used tax incentives to encourage the sale of Euro VI certified vehicles before full implementation of the standards.[9] The same technology packages being used to comply with Euro VI standards have been necessary to comply with US standards since 2010.

FILTER-BASED PM CONTROLS FOR DIESELS

Euro VI standards lower the limit on PM emissions by 67% relative to Euro IV and V,[10] and introduce a particle number limit making a diesel particulate filter (DPF) the most cost-effective solution to meet emission requirements. Due to the high efficiency of DPFs at capturing PM, this results in a 90% drop in PM emissions[11] and >99% reduction in the number of ultrafine particles.[12] DPFs have been used to meet PM standards for heavy-

3 Lowell, D. and Kamakate, F. (2012) Urban off-cycle NO_x emissions from Euro IV/V trucks and buses. The International Council on Clean Transportation. Retrieved from http://www.theicct.org/urban-cycle-nox-emissions-euro-ivv-trucks-and-buses

4 Weiss, M., Bonnel, P., Kühlwein, J., Provenza, A., Lambrecht, U., Alessandrini, S., Carriero, M., et al. (2012). Will Euro 6 reduce the NO_x emissions of new diesel cars? – Insights from on-road tests with Portable Emissions Measurement Systems (PEMS). *Atmospheric Environment*, Volume 62, December 2012, Pages 657-665

5 Franco, V., Posada Sanchez, F., German, J., and Mock, P., (2014). Real-world exhaust emissions from modern diesel cars. Part 1: Aggregated Results. The International Council on Clean Transportation. Retrieved from http://theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141010.pdf

6 Mock, P. (2013). World-harmonized light-duty vehicles test procedure. The International Council on Clean Transportation. Retrieved from http://theicct.org/wltp-november2013-update

7 The 2014 and 2017 dates refer to all new registrations; the implementation for new type approval was January 2013, with phase-in of additional provisions ending in 2016.

8 The provisions to be phased in by 2017 include lower OBD Threshold Limits

9 http://www.rijksoverheid.nl/nieuws/2012/05/30/subsidie-voor-schoonste-trucks-en-bussen.html

10 Regulation (EC) No. 595/2009, Annex I: Euro VI emission limits. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0595&from=EN

11 Based on COPERT 4 emissions model

12 May, J., Bosteels, D., Nichol, A., Andersson, J., and Such, C. (2007) The Application of Emissions Control Technologies to a Low-Emissions Engine to Evaluate the Capabilities of Future Systems for European and World-Harmonised Regulations, 16. Aachener Kolloquium Fahrzeug- und Motorentechnik, Retrieved from www.aecc.eu/content/pdf/AECC_PAPER_for_Aachen_Final_20070716.pdf.

duty vehicles sold in the US since 2007, and have proven highly effective at reducing PM mass, ultrafine particles, and air toxics, as well as black carbon, a potent short-lived climate pollutant.[13,14] Experiments investigating the health impacts of diesel exhaust that has passed through a DPF have found no evidence of cancer-causing effects, in contrast to unfiltered diesel exhaust.[15] By ensuring the use of DPFs, Euro VI provides much stronger air quality and health benefits than Euro V.

LIMITS ON PARTICLE NUMBER IN ADDITION TO MASS LIMITS

In addition to the more stringent limit on PM mass, Euro VI includes a limit on particle number, the measure of the number of individual particles emitted, and defines a new measurement procedure based on the work of the Particulate Measurement Programme (PMP) of the United Nations Economic Commission for Europe (UNECE).[16] The addition of the PN metric draws attention to emissions of ultrafine particles (less than 100 nanometers in diameter). Although ultrafine particles contribute little to the total PM mass, they are the dominant contributor to particle number. Because ultrafines can be inhaled more deeply into the lung, they are suspected of having greater toxicity than larger particles.[17] Wall-flow DPFs used on Euro VI engines reduce particle number emissions by >99%.[18]

REDUCED NO_x EMISSIONS

While Euro VI standards reduce the limit on NO_x emissions by 77% relative to Euro V, and by 89% relative to Euro IV, advanced test protocols that improve real-world conformity to NO_x limits result in real reductions that are closer to 95% relative to Euro V.[19] NO_x reductions are achieved with combustion improvements (high-pressure fuel injection and advanced air/fuel management), exhaust gas recirculation, and a closed-loop selective catalytic reduction (SCR) system. Euro VI vehicles are required to be certified under lower loads, lower speeds, and cold start conditions, ensuring that emission control systems are calibrated to function during the full range of driving conditions.

Real-world emissions data has shown that NO_x emissions from Euro V trucks and buses greatly exceed their certified limit values.[20,21] Low speed driving forms a major component of vehicle use in countries such as India. Euro VI addresses the Euro V problem of under-emphasizing high NO_x emissions at the low-speed, low-load driving conditions typical of urban areas with test cycles that better represent real-world driving conditions. Euro VI standards replace the European Transient Cycle (ETC) and Stationary Cycle (ESC) with the World Harmonized Transient Cycle (WHTC) and Steady-State Cycle (WHSC). The WHTC requires both cold and hot start conditions and includes more

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13 Khalek, IA, Bougher, Patrick M. Merritt & Barbara Zielinska (2011): Regulated and Unregulated Emissions from Highway Heavy-Duty Diesel Engines Complying with U.S. Environmental Protection Agency 2007 Emissions Standards, Journal of the Air & Waste Management Association, 61:4, 427-442

14 United States Environmental Protection Agency. (2012) Chapter 2: Black Carbon and Its Effects on Climate. *Report to Congress on Black Carbon*. Retrieved from http://www.epa.gov/blackcarbon/2012report/Chapter2.pdf

15 Health Effects Institute (2015). Synopsis of Research Report 184, Parts 1-4: Effects of Lifetime Exposure to Inhaled New-Technology Diesel Exhaust in Rats. Retrieved from http://pubs.healtheffects.org/getfile.php?u=1068

16 Commission Regulation (EU) No. 582/2011, Annex XV: Amendments to Regulation (EC) No 595/2009). Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0582&from=EN

17 HEI Review Panel on Ultrafine Particles (2013). Understanding the Health Effects of Ambient Ultrafine Particles. HEI Perspectives 3. Health Effects Institute, Boston, MA. Retrieved from http://pubs.healtheffects.org/getfile.php?u=894

18 May, J., Bosteels, D., Nichol, A., Andersson, J., and Such, C. (2007) The Application of Emissions Control Technologies to a Low-Emissions Engine to Evaluate the Capabilities of Future Systems for European and World-Harmonised Regulations, 16. Aachener Kolloquium Fahrzeug- und Motorentechnik, Retrieved from www.aecc.eu/content/pdf/AECC_PAPER_for_Aachen_Final_20070716.pdf.

19 Muncrief R. (2015). Euro IV, V, VI: Real World Off-Cycle NO_x Emissions Comparison. The International Council on Clean Transportation. Retrieved from http://theicct.org/comparing-real-world-nox-euro-iv-v-vi-mar2015

20 Ligterink, N., de Lange, R., Vermeulen, R., & Dekker, H. (2009). On-road NO_x emissions of Euro-V trucks. TNO Science and Industry, Delft. Retrieved from http://www.researchgate.net/publication/235961441_On-road_nox_emissions_of_Euro-V_trucks

21 Kleinebrahm, M. et al. (2008). 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.

than twice the idling time as the ETC. Similarly, the WHSC includes an average engine load about half that of the ESC. Euro VI also introduced off-cycle emissions testing requirements that follow the not-to-exceed (NTE) limit approach used in the US. Testing of Euro IV, V, and VI certified engines on six non-regulatory, real-world duty cycles found that Euro VI certified vehicles consistently conformed to regulatory limits, unlike Euro IV and V certified vehicles which have average emissions approximately two and five times higher than their respective certification levels.[22]

The benefits of NO_x reduction for air quality include reduced formation of secondary $PM_{2.5}$ and ground-level ozone, as well as lower direct NO_2 emissions. Possible complementary provisions to Euro VI may include in the future a maximum limit for the NO_2 component of NO_x.

IN-SERVICE CONFORMITY TESTING FOR TYPE APPROVAL AND IN-SERVICE VEHICLES

In addition to the changes in laboratory testing, Euro VI importantly introduces in-service conformity (ISC) testing requirements using a Portable Emission Measurement System (PEMS).[23] Although this complements the test-cycle changes in ensuring conformity to NO_x emissions limits, it has emerged as one of the most important new aspects of the Euro VI regulation. The first ISC test must occur within 18 months of type approval, and the vehicle model must be tested at least once every two years.[24] Testing includes a mix of urban, rural, and highway driving, and tracks emissions of carbon monoxide, total hydrocarbons, CO_2, NO_x for diesel engines and methane for gas engines. In-service conformity has been enforced by previous standards, but this provision marks the first time that in-use testing is included in European vehicle emission standards, and ensures conformity to the Euro VI regulations.

NEW AMMONIA LIMIT

Euro VI introduces a new limit on ammonia (NH_3) emissions.[25] The selective catalytic reduction (SCR) systems used to control NO_x emissions in Euro IV-VI may produce excess ammonia as a byproduct (ammonia slip). The limit requires precise control of urea injection and tuning of the SCR system to prevent excess NH_3 and may also require the use of a guard catalyst installed downstream of the SCR (ammonia slip catalyst). Because ammonia emissions lead to the formation of secondary PM, controlling ammonia can improve air quality[26] as well as preventing the harmful environmental effects of ammonia deposition in water.[27] Ammonia is also harmful if inhaled directly.[28]

TIGHTER, WIDER-REACHING CONTROL ON METHANE

Euro VI tightens methane limits for CNG vehicles by 50% and imposes the same limit on LPG vehicles. Methane is a potent greenhouse gas[29] and can contribute to ground-

22 Muncrief R. (2015). Euro IV, V, VI: Real World Off-Cycle NO_x Emissions Comparison. The International Council on Clean Transportation. Retrieved from http://theicct.org/comparing-real-world-nox-euro-iv-v-vi-mar2015
23 Commission Regulation (EC) No. 582/2011, Annex II, Appendix 1.
24 Commission Regulation (EC) No. 582/2011, Article 12. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:167:0001:0168:en:PDF
25 Commission Regulation (EC) No. 582/2011. Annex III, Appendix 1.
26 Kiesewetter, G., and Amann, M. (2014) Urban PM2.5 levels under the EU Clean Air Policy Package. TSAP Report #12. Retrieved from http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP_12_final_v1.pdf
27 United States Environmental Protection Agency (2013). Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater. US EPA Office of Water. Retrieved from http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/ammonia/upload/Aquatic-Life-Ambient-Water-Quality-Criteria-for-Ammonia-Freshwater-2013-Fact-Sheet-April.pdf
28 MedlinePlus. Ammonia Poisoning. Retrieved from http://www.nlm.nih.gov/medlineplus/ency/article/002759.htm
29 Methane has a warming effect 28 times that of carbon dioxide, reported in the IPCC Fifth Assessment Report, http://www.ipcc.ch/report/ar5/wg1/

level ozone formation. Controlling emissions from alternative-fuel vehicles is increasingly important in regions where their market share is expected to grow.

EXTENDED DURABILITY REQUIREMENTS

Euro VI increases the durability distance requirement for all vehicle categories, but allows the same year period requirement as Euro IV and V. It requires durability of 160,000 km or 5 years (whichever occurs sooner) for small buses and pick-up trucks[30] compared to 100,000 km under Euro V; durability of 300,000 km or 6 years for mid-size trucks and buses[31] compared to 200,000 km under Euro V; and 700,000 km and 7 years for heavy trucks and buses[32] compared to 500,000 km under Euro V. Higher durability requirements in Euro VI ensure that emissions stay low throughout the useful life of the vehicle. Ensuring that the emissions control equipment is functioning through the most productive lifetime is especially critical for long-lived and intensively-used diesel vehicles.

IMPROVEMENTS IN OBD SYSTEMS

On-Board Diagnostic (OBD) systems for heavy-duty vehicles are increasingly important as more sophisticated in-cylinder controls and aftertreatment systems are added to vehicles. In addition to inducements to ensure proper operation, including torque limits when NO_x emissions exceed a threshold of 7.0 g/km or the system detects insufficient urea levels or quality, Euro IV standard introduced the first requirements for OBD monitoring of NO_x control systems. With Euro VI standards, OBD systems are also required to monitor the performance of the fuel injection system, exhaust gas recirculation (EGR) system, DPF, and any other emission related component.[33] They are also required to issue warnings for unexpected levels of urea consumption, and impose more severe inducements when urea level or quality is not sufficient for proper SCR performance. OBD threshold limits (OTLs), which if exceeded will signal a fault, are 82% lower for NO_x and 75% lower for PM with respect to Euro IV and Euro V OTLs. Finally, Euro VI requires improved communication procedures for OBD systems and requires improved access to OBD data for vehicle repair and maintenance.

EURO 6 LIGHT DUTY VEHICLE STANDARDS

Euro 6 standards narrow the gap between diesel and gasoline light-duty vehicle standards and strengthen OBD requirements. Some of the biggest changes to come with Euro 6, real-word driving testing and the introduction of new test cycle procedures, are almost finalized and are expected to be fully implemented within the 2017-2020 timeframe.

In the EU, Euro 6 is being introduced in three stages. Vehicles that were certified to meet Euro 6 limits ahead of the September 2015 regulatory deadline were allowed relaxed OBD requirements and no particle number limit for gasoline vehicles (the 6a stage). After September 2015,[34] all new-vehicle registrations must meet Euro 6 standards, including full Euro 6 OBD requirements but with preliminary OBD threshold limits and a relaxed PN limit for DI gasoline vehicles (the 6b stage). After three years of Euro 6 implementation,

30 N1 and M2 vehicle categories
31 N2; N3 ≤ 16 ton; and M3 Class I, Class II, Class A, and Class B ≤ 7.5 ton
32 N3 > 16 ton; M3 Class III, and Class B > 7.5 ton
33 Posada, F., and Bandivadekar, A. (2015). Global overview of on-board diagnostic (OBD) systems for heavy-duty vehicles. The International Council on Clean Transportation. Retrieved from http://www.theicct.org/global-overview-board-diagnostic-obd-systems-heavy-duty-vehicles
34 September 2015 is the implementation date for all new registrations of passenger cars (category M1) and light commercial vehicles (category N1, class I). The implementation for new type approvals occurs a year earlier, in September 2014. For heavier commercial vehicles (category N1 class II and III, category N2), Euro 6 will come into effect for new type approvals in September 2015, and apply to all new registrations in September 2016.

or after September 2018[35] for all new registrations, the stricter PN emission limit (equal to the diesel limit introduced with Euro 5b) becomes mandatory for all gasoline vehicles, final OBD threshold limits will be enforced, and real world driving emissions (RDE) requirements will be introduced (stage Euro 6c). As a final component of Euro 6c, the Worldwide harmonized Light vehicles Test Cycles (WLTC) will be adopted in place of the current New European Driving Cycle (NEDC). The timing of the WLTC adoption is not yet determined, but it is likely to happen in 2017–2020. No change in the Euro 6c regulated pollutants limits is expected with the introduction of WLTP, only the CO_2 targets.

LIMITS ON PARTICLE NUMBER FOR ALL FUEL TYPES

Limits on particle number (PN), important for controlling ultrafine particle emissions, were introduced in Euro 5b for compression-ignition vehicles.[36] While these PN limits applied to all light-duty diesel vehicles, they did not apply to the increasingly popular gasoline direct-injection (GDI) technology, which generates more particles than traditional port-fuel gasoline engines.[37] Euro 6c requires all vehicles to meet uniform PN standards, including those with spark-ignition GDI engines.[38] It is expected that GDI vehicles will meet PN standards with relatively low-cost gasoline particulate filters, estimated to cost less than USD$100.[39]

TIGHTER LIMITS FOR DIESELS NARROWS THE GAP BETWEEN FUEL TYPES

Euro 6 tightens the diesel NO_x standard by 55% with respect to Euro 5, and tightens the HC+NO_x standard by 26%–39% depending on vehicle type.[40] This partially addresses the long-standing issue that European emission standards are not fuel-neutral. Even under the Euro 4 standards, NO_x limit values for diesel vehicles were three times the limit values for gasoline vehicles. With Euro 6, NO_x emission limits for diesel vehicles are only 25% higher than for gasoline vehicles, a smaller margin than in any previous standard. With the use of DPFs to meet Euro 5 PM and PN limits, particulate emissions from diesel cars also approach those of gasoline cars. Euro 6 limits bring overall emissions of diesel and gasoline vehicles close to parity, provided that vehicles of both fuel types conform to standards in real-world driving conditions.

REAL-WORLD DRIVING TESTING

As with the Euro VI in-service conformity standards for heavy-duty vehicles, real driving emissions (RDE) testing will be included as an additional requirement for type approval in the final stage of Euro 6. Portable Emission Measurement System (PEMS) testing of early Euro 6-certified diesel vehicles has revealed that NO_x emission control systems that are sufficient to pass laboratory-based emissions tests may not operate at certified levels in real world driving conditions, with real-driving NO_x emissions three to six times those indicated by certification testing.[41] With RDE provisions, vehicle emissions of CO, NOx, and PN will be measured on the road using PEMS testing to ensure that emissions during real-world driving stay within reasonable limits. RDE testing will begin with a pilot

35 September 2017 for new type approvals
36 Commission Regulation (EC) No. 692/2008, Annex XVII: Amendments to Regulation (EC) No. 715/2007. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0692&from=EN
37 Mamakos, A., Dardiotis, C., and Martini, G. (2012). Assessment of particle number limits for petrol vehicles. JRC Scientific and Policy Reports. European Commission Joint Research Centre, Institute for Energy and Transport. Retrieved from http://publications.jrc.ec.europa.eu/repository/bitstream/JRC76849/lbna25592enn.pdf
38 Commission Regulation (EU) No. 459/2012. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0459&from=EN
39 http://www.theicct.org/sites/default/files/publications/GFPworkingpaper2011.pdf
40 Commission Regulation (EC) No 715/2007, Annex I: Emission Limits. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0715&from=EN
41 http://theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141010.pdf

phase from 2015 through 2017. No limits will be enforced during this monitoring phase. An initial conformity factor will be set in 2015; the Euro 6 limit values will be multiplied by this conformity factor to determine the limits for RDE testing. In 2017, RDE testing against this conformity factor will begin. Conformity factors will be defined for NO_x and PN; they may be tightened in the future.

LOWER OBD THRESHOLDS

The On-Board Diagnostic (OBD) thresholds (OTLs) for Euro 6 are 70-75% lower than Euro 5 OTLs for NO_x and PM, depending on vehicle type, and about 10% lower for carbon monoxide (CO) and non-methane hydrocarbons (NMHC).[42] This means the OBD system is sensitive to more minor malfunctions in the emission control system, leading to earlier detection and corrections of such problems.

PLANNED MOVE TO A HARMONIZED TEST CYCLE

With full implementation of Euro 6, the World Harmonized Light Vehicles Test Procedure (WLTP) will replace the current test procedure. Under the new protocol, the World Harmonized Light-duty Vehicle Test Cycle (WLTC) will replace the New European Drive Cycle (NEDC), and a variety of test parameters will be adjusted to close loopholes and address shortcomings of the NEDC procedure.[43] The WLTC is more representative of real-world driving conditions than the NEDC[44], and will be complemented by the RDE testing efforts to ensure better conformity to standards in real driving conditions. The WLTP has other benefits for vehicle efficiency testing, and the use of a harmonized test will save auto manufacturers in development and certification costs.

CONCLUSION

Given the availability of ultra-low sulfur fuel (sulfur content less than 10 ppm), greater air-quality benefits can be gained from a leap from Euro 4/IV to Euro 6/VI than a path that includes the intermediate Euro5/V stage. For countries that are at prior standards for heavy-duty vehicles, skipping Euro IV and V altogether may also be an attractive option. Accelerating the adoption of heavy-duty vehicle Euro VI standards has two-fold benefits for air quality: the use of DPFs to comply with new PM and PN leads to a 90% or greater reduction of $PM_{2.5}$ emissions, and the new test cycle and in-service conformity requirements provide real-world reductions in NO_x emissions of 95% or greater, providing emission control even in urban driving conditions that remained a problem in Euro V. Light-duty Euro 6 standards promise a similar reduction in real-world NO_x emissions from diesel cars, through tighter emissions limits, a future move to the WLTP, and the inclusion of PEMS testing in the type approval process to ensure conformity to standards in actual driving conditions. Countries like India are poised to take full advantage of the mature, effective control technologies now available by skipping Euro 5/V and moving directly to Euro 6/VI.

42 Commission Regulation (EC) No 692/2008, Annex XI: On-Board Diagnostics (OBD) for Motor Vehicles. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0692&from=EN

43 Mock, P., Kühlwein, J., Tietge, U., Franco, V., Bandivadekar, A., and German, J. (2014) The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU. The International Council on Clean Transportation. Retrieved from http://theicct.org/sites/default/files/publications/ICCT_WLTP_EffectEU_20141029.pdf

44 Mock, P. (2013). World-harmonized light-duty vehicles test procedure. The International Council on Clean Transportation. Retrieved from http://theicct.org/wltp-november2013-update