



Autojen todelliset päästöt liikenteessä

41. Ilmansuojelupäivät

Lappeenranta, 28–29.8.2016

Juhani Laurikko, VTT



Lainsäädännön perusteita

- Pakokaasupäästöjä rajoitetaan osana moottoriajoneuvojen teknisiä määräyksiä
- Kaikkien markkinoille tulevien uusien autojen tulee olla yhtenäisten määräysten mukaisia
- EU:ssa osa sisämarkkinoiden harmonisointia, ei ympäristölainsäädäntöä kuten USA:ssa



Lainsäädännön perusteita

- Sääöksissä määritetään:
 - Mitkä ovat päästöjen sallitut enimmäisarvot
 - Miten päästöt mitataan:
 - laitteisto
 - olosuhteet
 - ajo-ohjelma
 - Soveltamisen aikataulu

Euro5/Euro6 raja-arvot - Ottomoottorit

Kipinäsytysmoottoriset (SI) - Bensiini, E85					
yhdiste	yksikkö	Euro5a	Euro5b	Euro6b	Euro6c
THC	mg/km	100	100	100	100
NMHC		68	68	68	68
NOx		60	60	60	60
CO		1000	1000	1000	1000
PM ⁽¹⁾		5	4.5 ⁽²⁾	4.5 ⁽²⁾	4.5 ⁽²⁾
PN	Nb/km	-	-	6.0*E11 ⁽³⁾	6.0*E11
¹ vain suoraruiskutteiset (GDI) moottorit					
² PMP-mittausmenetelmä (UN-ECE-R83, suppl. 7.)					
³ 6.0*E12 raja-arvoa voidaan soveltaa 3 v. ylimenoajan					

Euro5/Euro6 raja-arvot - Ottomoottorit

Kipinäsytysmoottoriset (SI) - Bensiini, E85					
yhdiste	yksikkö	2012 >	2013 >	07/2016>	07/2017>
THC	mg/km	100	100	100	100
NMHC		68	68	68	68
NOx		60	60	60	60
CO		1000	1000	1000	1000
PM ⁽¹⁾		Raja-arvot kaasumaisille päästöille pysyvät samoina 2020 asti			
PN	Nb/km				
¹ vain suoraruiskutteiset (GDI) moottorit					
² PMP-mittausmenetelmä (UN-ECE-R83, suppl. 7.)					
³ 6.0*E12 raja-arvoa voidaan soveltaa 3 v. ylimenoajan					

Euro5/Euro6 raja-arvot - Ottomoottorit

Kipinäsytysmoottoriset (SI) - Bensiini, E85					
yhdiste	yksikkö	Euro5a	Euro5b	Euro6b	Euro6c
THC		100	100	100	100
NMHC		68	68	68	68
NO _x				60	60
CO				1000	1000
PM ⁽¹⁾		5	4.5	4.5 ⁽²⁾	4.5 ⁽²⁾
PN	Nb/km	-	-	6.0*E11 ⁽³⁾	6.0*E11

Suurimmat haasteet liittyvät hiukkaspäästöihin

Hiukkassuodattimia myös GDI-bensiiniautoihin!



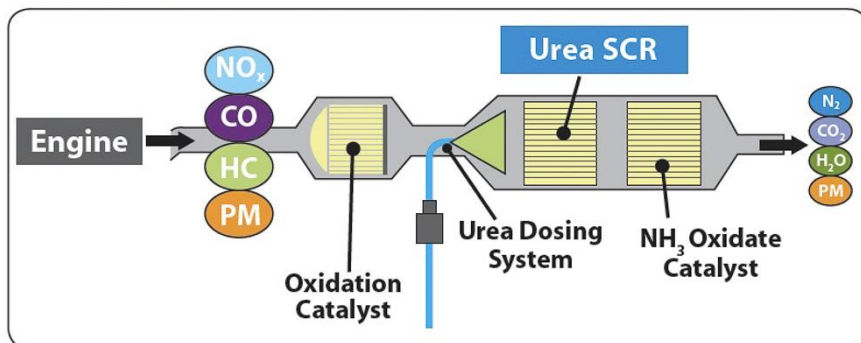
Euro5/Euro6 raja-arvot - Dieselmoottorit

Puristusytysmoottoriset (CI) - Diesel				
yhdiste	yksikkö	Euro5a	Euro5b	Euro6b/c
NOx	mg/km	180	180	80
HC+NOx		230	230	170
CO		500	500	500
PM		5	4.5	4.5
PN	Nb/km	-	6.0*E11	6.0*E11

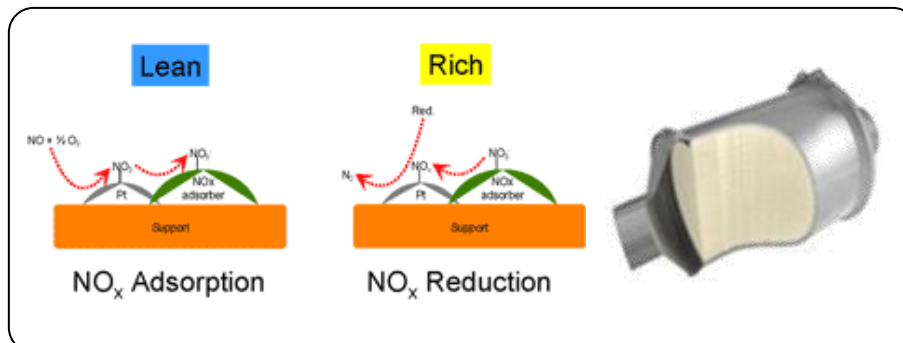
Euro5/Euro6 raja-arvot - Dieselmootorit

Puristusytismootoriset (CI) - Diesel				
yhdiste	yksikkö	Euro5a	Euro5b	Euro6b/c
NO _x	mg/km	180	180	80
HC+NO _x		Suurimmat haasteet liittyvät NO_x-päästöihin		170
CO				500
PM				4.5
PN	Nb/km	-	6.0*E11	6.0*E11

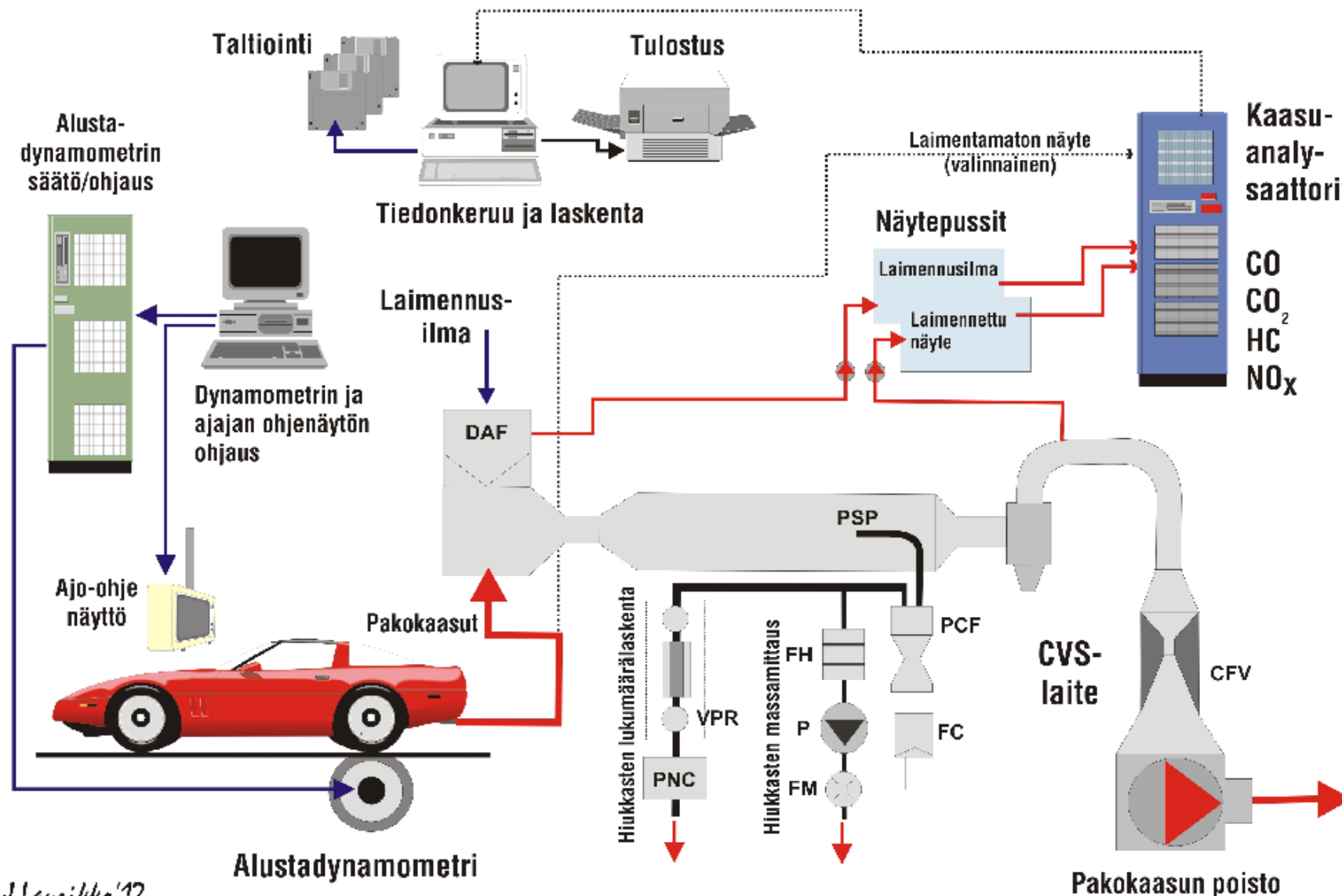
SCR SYSTEM



LEAN-NO_x TRAP (LNT)



Pakokaasujen mittaaminen - henkilöautot



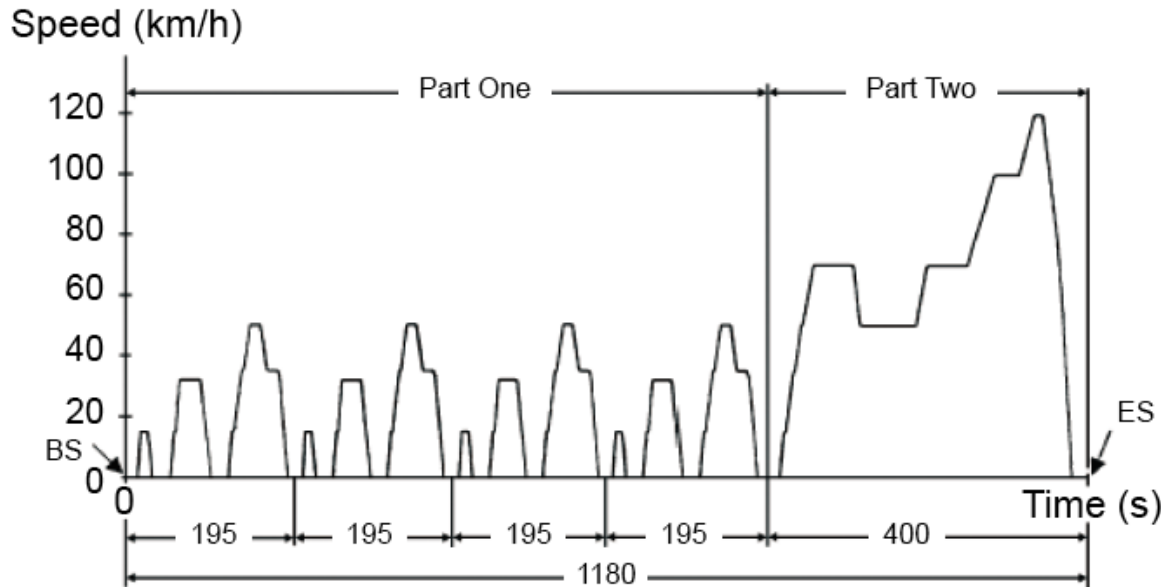
Pakokaasujen mittaaminen - henkilöautot



EUROPEAN UNION

DRIVING CYCLES

URBAN (ECE) + EXTRA-URBAN (EUDC) CYCLES



Length: 11.007 km

Duration: 1180 s

Max. speed: 120 km/h

Average Speed: 33.6 km/h

BS: Beginning of Sampling, engine start

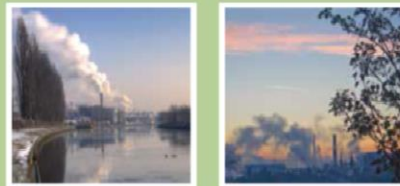
ES: End of Sampling

Urban cycle = 820 s

Euro 3
onw.

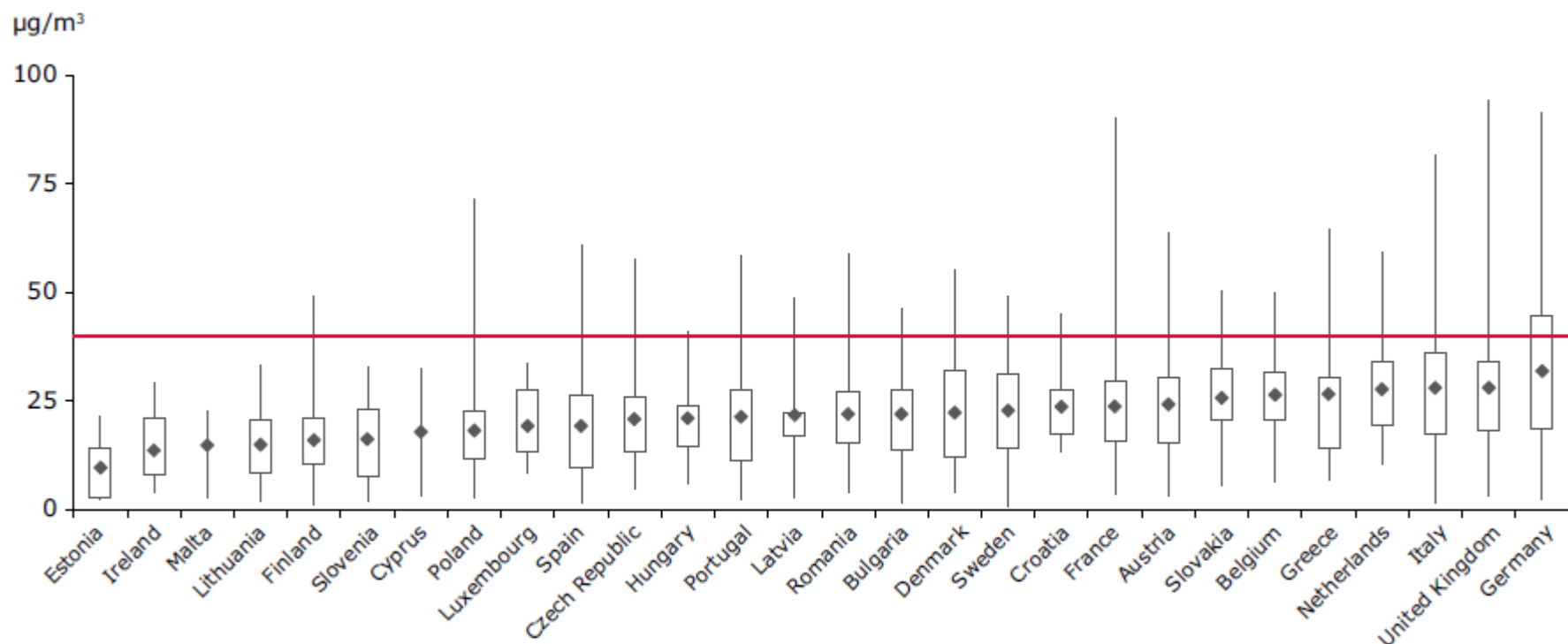
Urban + Extra-urban cycles = 1.180 s (MVEG-B) Revised

Urban cycle = 780 s (-7°C)



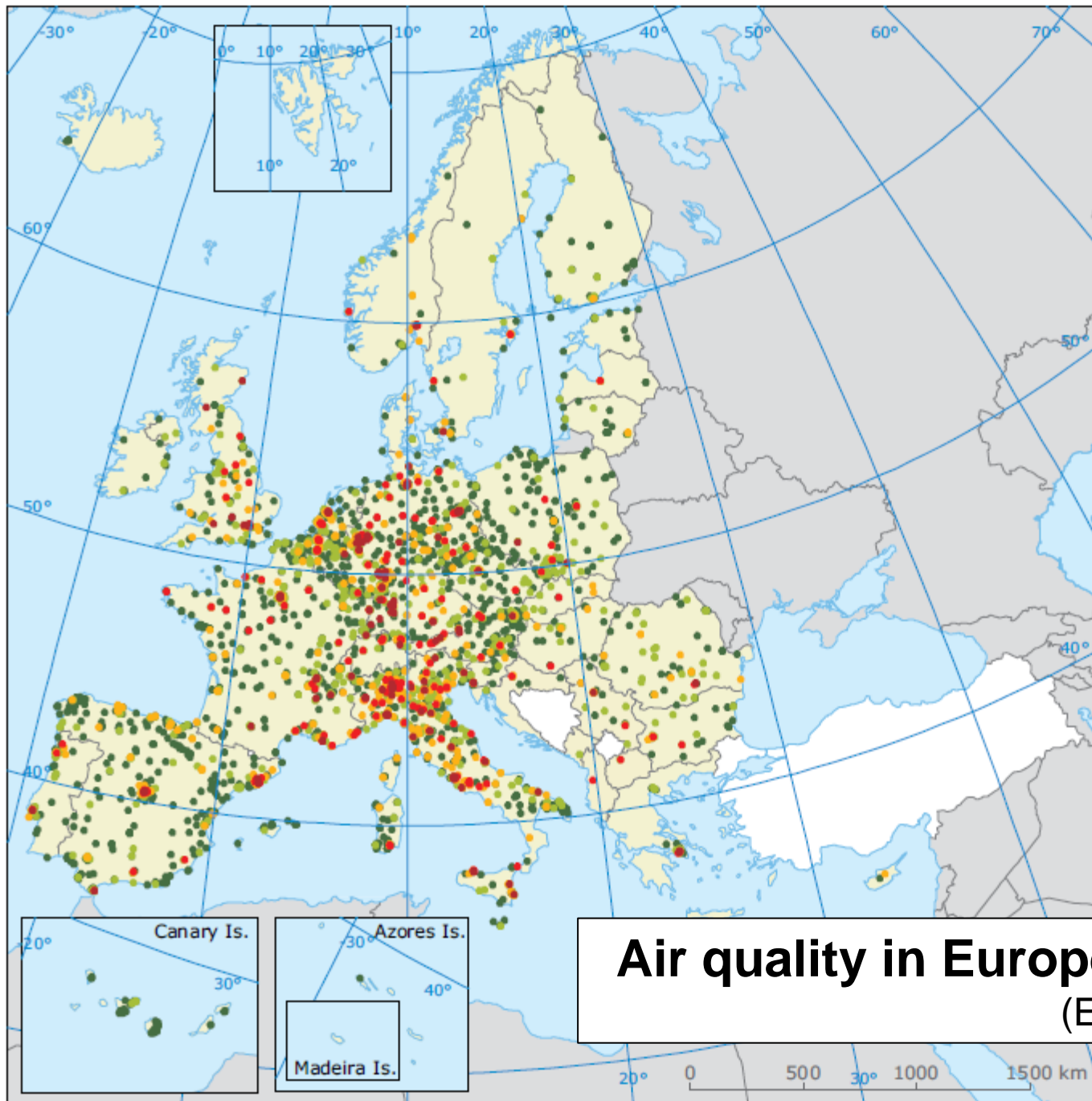
- **Violations of EU Air Quality Standards (NO₂) are reported by almost all Member States, despite**
 - **advances in EU Emissions Regulations (Euro4> Euro5> Euro6), and**
 - **slight falling trend in annual mean NO₂ concentrations**
- **Therefore, NO_x and especially direct NO₂ emissions from motor vehicles remain as a serious problem**

Figure 4.8 Attainment situation for annual limit value of NO₂ in the EU-28 (2012)



Note: The graph is based on the annual mean concentration values for each Member State. For each country, the lowest and the highest value observed (in µg/m³) are given, and the average value is given as a dot. The rectangle gives the 25 and 75 percentiles of the observed values for each country. The limit value set by EU legislation is marked by the red line.

Air quality in Europe — 2014 report
(EEA Report No 5/2014)



Annual mean nitrogen dioxide 2012, based on daily averages with percentage of valid measurements $\geq 75\%$ in $\mu\text{g}/\text{m}^3$

- ≤ 20
- 20–30
- 30–40
- 40–50
- > 50

No data

Countries/regions not included in the data exchange process



Air quality in Europe — 2014 report
(EEA Report No 5/2014)



Laboratorio vs. ”normaali liikenne”





icct

THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

<http://www.theicct.org/>

TE TRANSPORT &
ENVIRONMENT

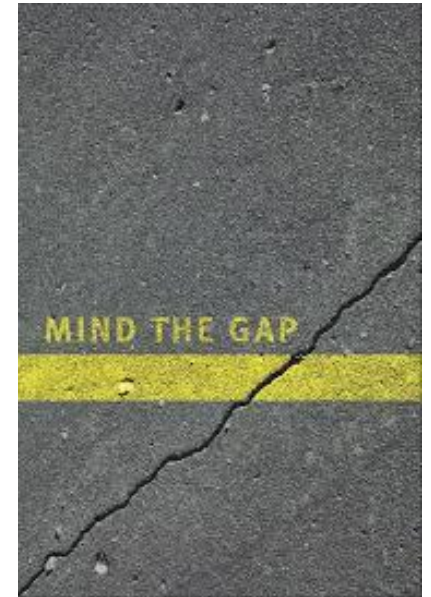
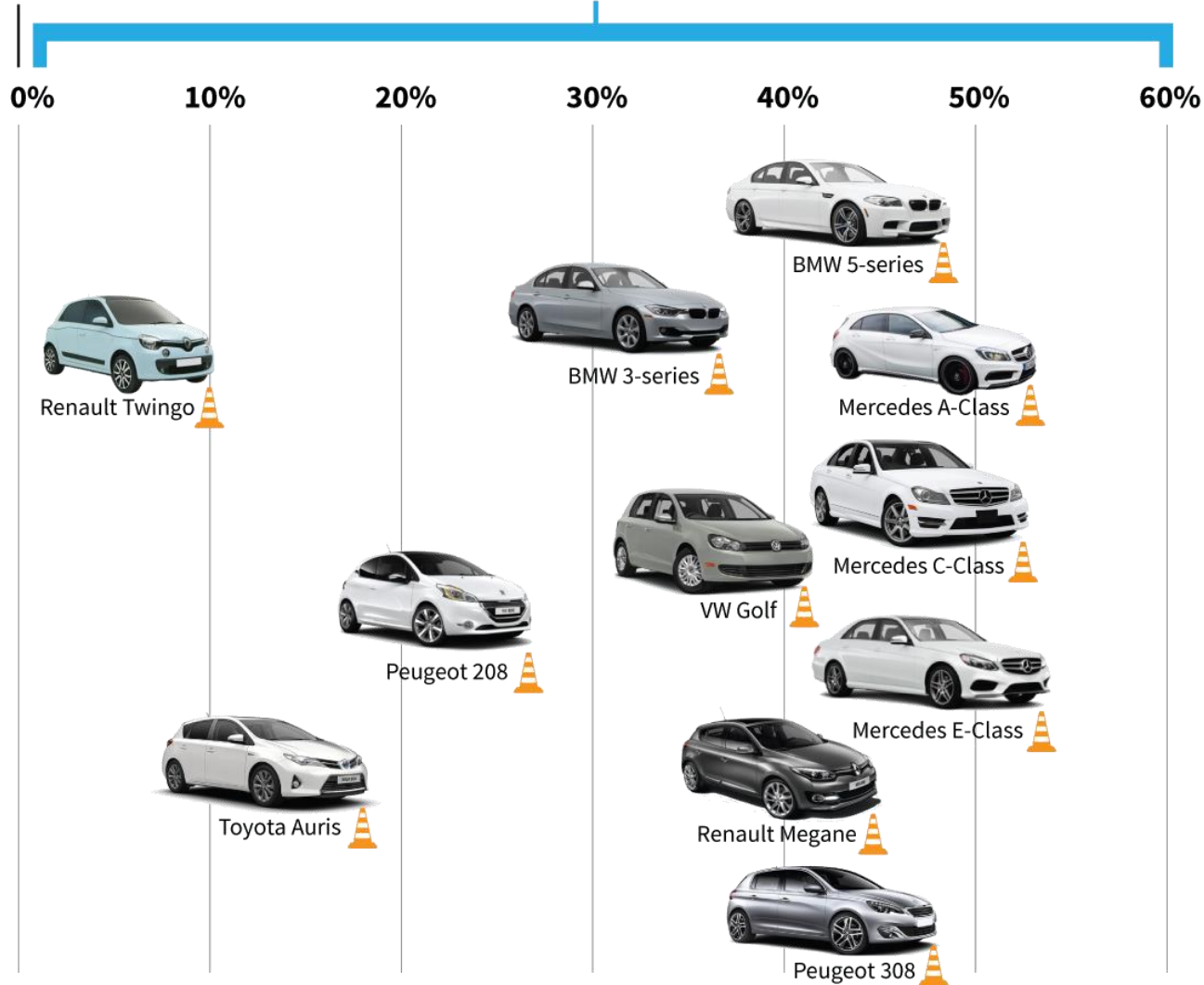
<https://www.transportenvironment.org/>

Mind the Gap

Difference between official car CO₂ test results and real-world emissions in 2014

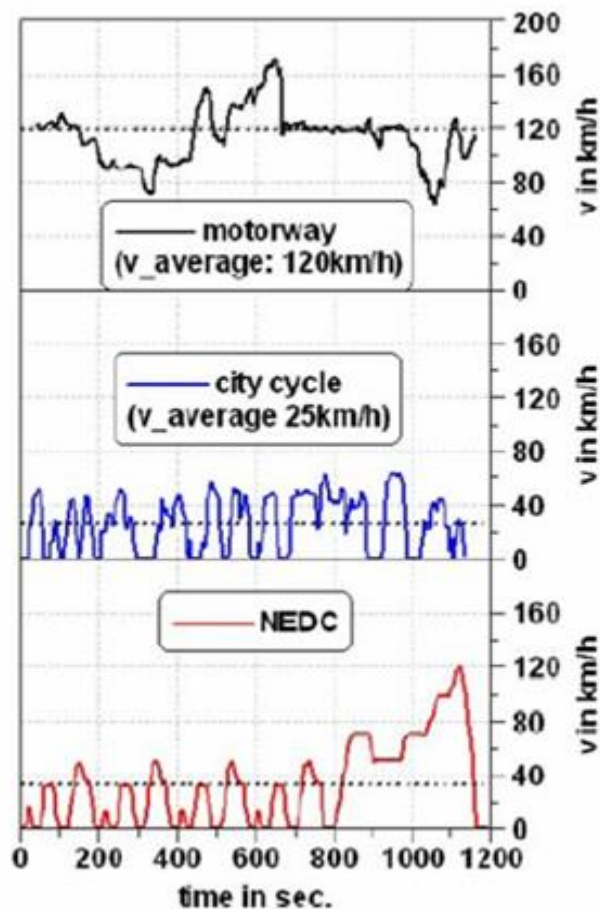
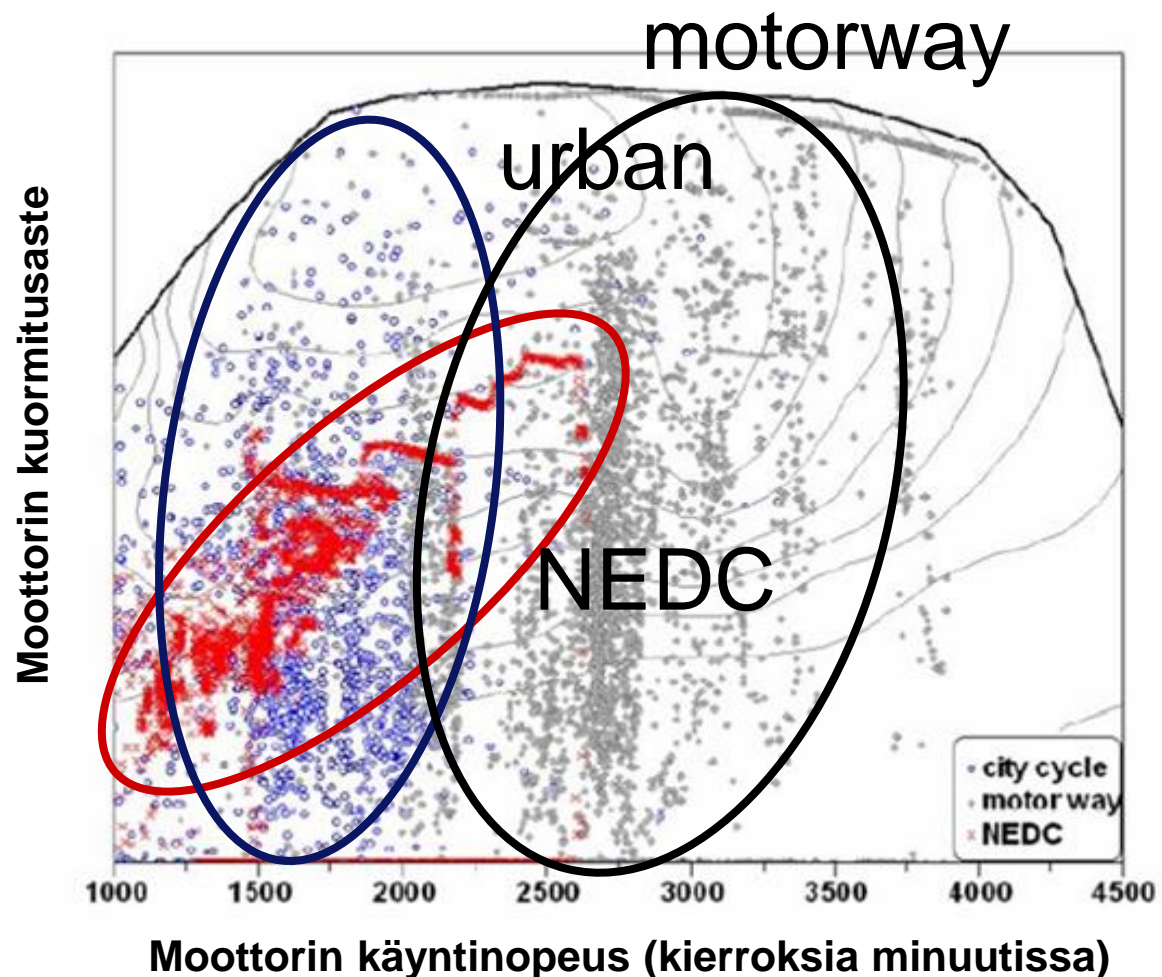
No gap between official and real-world emissions

Gap between official and real-world



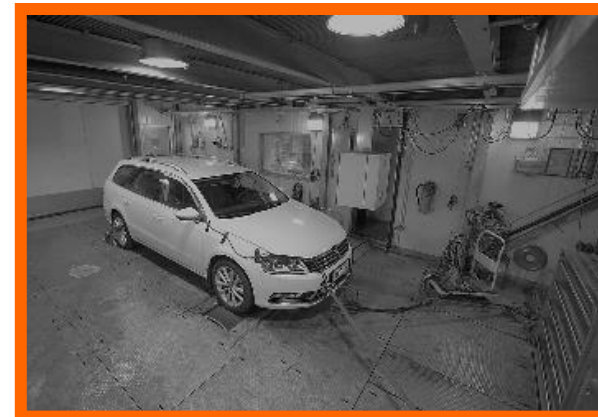
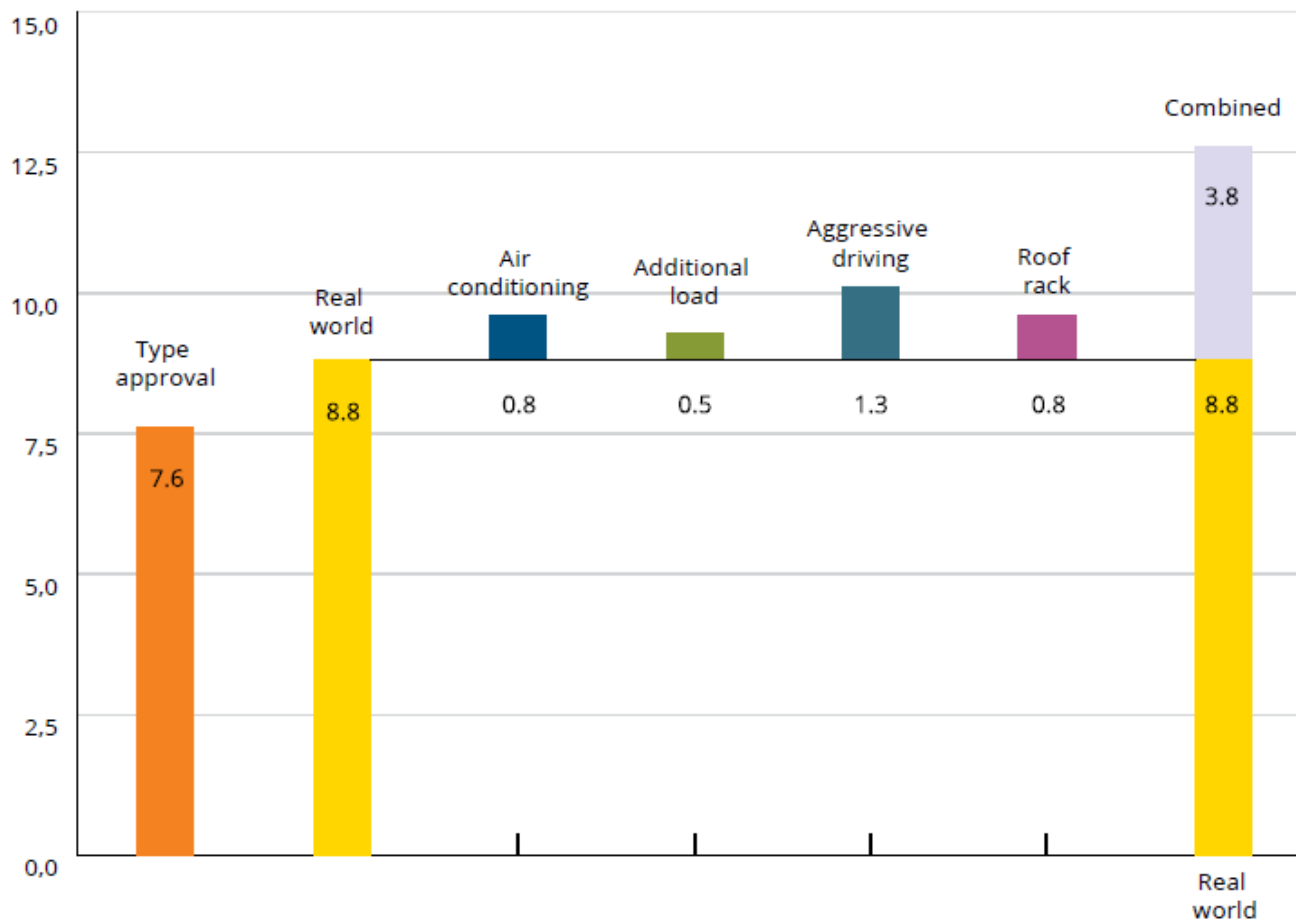
Standardisykleissä moottorit toimivat vain pienellä osalla kuormitusalueestaan

Quelle: Georghiou; HAW Hamburg, 2007



Impact of selected vehicle and driving conditions on fuel economy for a typical mid-sized petrol car

Fuel consumption l/100 km

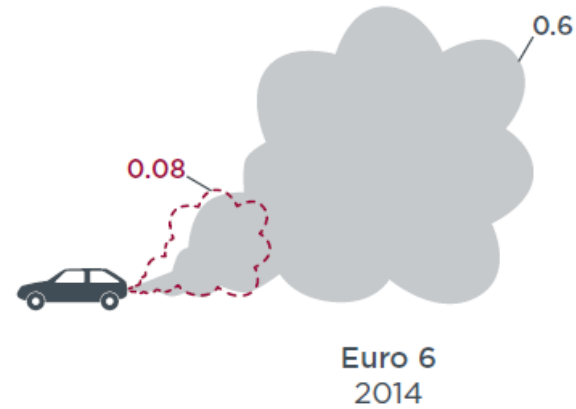
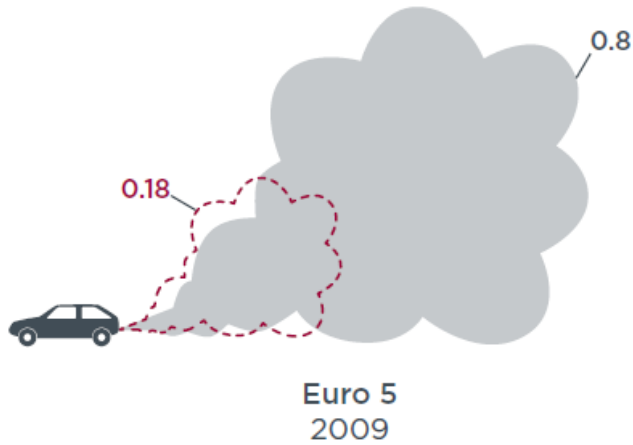
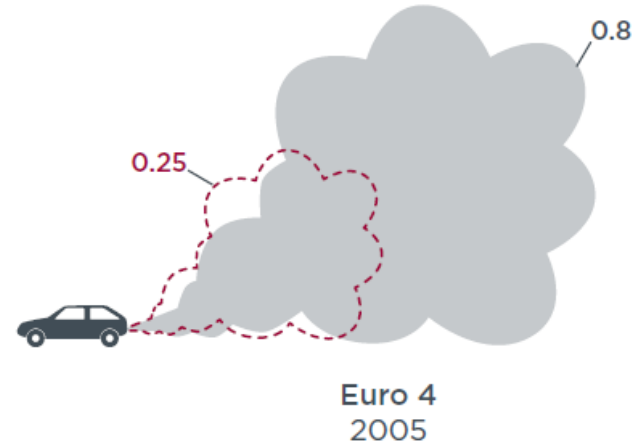
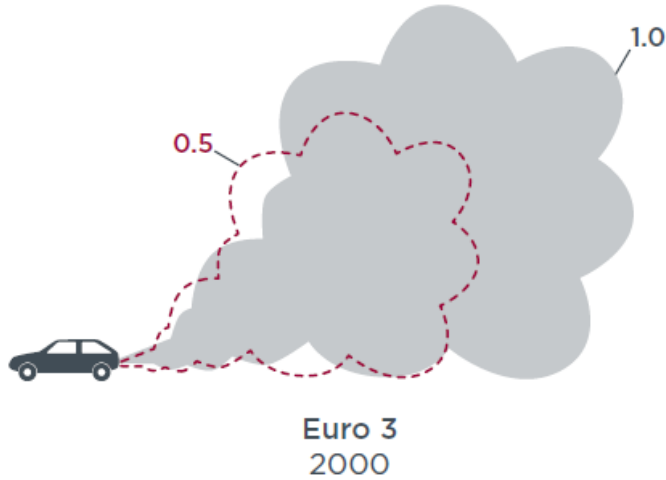


Note: The combined value of all these parameters does not equal the sum of the individual values, as their effects are non-linear.

Source: AVL, 2015.

Sallitut arvot vs. todelliset päästöt

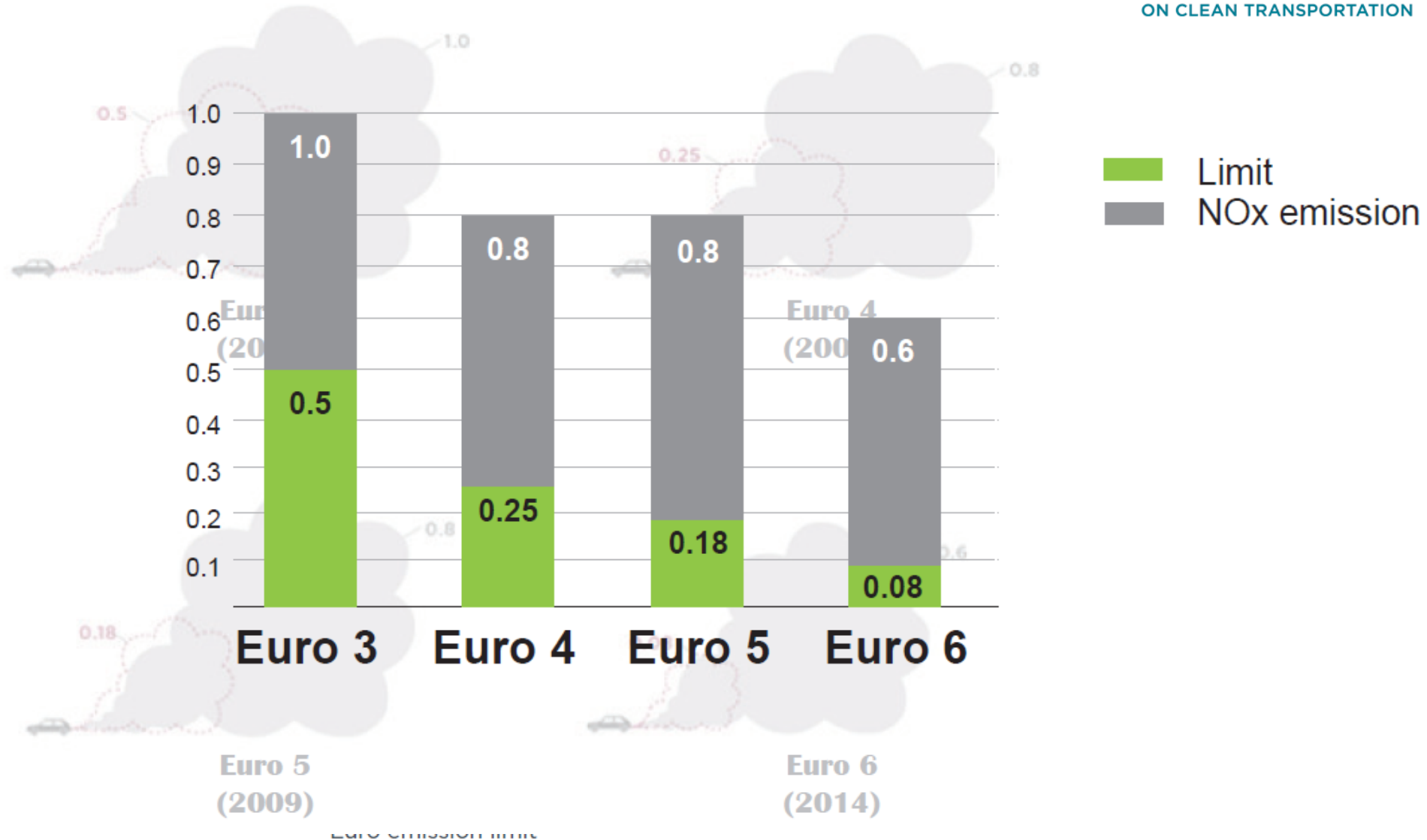
Diesel cars: Nitrogen oxides (NO_x) emissions (in g/km)

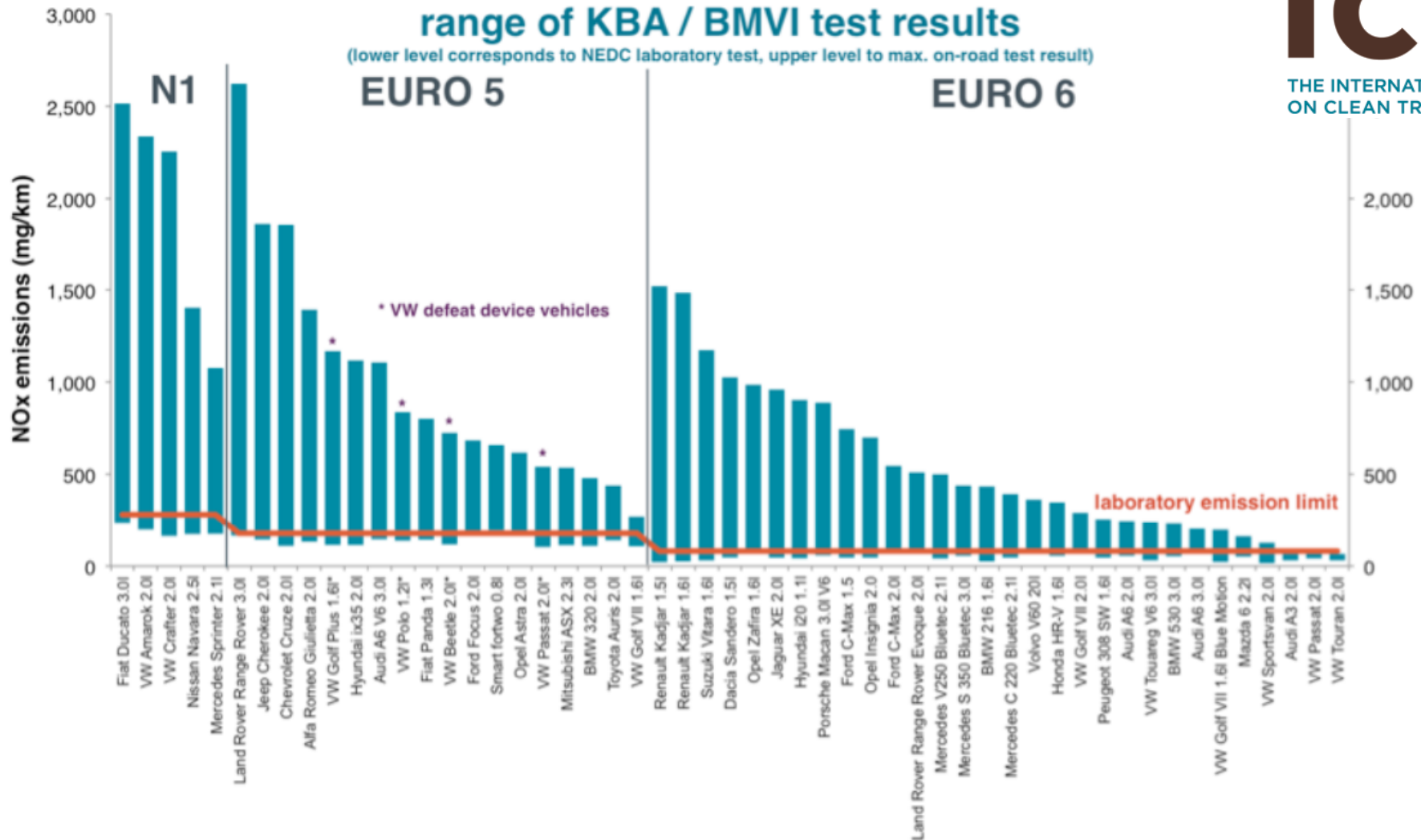


■ On-road measured value (Carslaw, 2011) / (ICCT, 2014)
--- Euro emission limit

Sallitut arvot vs. todelliset päästöt

Diesel cars: Nitrogen oxides (NO_x) emissions (in g/km)



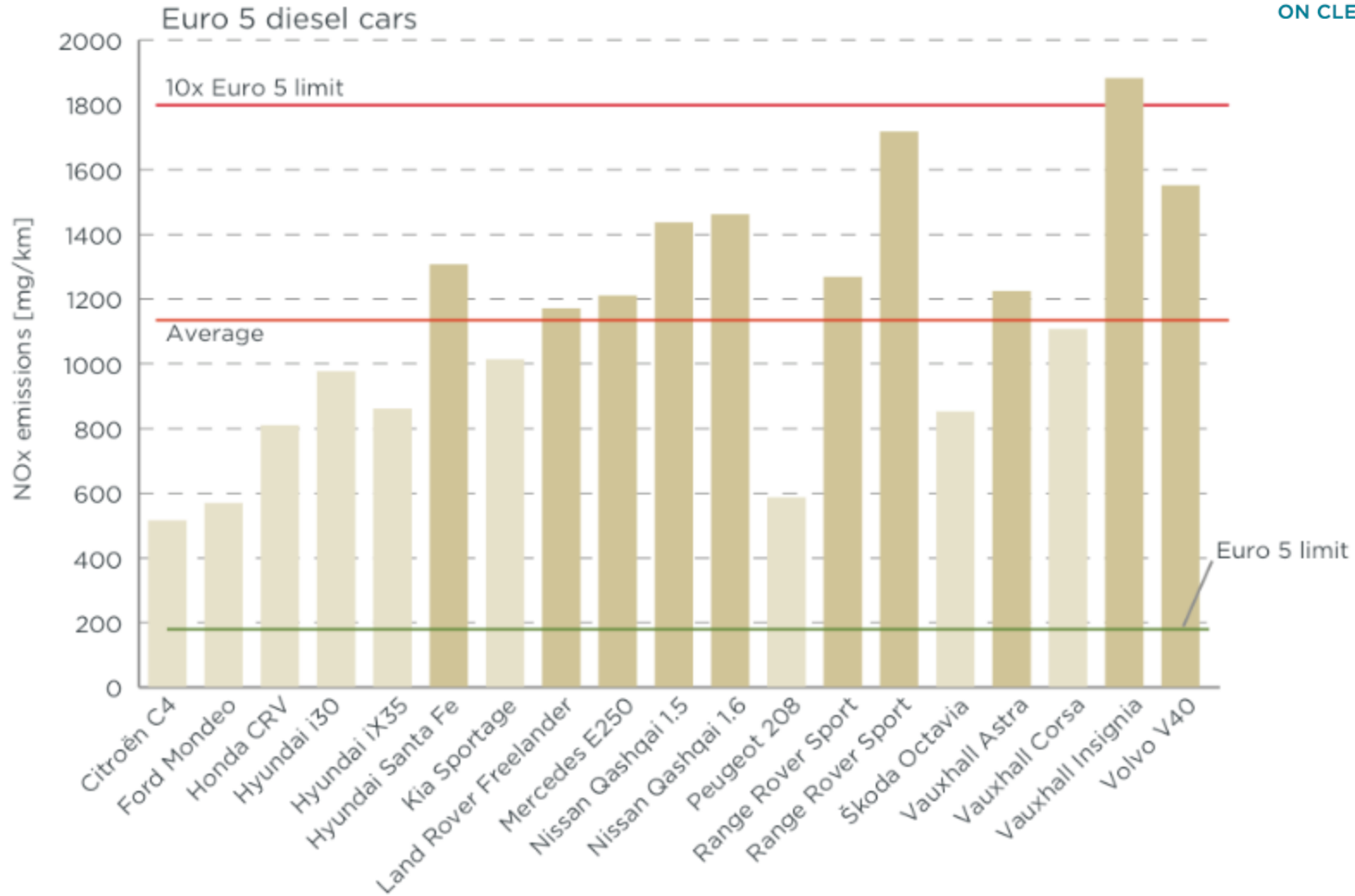


Overview of the laboratory and on-road test results of the vehicle testing program by the German Ministry for Transport.

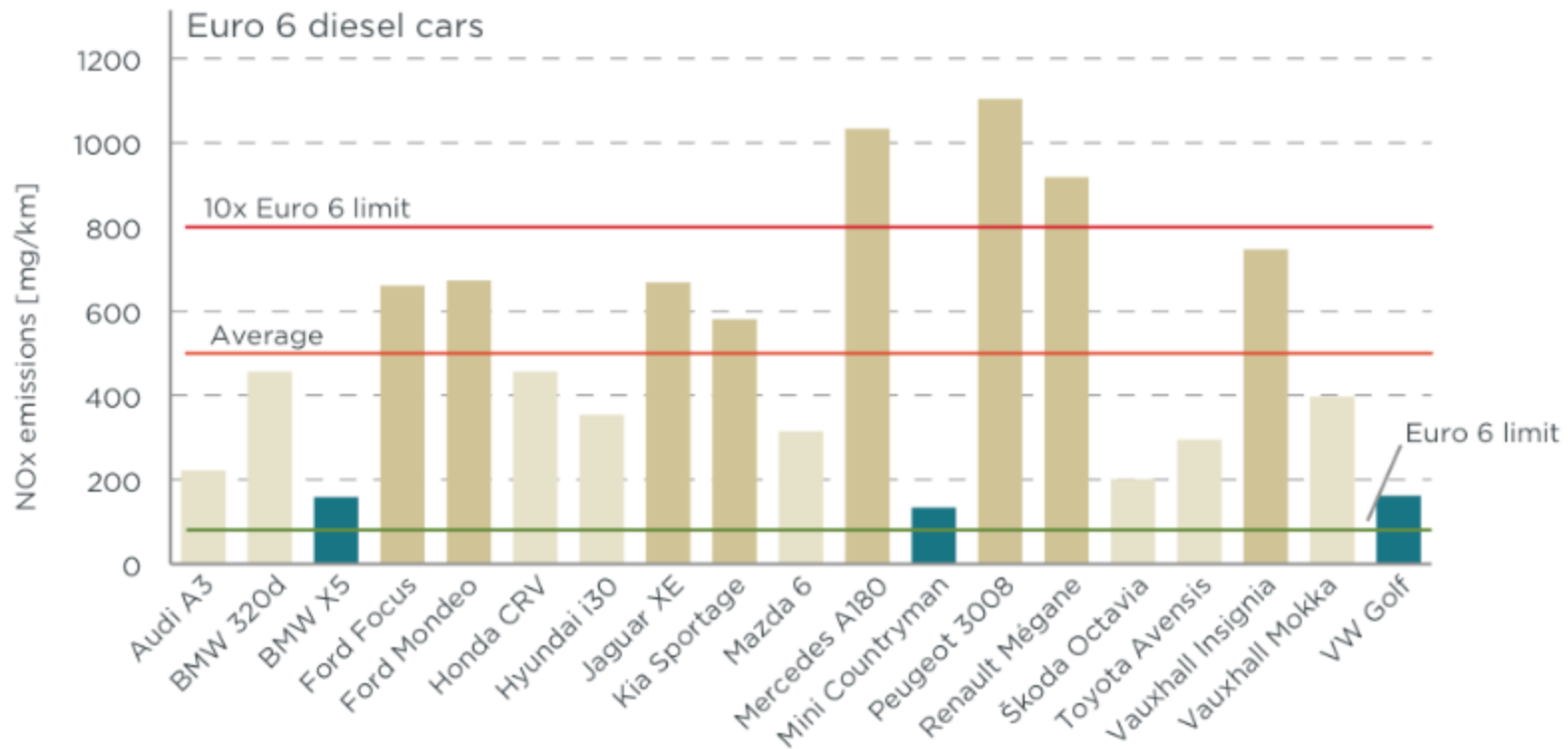
http://www.bmvi.de/SharedDocs/DE/Anlage/VerkehrUndMobilitaet/Strasse/bericht-untersuchungskommission-volkswagen.pdf?__blob=publicationFile

Lähde: <http://www.theicct.org/blogs/staff/first-look-results-german-transport-ministrys-post-vw-vehicle-testing>

On-road tests (UK)

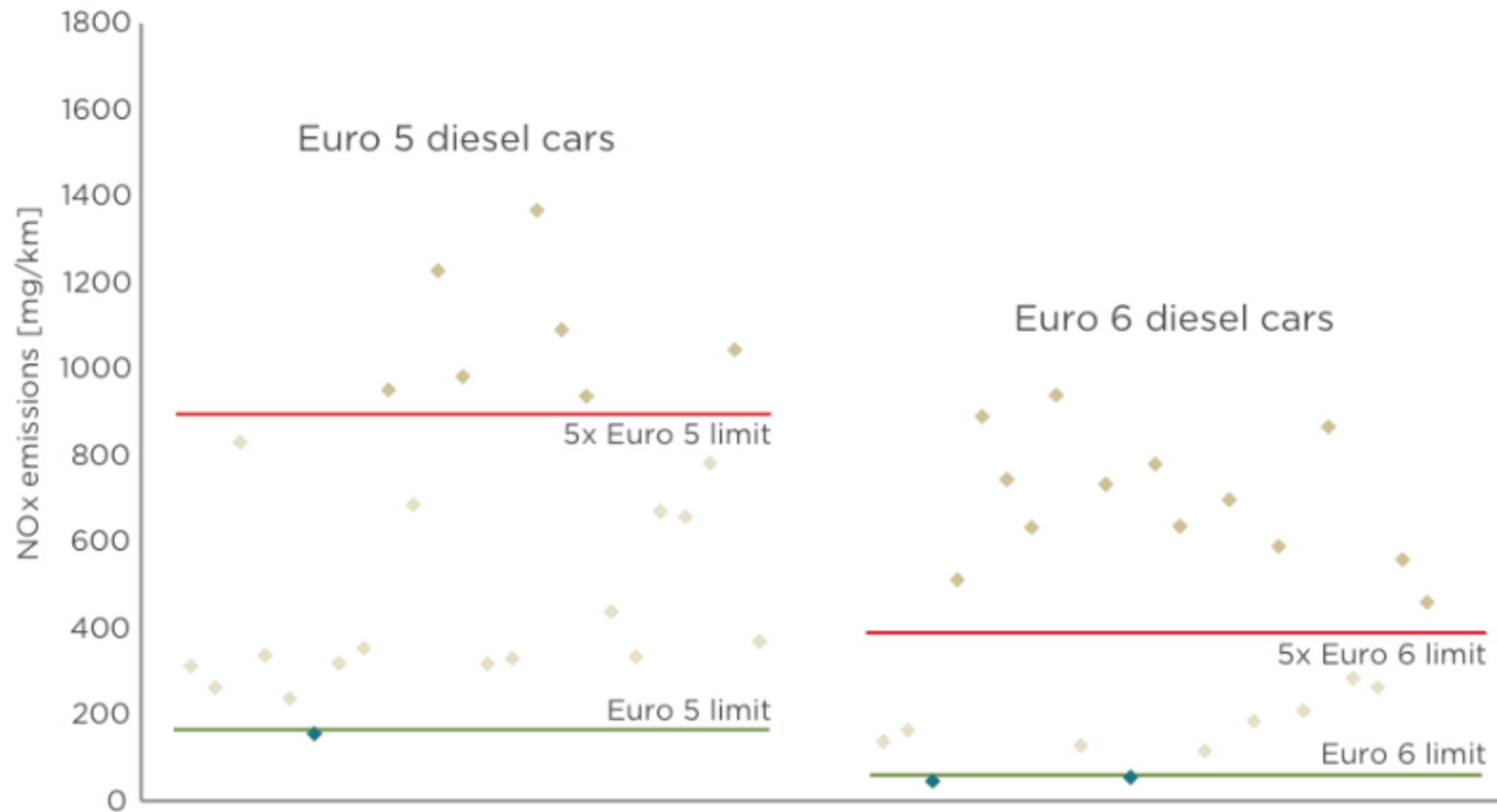


https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/535501/vehicle-emissions-testing-programme-web.pdf

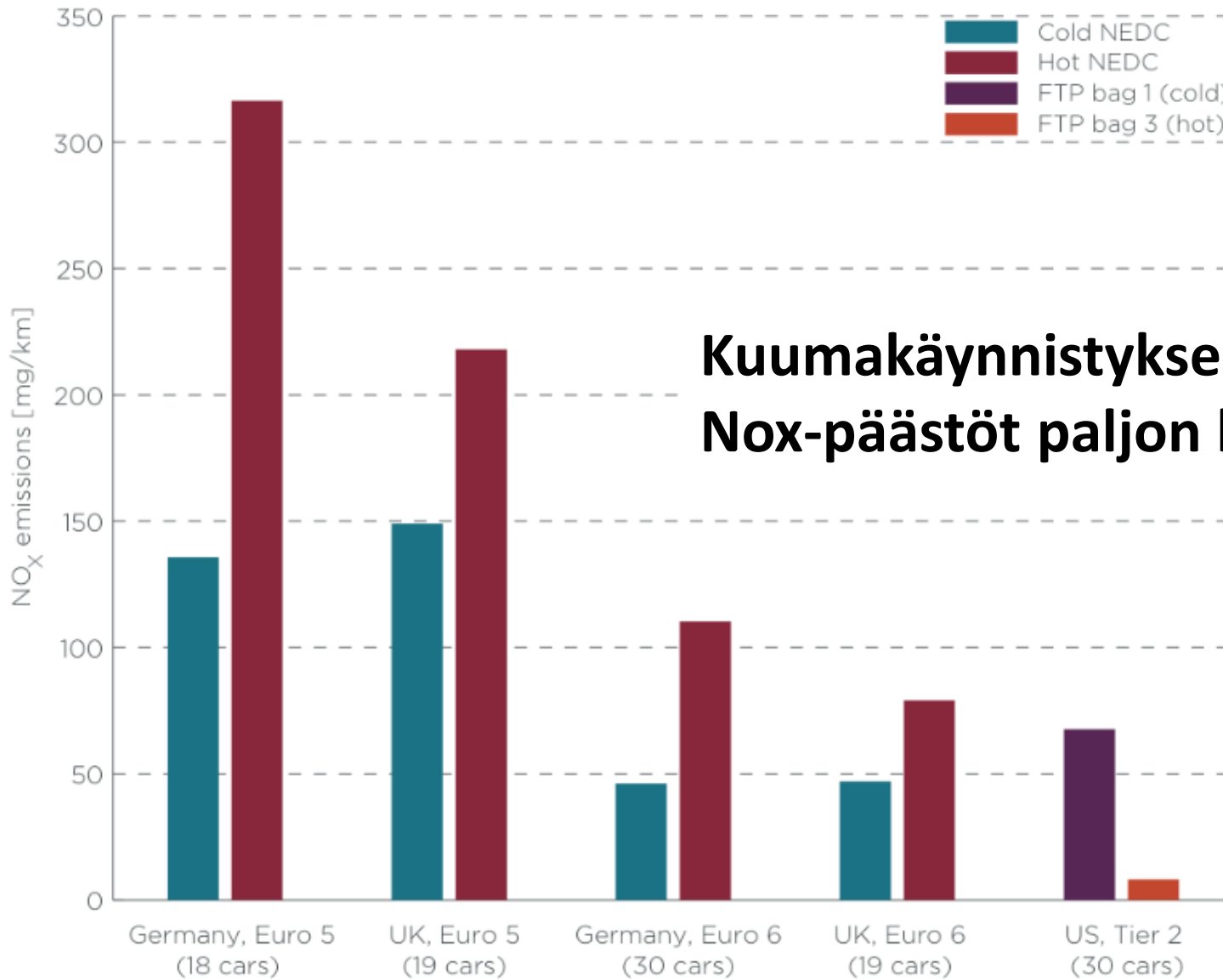


https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/535501/vehicle-emissions-testing-programme-web.pdf

On-track NEDC tests (France)



http://www.developpement-durable.gouv.fr/IMG/pdf/2016-04-07_-_DP_Resultats_Commission_UTAC.pdf



NOx emissions from cold-start and hot-restart tests by Germany and the UK, compared to similar test data from U.S. EPA

Summary of defeat device testing protocols used by France, UK, and Germany

Test	France	UK	Germany
<i>Dynamometer Test</i>			
NEDC Type approval test		✓	✓
NEDC test with warm start		✓	✓
NEDC test with variation of hood position, four-wheel dyno, altered shifting pattern	✓		
NEDC but with slightly modified speed trace	✓	✓	
NEDC test in cold ambient conditions (10 °C)			✓
<i>On-Road Test</i>			
NEDC speed trace	✓	✓	✓
NEDC but with slightly modified speed trace			✓
RDE testing		✓	✓

The 'Dirty 30' highly polluting diesel cars in Europe and the national regulators failing to act

June 2016

A briefing by  **TRANSPORT & ENVIRONMENT**

Who approved the Dirty 30?



UK



GERMANY



FRANCE



NETHERLANDS



LUXEMBOURG



SPAIN



ITALY



Ei yhtään VAG konsernin autoa!



**Mitkä ovat pahimmat
ongelmat ja miten
niihin reagoidaan?**

Havaittuja pulmia ja niiden korjaamisen tilanne

▪ Pulma

- Tyyppihyväksymiskokeessa saavutetaan hyvät tulokset, mutta ”todellisessa ajossa” päästöt ovat korkeammat
- Havaittiin ensin CO₂:n osalta, koska todellinen kulutus (ja CO₂) on isompi kuin normin mukaan mitattu ja ilmoitettu
- Myöhemmin paljastui vakava NO_x-päästömanipulointi (VW et.al.)

▪ Syy

- Pakokaasukokeen ajo-ohjelma liian ”helppo”

▪ Korjaavat toimenpiteet

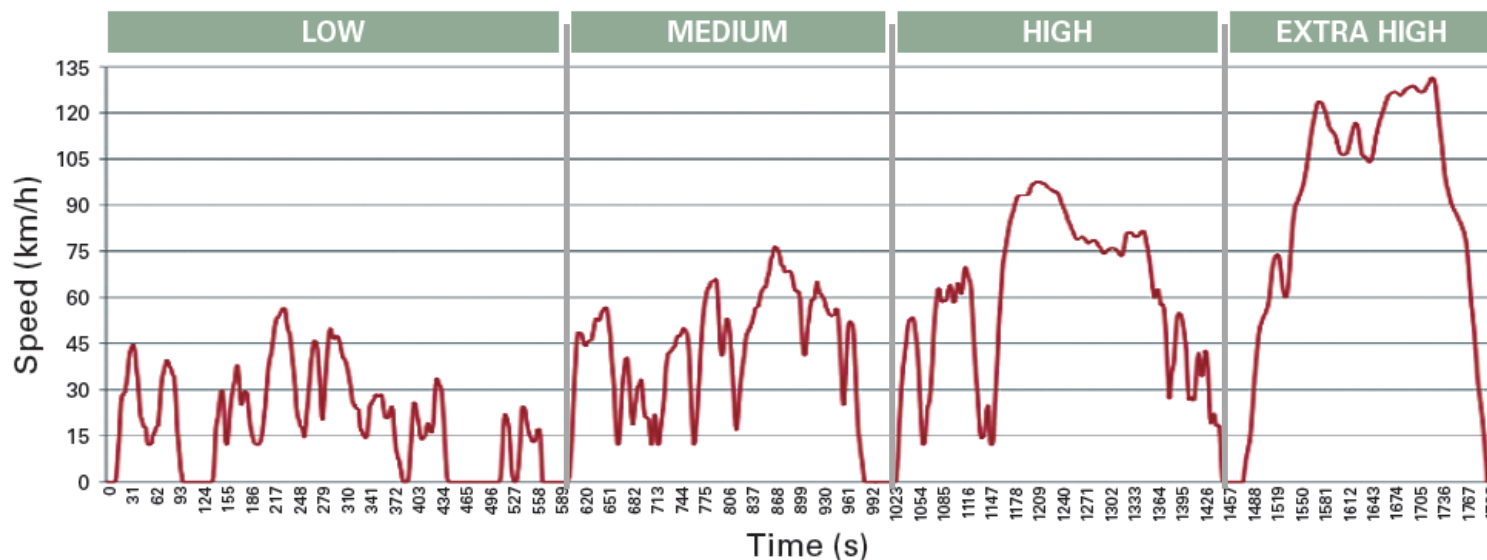
- Ajo-ohjelman muuttaminen paremmin todellisuutta vastaavaksi
 - Uusi, globaali WLTC-ajosykli
 - Testilämpötila matalammaksi (+23°C >> +14°C)

▪ Status

- ”under development”; Euro 6c (TA 09/2017)

Uusi "World Harmonised" ajosykli (WLTC)

WLTC VERSION 5 (PROPOSAL)



	MVEG-B	WLTC
Length (s)	1.180	1.800
Length (km)	11,007	23,26
Idle time (%)	21,8	13
V_{\max} (km/h)	120	131,6
V_{average} (km/h)	33,6	46,3
Accel_{\max} (m/sec ²)	1	1,6

Havaittuja pulmia ja niiden korjaamisen tilanne

▪ Pulma

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- Myöhemmin paljastui vakava NO_x-päästömanipulointi (VW et.al.)

▪ Syy

- Laboratoriossa suoritettava pakokaasukoe voidaan tunnistaa

▪ Korjaavat toimenpiteet

- Käytetään satunnaistettua sykliä ja/tai
- ”Real World Driving Emissions” (RDE) -lisäkokeet, joissa mittauksia tehdään todellisessa liikenteessä (PEMS)

▪ Status

- ”under development”; tulee mukaan Euro 6c (TA 09/2017)

PEMS = Portable Emissions Measurement System



Tässä vaiheessa mitataan CO₂, NO_x ja PN



REAL DRIVING EMISSION TESTING (RDE)

Certification in Lab



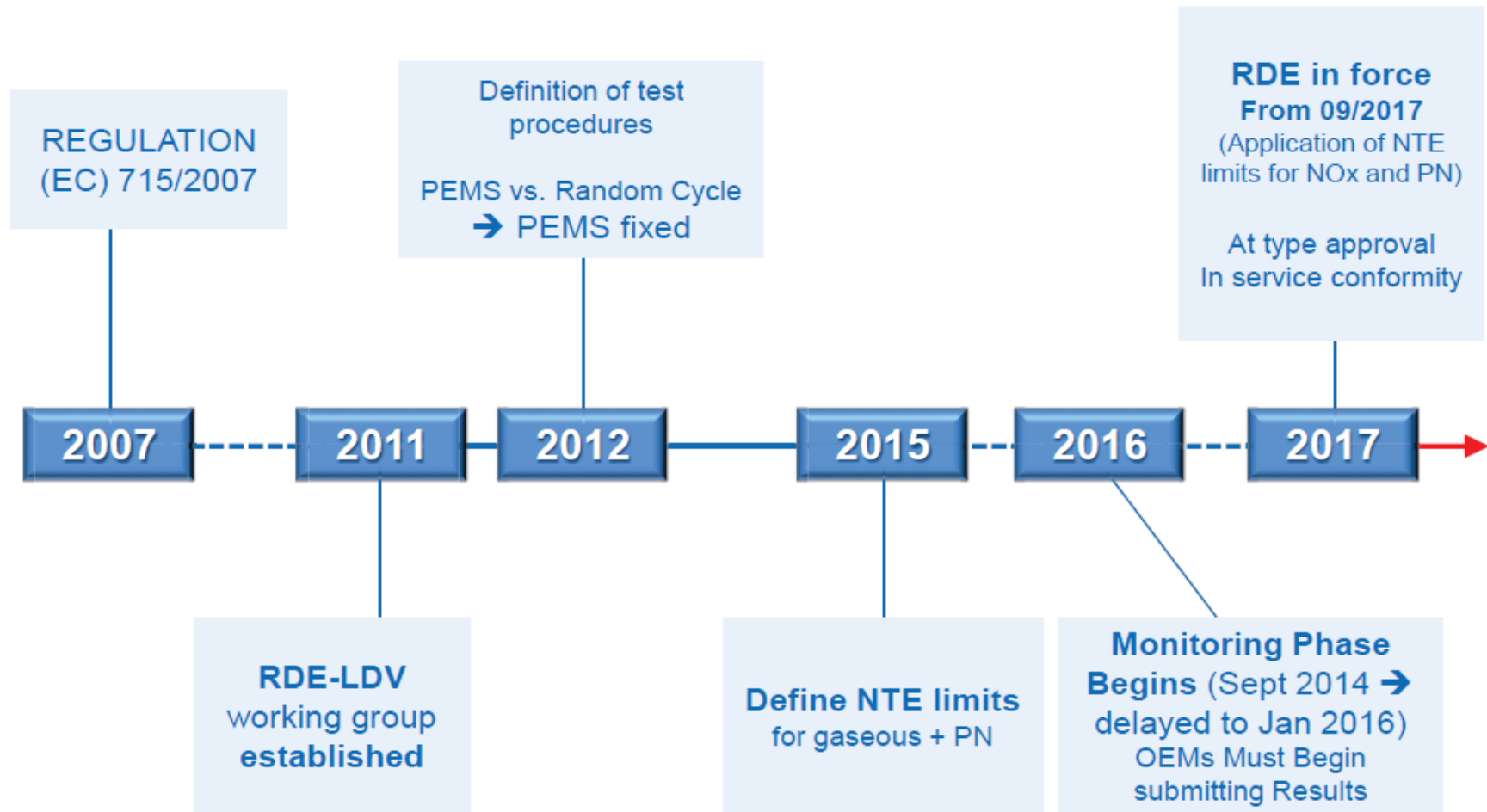
- Test Object → Engine (HD, OF) or Vehicle (LD)
- Environmental relevance → limited (Standard cycle)
- Standardization → Results can be compared
- Reproducibility → yes (most important for development)
- Driving conditions → „straight and without hills“
- Ambient conditions → standardized and constant

Real Driving Emissions



- Test Object → Vehicle, Driver, traffic, environment
- Environmental relevance → high since realer world
- Not standardized → Results can not be compared
- Reproducibility → not possible
- Driving conditions → „with turns and hills“
- Ambient conditions → variable in defined limits

RDE LEGISLATION TIME LINE – EU PROPOSAL



2016
RDE without Limits

2017
RDE for gaseous
And PN emissions

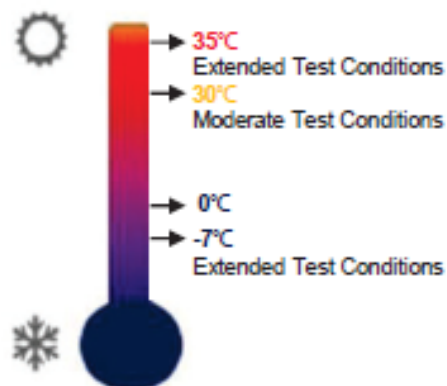
2017+
Member state
surveillance

RDE-LDV BOUNDARY CONDITIONS



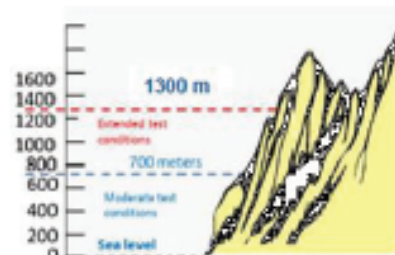
Vehicle payload and test mass

- The vehicle payload = Driver + test equipment(including the mounting and the power supply devices)
- The vehicle test mass shall not exceed 90% of the Gross Vehicle Weight



Ambient temperatures

- Moderate test conditions: $\geq 0^{\circ}\text{C}$ & $\leq 30^{\circ}\text{C}$
- Extended test conditions: $\geq -7^{\circ}\text{C}$ & $< 0^{\circ}\text{C}$ or $> 30^{\circ}\text{C}$ & $\leq 35^{\circ}\text{C}$



Maximum altitude

- Moderate test conditions: ≤ 700 m (sea level)
- Extended test conditions: > 700 m & ≤ 1300 m (sea level)

RDE-LDV TRIP REQUIREMENTS

Trip Requirements for PEMS Testing

Consist of	Urban	Rural	Motorway
Speed	$0 \leq V < 60\text{km/h}$	$60 \leq V < 90\text{km/h}$	$90\text{km/h} \leq V$
Distance based %	~34% ($\pm 10\%$)	~33% ($\pm 10\%$)	~33% ($\pm 10\%$)
Min. Distance	16km	16km	16km
Min. Distance based %	> 29%	-	-



- The trip duration shall be **between 90 and 120 minutes**.
- The start and the end point shall not differ in their elevation above sea level by more than 100 m.
- Positive altitude gain shall be less than 1,000m (/100km)

RDE-LDV OPERATIONAL REQUIREMENTS

Vehicle Operational Requirements

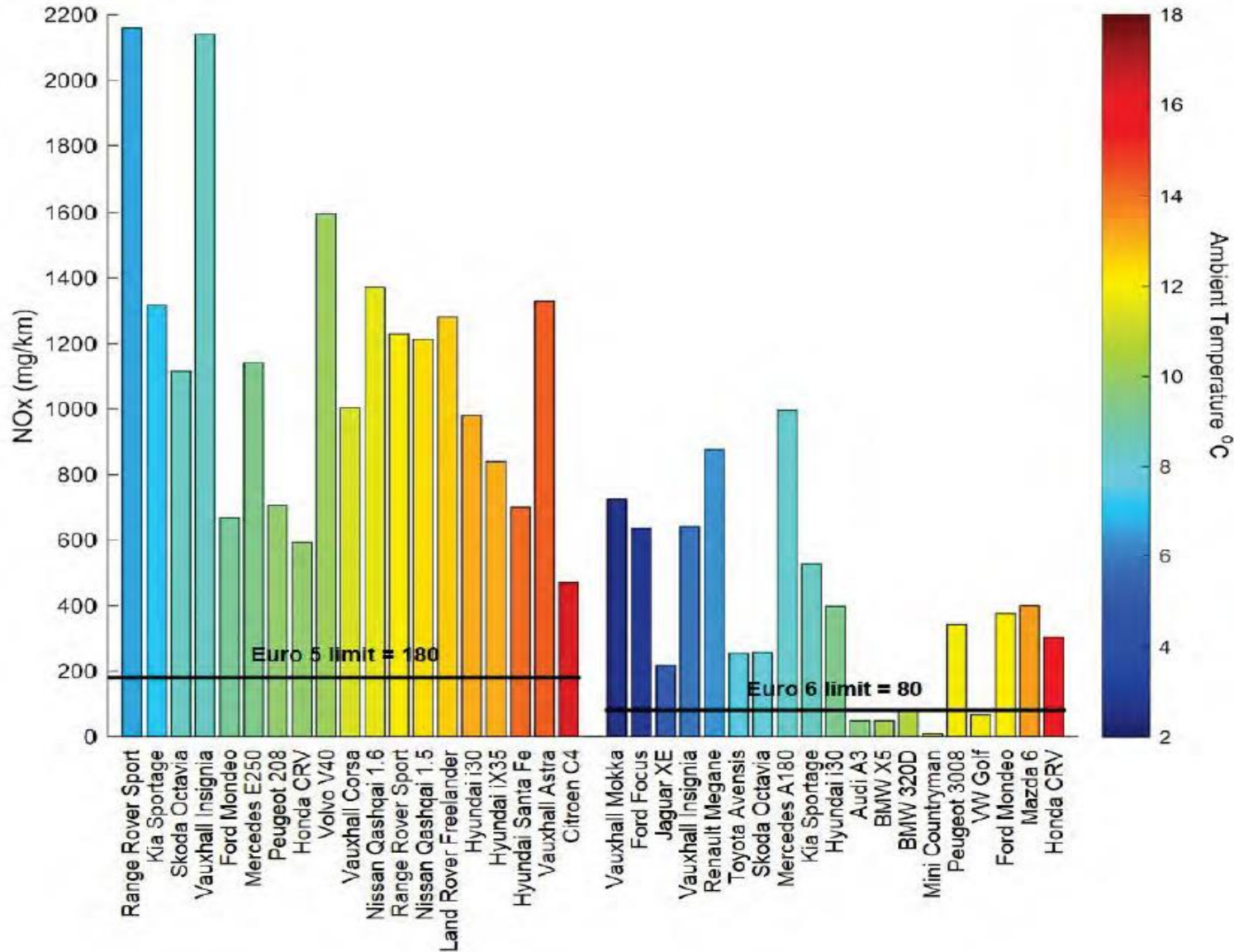


- **Testing shall not be uninterrupted**
- **Data continuously recorded** to reach the minimum test duration
- Emissions and other data sampling shall start **prior to starting the engine.**
- IF the engine stalls, it may be restarted.
- BUT the sampling **shall not be interrupted**
- **NO combine** data of different trips
- **NO modify or remove** data from a trip
- TEST shall be conducted on **paved roads and streets**

Lämpötilan vaikutus RDE-tuloksiin



Department
for Transport



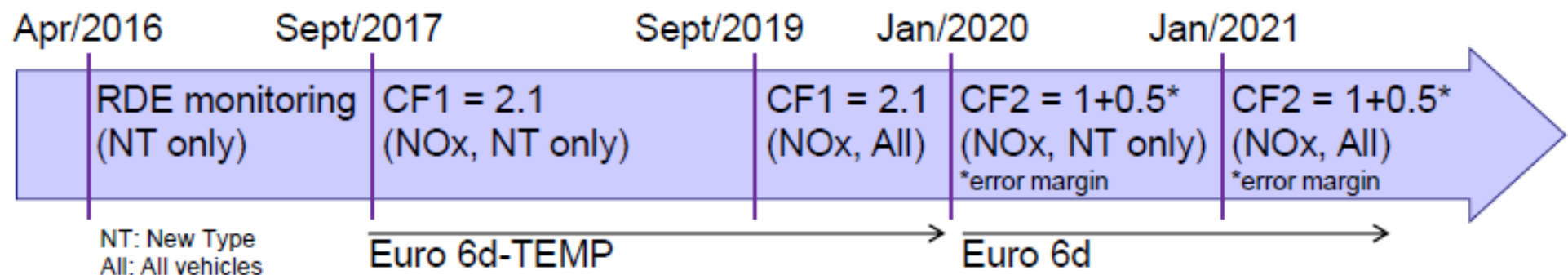
RDE – Conformity Factor (CF) & Not to Exceed (NTE)

Not-to-exceed (NTE) = Euro 6 limit x Conformity Factor (CF)

- CF defined for NO_x, PN expected
- CF error margin to be reviewed annually

CF applies to urban part and total trip

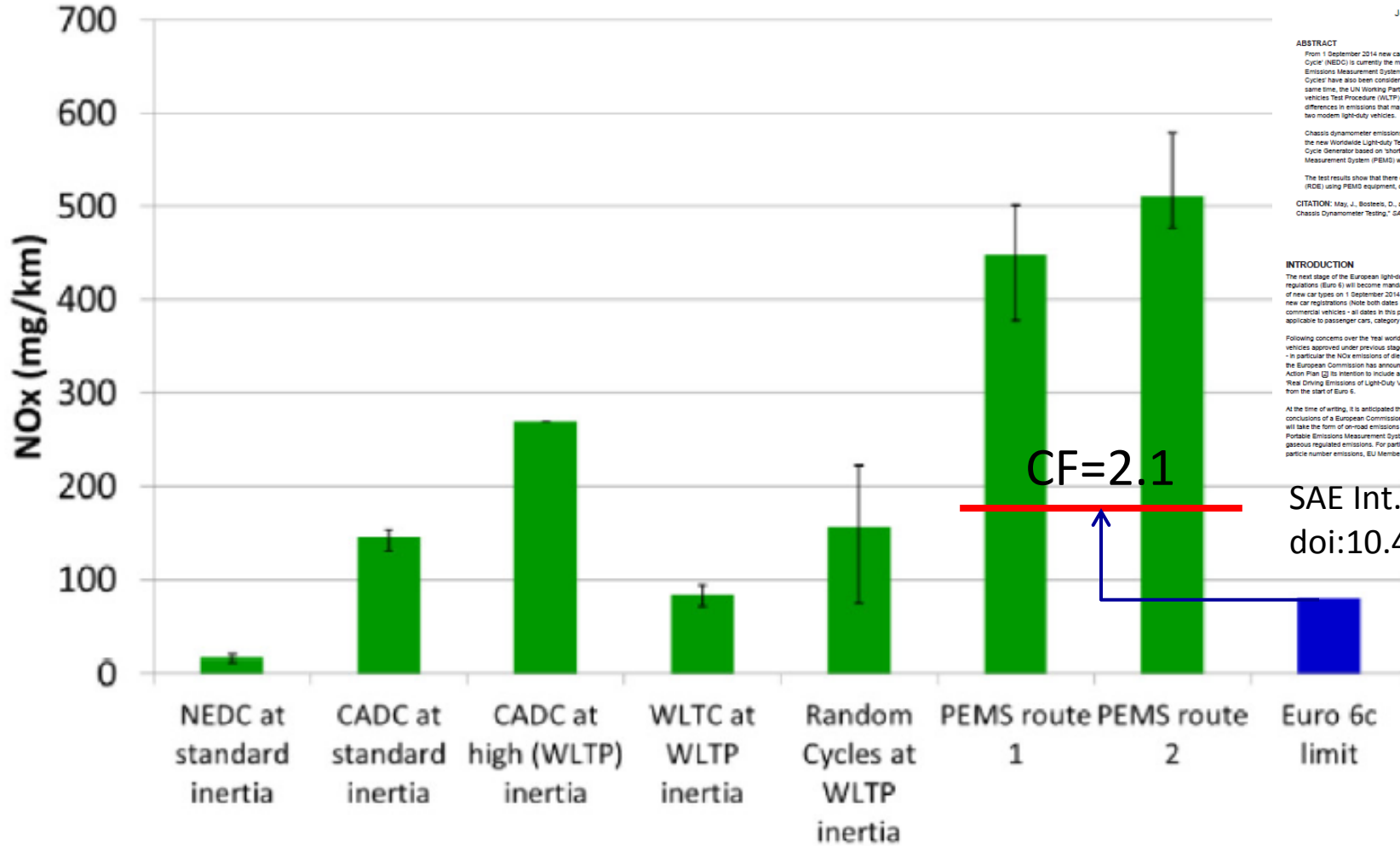
Portable Emissions Measurement Systems (PEMS) are used



Eri mittaustapojen vertailua



NOx emissions - diesel vehicle



2014-01-1581
 Published March 2014
 Copyright © 2014 SAE International
 doi:10.4271/2014-01-1581
www.sae.org

An Assessment of Emissions from Light-Duty Vehicles using PEMS and Chassis Dynamometer Testing

John May, Dirk Bosteels, and Cecile Favre
 AECC

ABSTRACT

From 1 September 2014 new car types in the EU must meet 'Euro 6' emissions requirements. The 'New European Driving Cycle' (NEDC) is currently the main test for this, but the European Commission intends to also introduce PEMS (Portable Emissions Measurement System)-based procedures to ensure that emissions are well contained in real use. 'Random Cycles' have also been considered and remain a possible option for 'real world' particle number measurement. At the same time, the UN Working Party on Pollution and Energy (ORPE) has developed the new Worldwide harmonized Light vehicles Test Procedure (WLTP) that is expected to be adopted in the EU in the near future. To identify and understand the differences in emissions that may arise between these various methodologies, AECC has conducted some initial tests on two modern light-duty vehicles.

Chassis dynamometer emissions tests were conducted over the NEDC, the Common Artemis suite of test cycles (CADC), the new Worldwide Light-duty Test Cycle (WLTC) - the test cycle for WLTP and a set of cycles produced by a Random Cycle Generator based on 'short trip' segments from the EU database used to construct WLTC. A Portable Emissions Measurement System (PEMS) was used to measure emissions during real driving over one-selected routes.

The test results show that there can be substantial differences for some pollutants measured as 'real driving emissions' (RDE) using PEMS equipment, compared to the test cycles.

CITATION: May, J., Bosteels, D., and Favre, C., "An Assessment of Emissions from Light-Duty Vehicles using PEMS and Chassis Dynamometer Testing," SAE Int. J. Engines 7(3):2014, doi:10.4271/2014-01-1581.

INTRODUCTION

The next stage of the European light-duty emissions regulations (Euro 6) will become mandatory for Type Approval of new car types on 1 September 2014 and 1 year later for all new car registrations. (Note both dates are 1 year later for light commercial vehicles - all dates in this paper refer to the dates applicable to passenger cars, category M1).

Following concerns over the 'real world' performance of vehicles approved under previous stages of EU regulation [1] - in particular the NOx emissions of diesel (light-duty) vehicles - the European Commission has announced in its 'Clean 2020 Action Plan' [2] its intention to include an additional test for 'Real Driving Emissions of Light-Duty Vehicles (RDE-LDV)' from the start of Euro 6.

At the time of writing, it is anticipated that, following the conclusions of a European Commission working group [3], this will take the form of on-road emissions measurements using Portable Emissions Measurement Systems (PEMS) for gaseous regulated emissions. For particulate mass and/or particle number emissions, EU Member States have stated

their interest in applying the same RDE-LDV method to all pollutants, if appropriate and technically feasible. However, PEMS systems for light-duty PM measurement are at an earlier stage of development and so 'Random Cycles' remains an option for this aspect. These RDE-LDV procedures are planned to be gradually implemented from 2014 onward, initially by inclusion of test procedures in the Euro 6 Regulation, with the introduction of 'Conformity Factors' proposed from the Euro 6c stage starting in 2017.

A further aspect of development is that although emissions limits have so far been set using the New European Driving Cycle (NEDC) [4], the UN Working Party on Pollution and Energy (ORPE) has developed a Worldwide harmonized Light vehicles Test Procedure (WLTP) [5] and associated cycle (Worldwide Light-duty Test Cycle, WLTC) that is expected to be adopted in the EU in the near future. It is expected that in the EU this cycle will be first required for CO₂ measurements, but is expected to also be available for pollutant measurement.

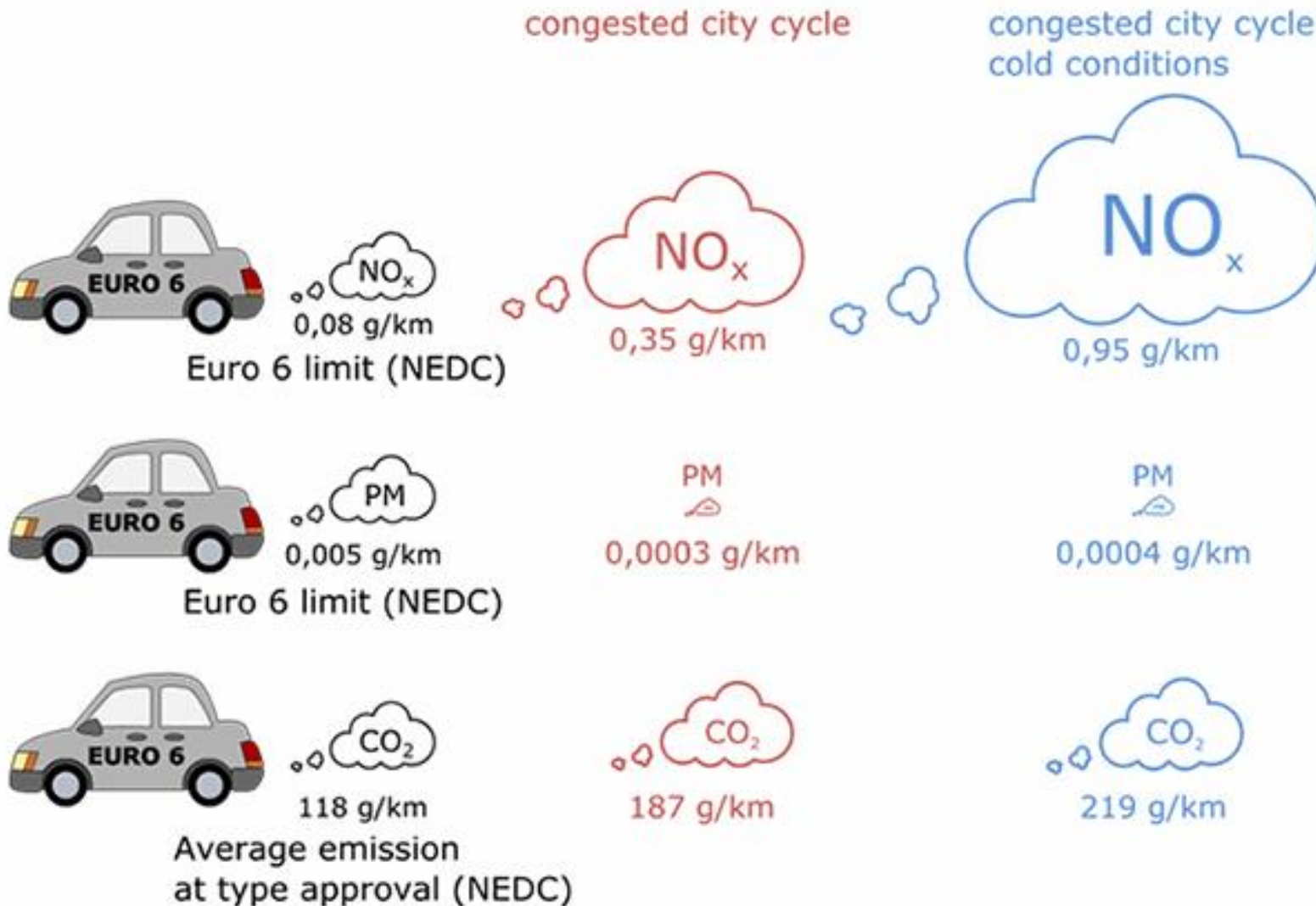
SAE Int. J. Engines 7(3):2014,
 doi:10.4271/2014-01-1581

Keli- ja liikenneolosuhteet vaihtelevat koko ajan

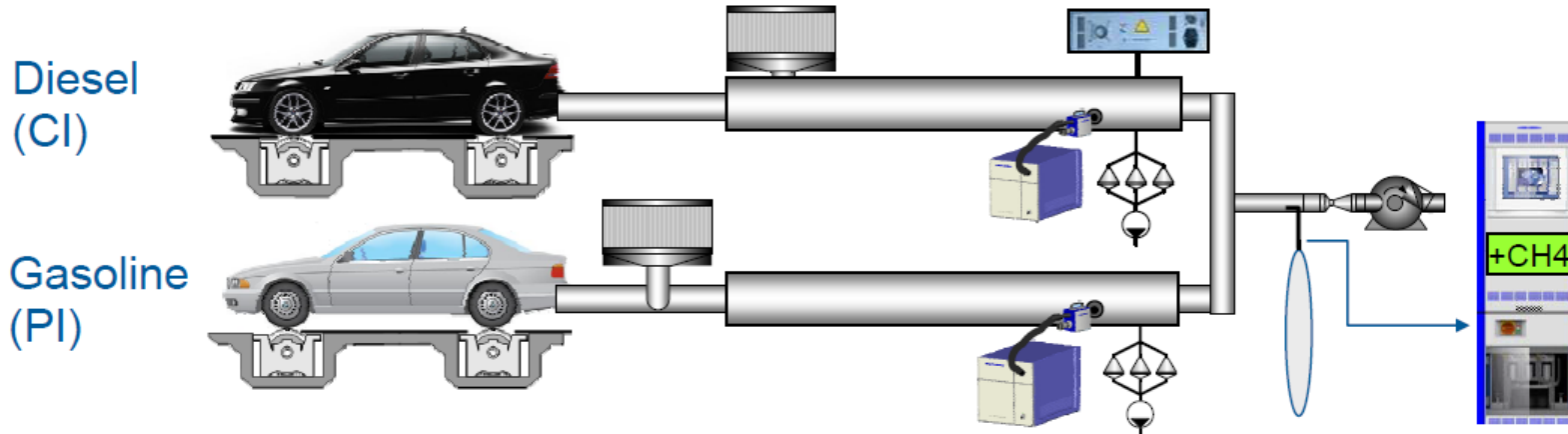
Millaista on "todellinen ajaminen"?




Sääolosuhteiden ja liikenteen vaikutus



Myös laboratoriomittauslaitteisto kehitty jatkuvasti



 Emission	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 5+	Euro 6
	1992	1996	2000	2005	2009	2011	2014
CO, THC, NOx, CO2	✓						
Diluted Hot THC – CI only („Diesel“)	✓						
Particulate Mass – CI only („Diesel“)	✓						
NMHC					✓		
Particulate Mass – PI-GDI only					✓		
Particle Number – CI only („Diesel“)						✓	
CO2 Limit						✓	
Particle Number – all PI („Gasoline“)							(✓)

Laboratorio vs. ”todellinen ajaminen”

- Kumpi on ”oikeassa”?



Tarkasti kontrolloitu

- + Toistettavuus hyvä
- + Monipuoliset mittalaitteet
- Ei aina vastaa ”todellisuutta”
- Altis ”manipuloinnille”



Lähes ”kaottinen”

- + Testitilanne vaikeammin manipuloitavissa
- Rajoitetut mittalaitteet
- Heikko toistettavuus

Yhteenveto

- "Dieselgate" nosti dieselmoottorin suuret (ajon aikaiset) päästöt otsikoihin syksyllä 2015
- Ongelma koski kuitenkin etupäässä jo "vanhoja" Euro5-autoja, ja muutkin merkit kuin VAG-konserni saivat siitä osansa
- Suuri osa "korjaavista toimista", kuten uusi ajosykli (WLTP) ja "Real Driving Emissions" (RDE) -mittaus todellisessa liikenteessä olivat jo tulossa, ja astuvat voimaan syyskuussa 2017
- RDE-mittaus täydentää laboratoriomittauksia, ja varmentaa, että autoissa ei käytetä testitilanteen ja -olosuhteiden tunnistusta ja muutakaan puhdistusjärjestelmän tehokkuutta heikentäviä järjestelmiä
- Dieselmoottorin hintakilpailukyky on kuitenkin vaarassa, koska Euro6b/Euro6c edellyttävät hyvin tehokasta ja kallista jälkipuhdistusta

Loppu



Kysymyksiä?

■ **Kiitos**

mielenkiinnostanne!

