Additional technical issues for Euro 7 LDV

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Topics addressed

- “Normal” and “Extended” driving conditions and related emission limit setting
- On the definition of the minimum “reference” test distance
- Emission limit setting accounting for limit of quantification and uncertainty
- Options for N_2O and CH_4 emission limits
- GPF filtration efficiency
- Filter regeneration
- Proposed Euro 7 limits - updated
- Strengthening MIL (TCI)
- Fuel Evaporation

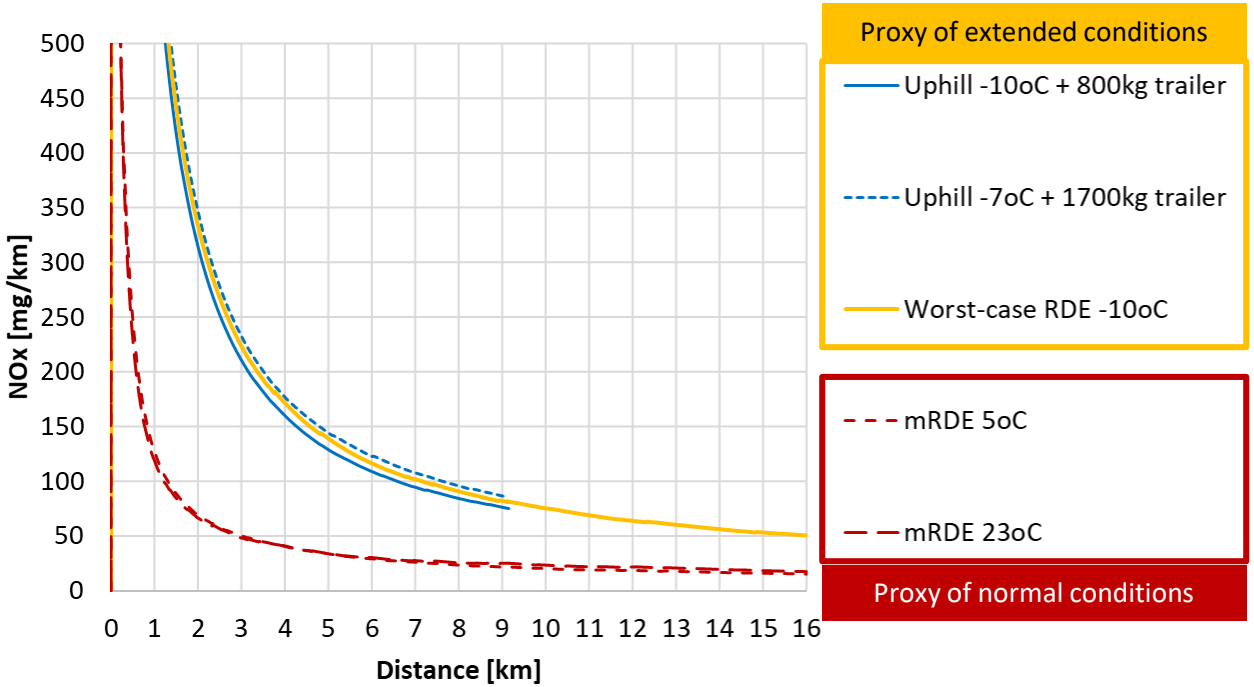
Proposed testing conditions for Euro 7

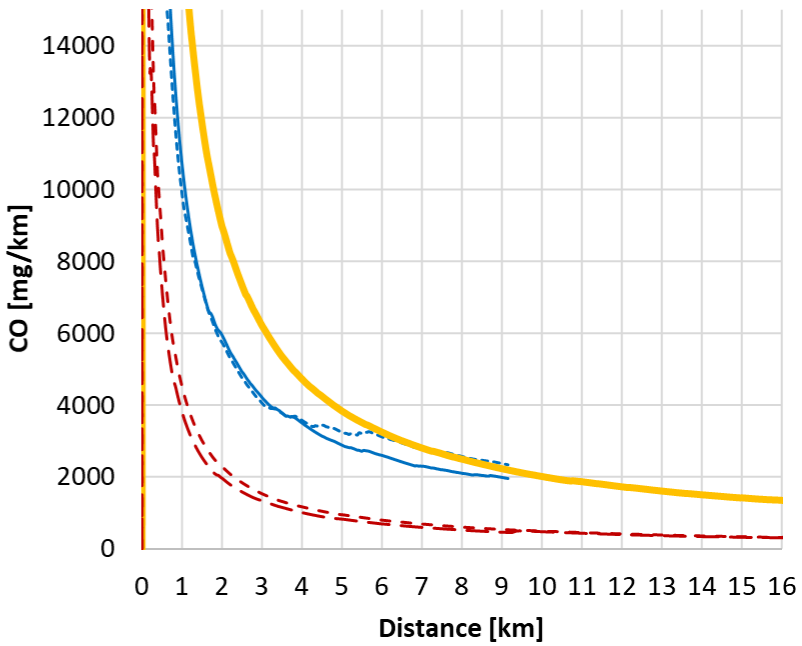
Parameter	Current RDE boundaries	EURO 7 Normal Conditions of use	EURO 7 Extended Conditions of use
Emission Limit Form	Constant value in mg/km or #/km	A budget up to 16 km and a constant value in mg/km or #/km above 16 km	3 times the limit of normal conditions
Ambient temperature [°C]	Moderate: 0 – 30°C | Extended: -7 – 0°C & 30 – 35°C	-7 to 35°C	-10 to +45°C
Average speed [km/h]	Urban: 15-40 km/h, Limitations for trip distance and duration, and speed range coverage	Any condition	Any condition
Trip composition	33% urban, 33% rural, 33% highway	Any condition	Any condition
$v \times a_{pos}$ [95th] [W/kg]	Speed-based calculated maximum limits	A restriction is applied to the maximum power developed for the first 2 km (the exact approach and values are under investigation and testing)	Any condition
Relative positive acceleration RPA m/s^2	Speed-based calculated minimum limits		Any condition
Drive-off	—		Any condition
Positive elevation gain [m/100km]	Total: <1200 [m/100km] Urban: <1200 [m/100km]		Any condition
Max. altitude [m]	Moderate: 0 – 700m | Extended: 700 – 1300m	1600 m	2200 m
Towing/aerodynamic modifications	Not included	Not included	Allowed
Age/Mileage of Vehicle [km]	ISC 100k | MaS 160k	Up to 240k km or 15 years (1)	Up to 240k km or 15 years (1)
Minimum mileage before testing	15000 km (ISC testing)	3000 km	Any condition
Trip distance [km]	U/R/M >16 km each	Any	Any
Max. speed	145 [160] km/h	Any <160 km/h	Any (European) condition

(1) The durability of the emission control systems until the end of their lifetime will be dealt separately

Test cycles as proxy of normal and extended conditions

- Measurement results from a dedicated test campaign performed by JRC on a Euro 6d-temp GDI vehicle

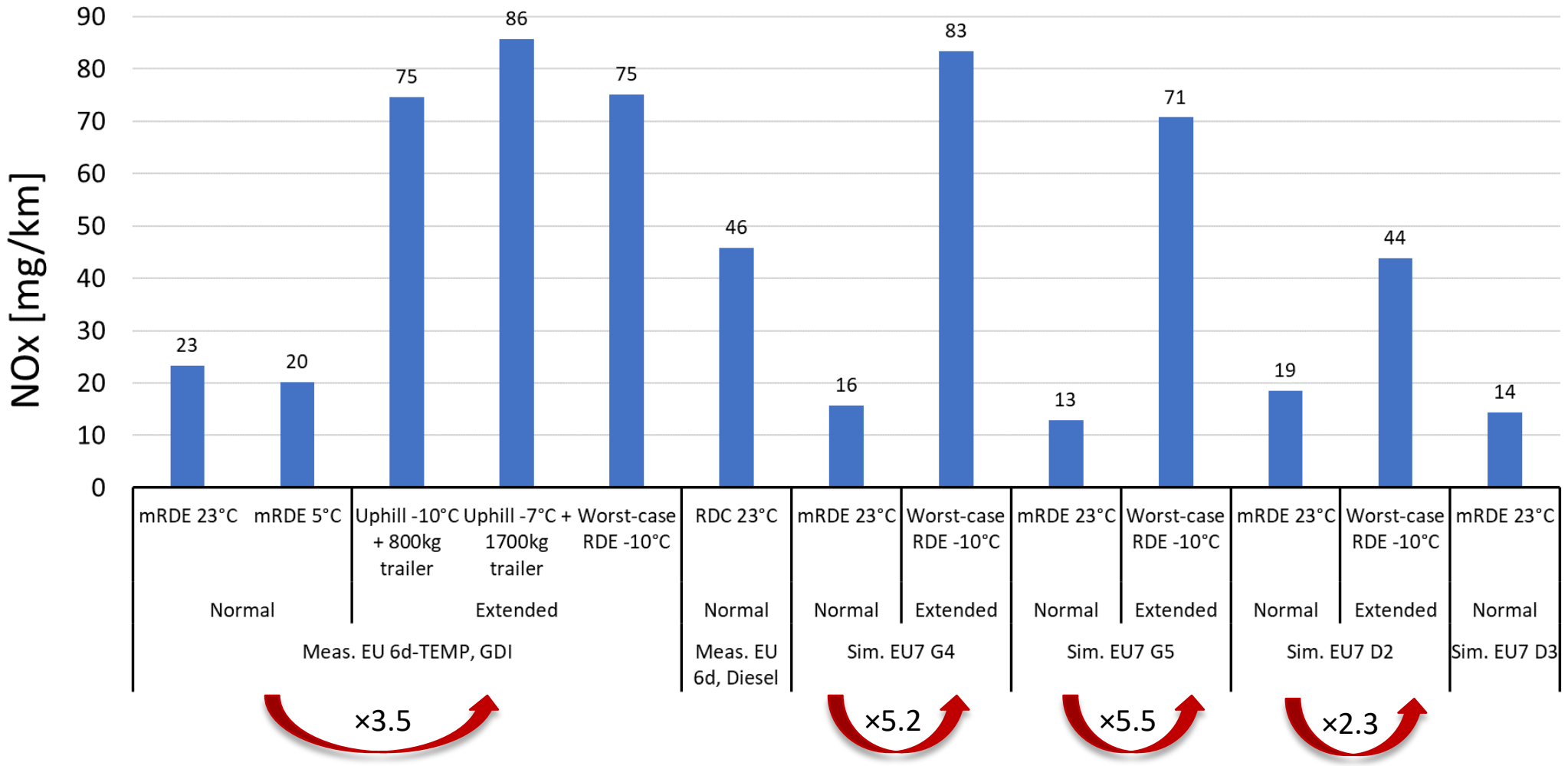




Distance [km]	NOx wcRDE -10°C / mRDE 23°C	CO wcRDE -10°C / mRDE 23°C
2	5.0	4.6
5	4.1	4.7
10	3.3	4.1
16	2.9	4.4

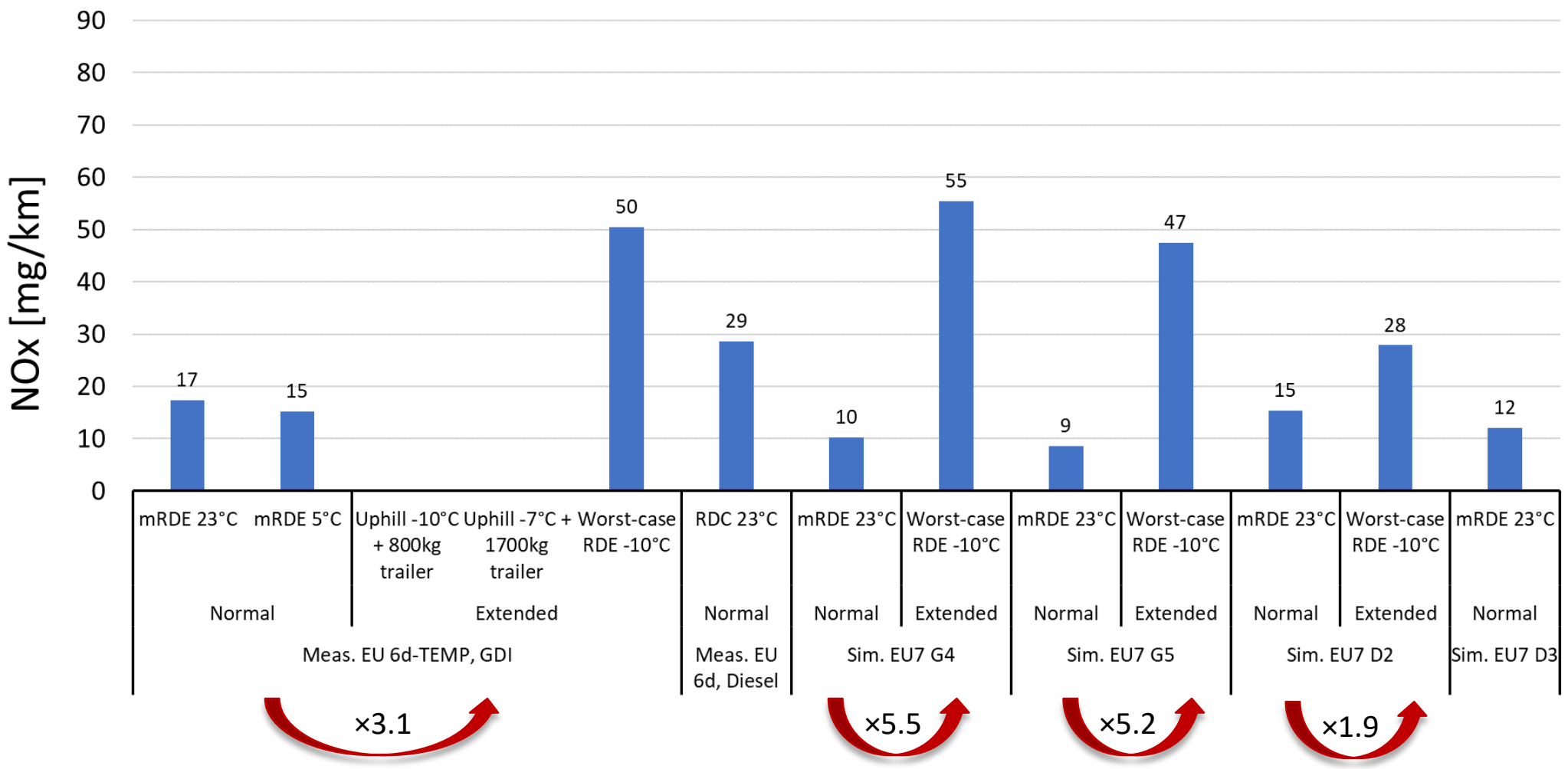
Normal and Extended driving and emission limit setting

- Measurement and simulation results for current and future technologies at **10km**



Normal and Extended driving and emission limit setting

- Measurement and simulation results for current and future technologies at **16km**



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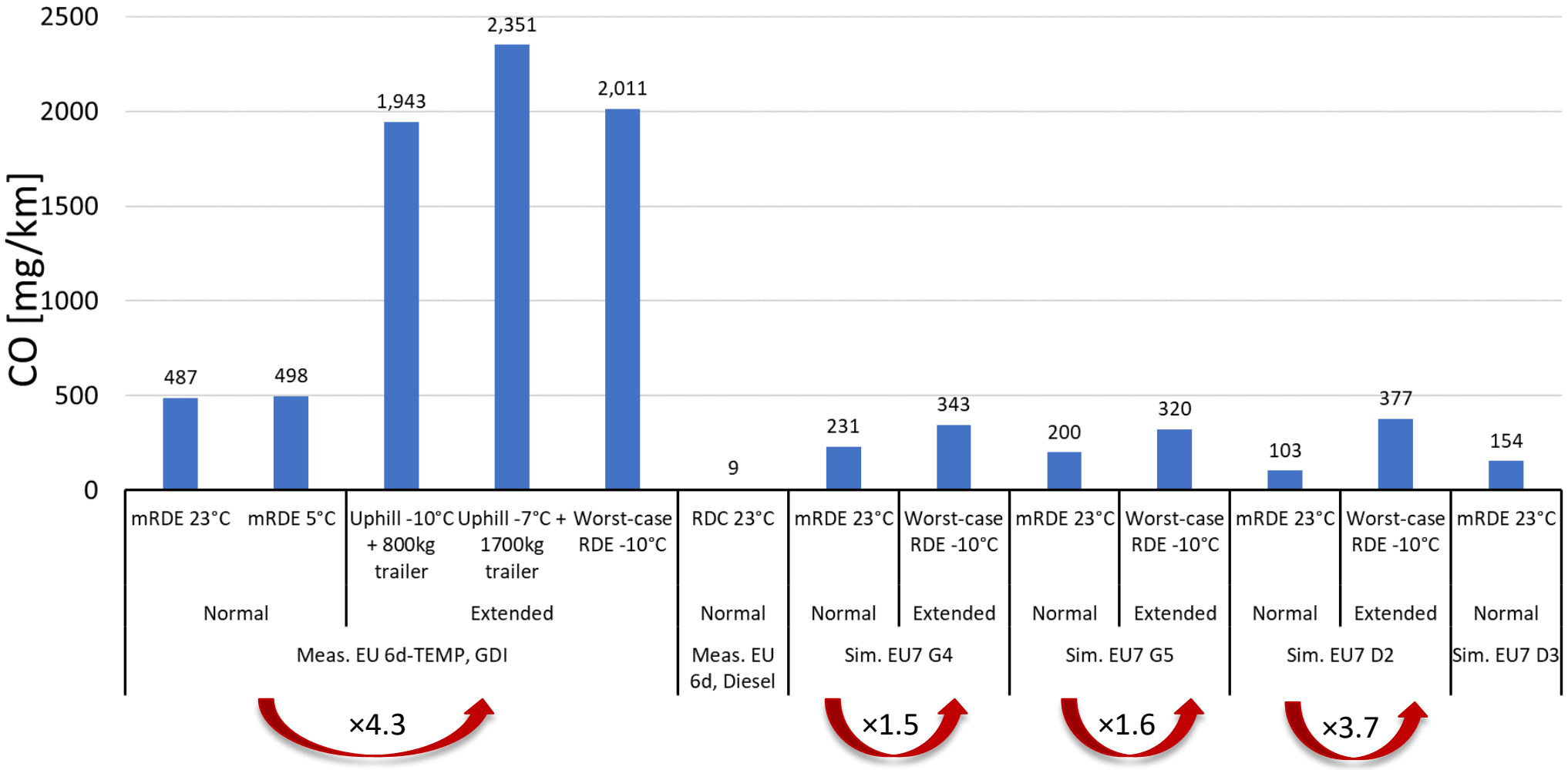

Normal and Extended driving and emission limit setting

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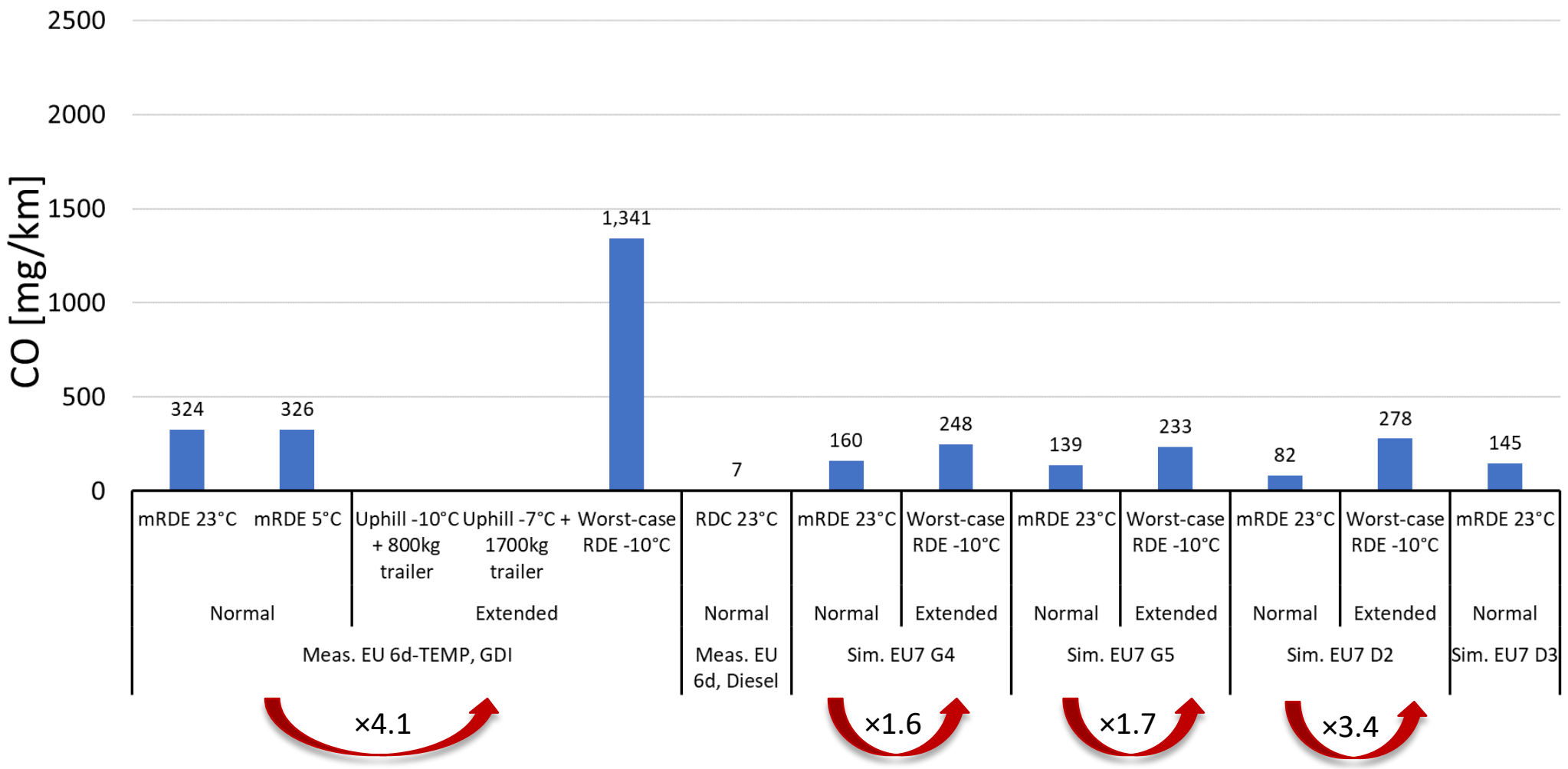

Normal and Extended driving and emission limit setting

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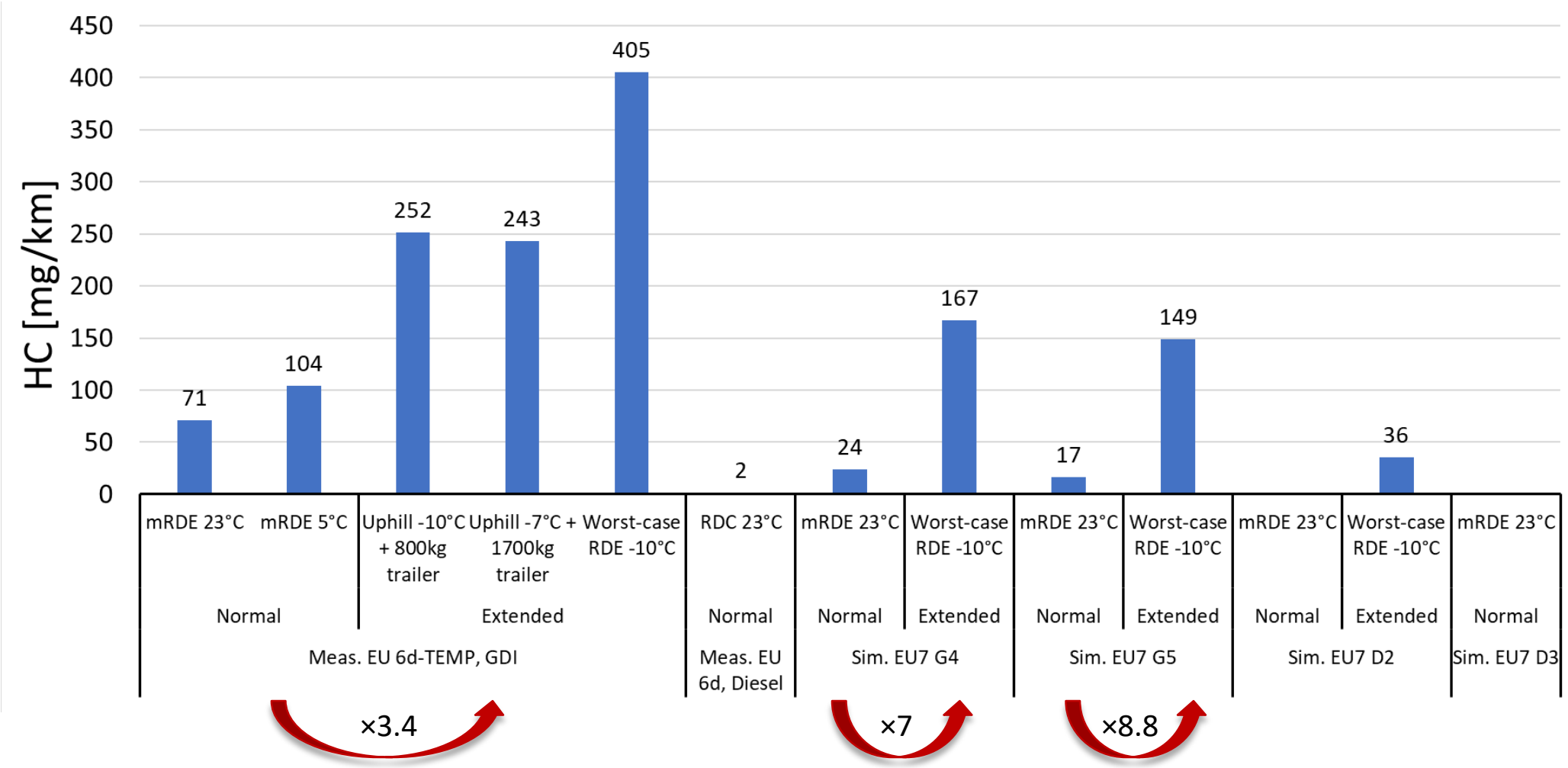

Normal and Extended driving and emission limit setting

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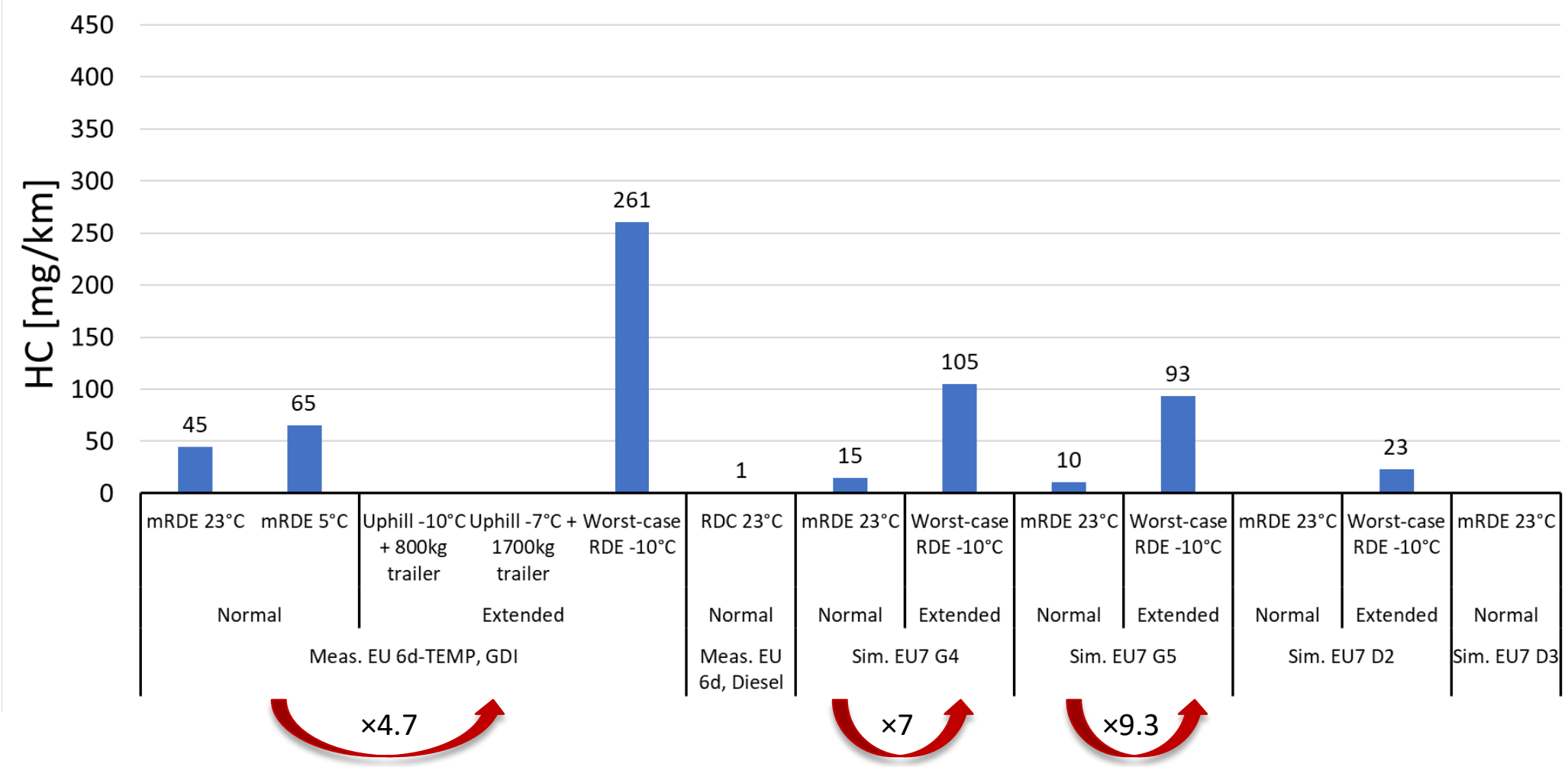


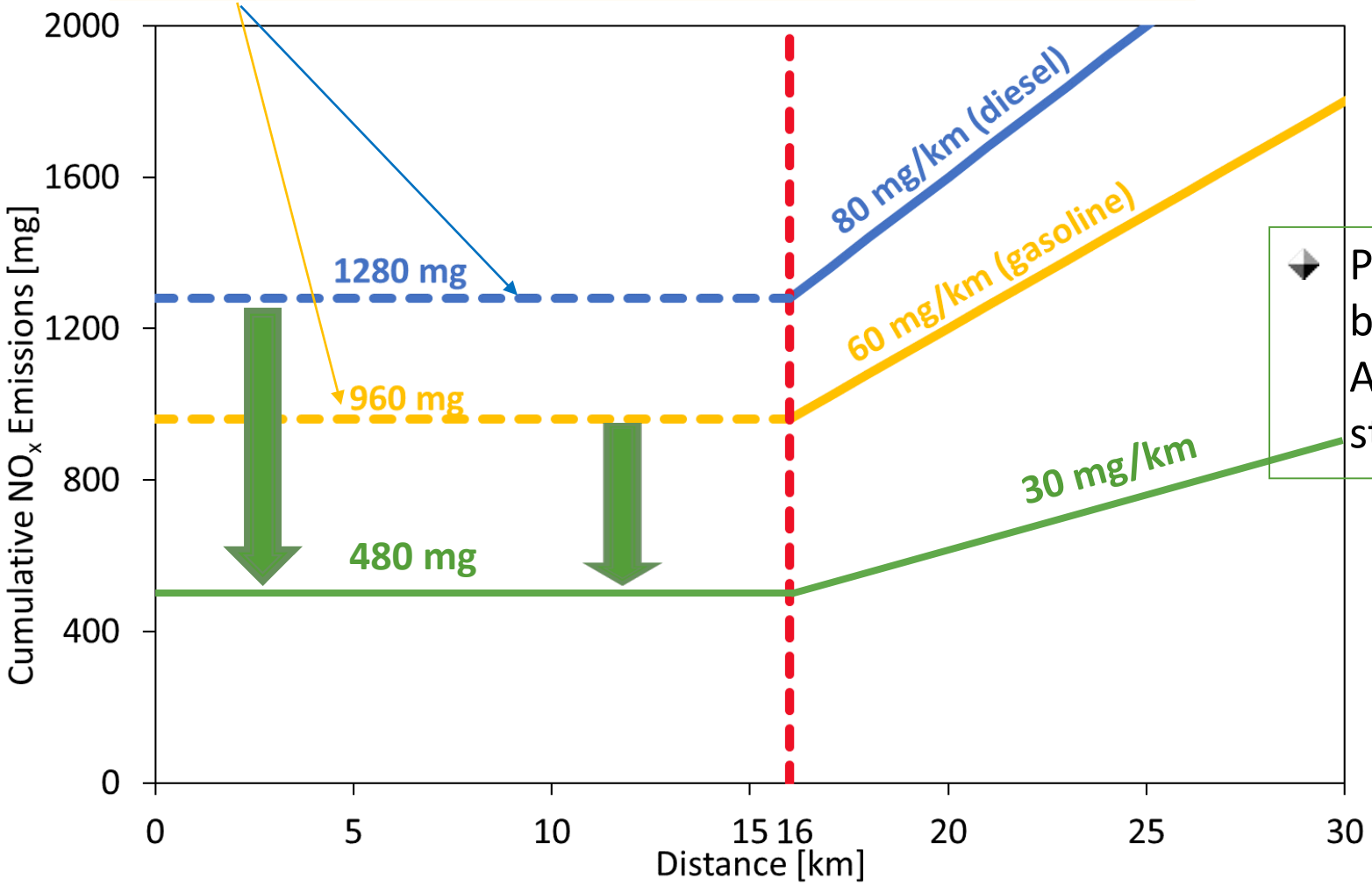
Summary and additional clarifications

- Emissions ratios between extended and normal conditions can vary significantly among the different technologies and pollutants.
  → CLOVE proposal: to introduce a ×3 multiplier for all pollutants.

- Clarifications (under discussion):
  - The ×3 multiplier is applied even if one condition falls within the extended conditions
  - If more than one conditions fall within extended conditions (e.g. low temperature and trailer and high altitude), the ×3 multiplier is applied only once
  - Application of the ×3 multiplier:
    - within budget distance (16 km): if any condition falls within extended conditions once, the ×3 factor is applied in the whole budget
    - beyond 16 km: the ×3 factor is applied only during the extended conditions period, not for the complete test. The exact implementation method/approach to be defined.

The proposed budget in comparison to Euro 6

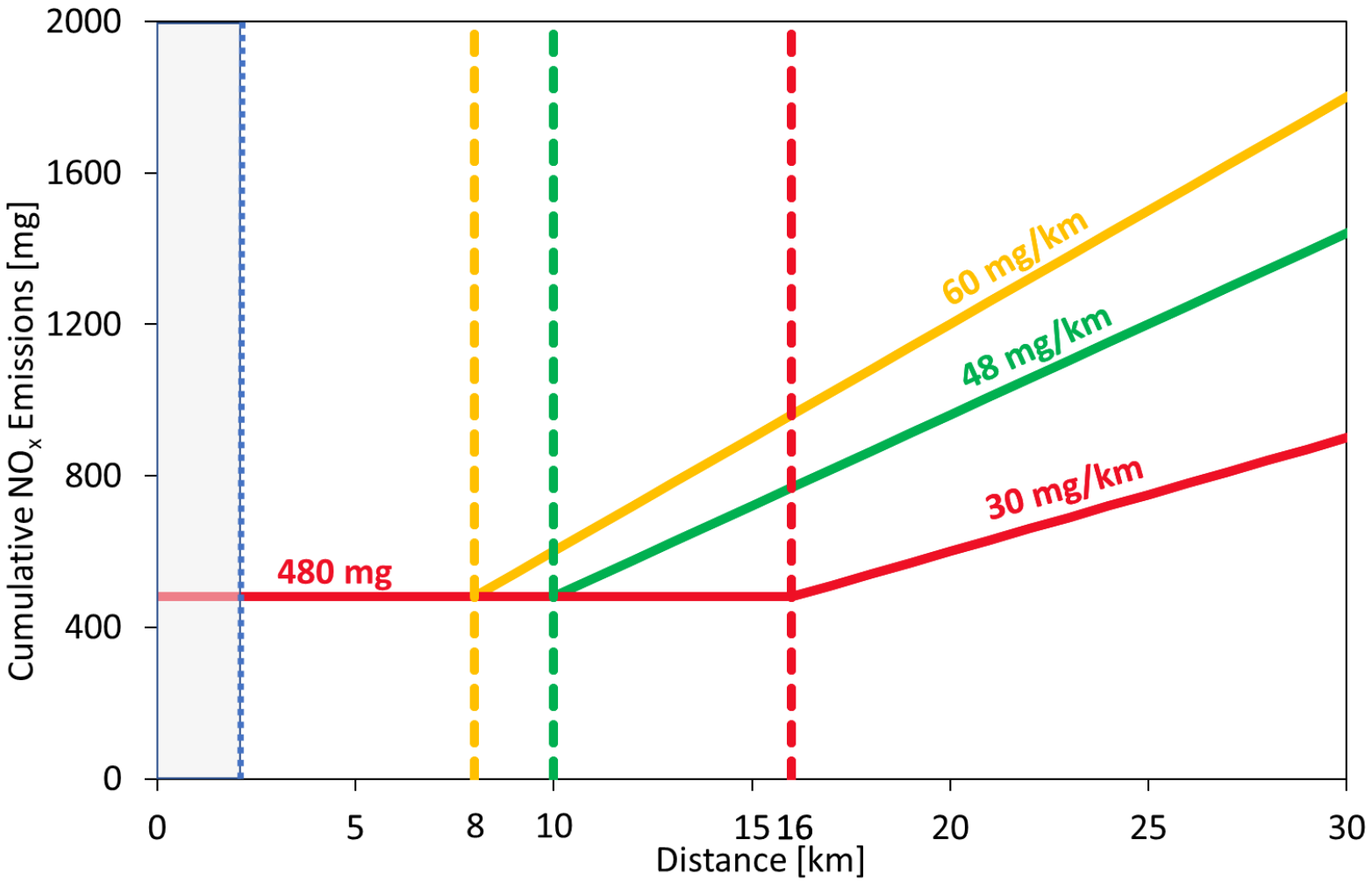
- Current Euro 6 situation without conformity factor. Emission limit applies from 16 km and above



- Proposed Euro 7 budget (Scenario 1). Applicable from start

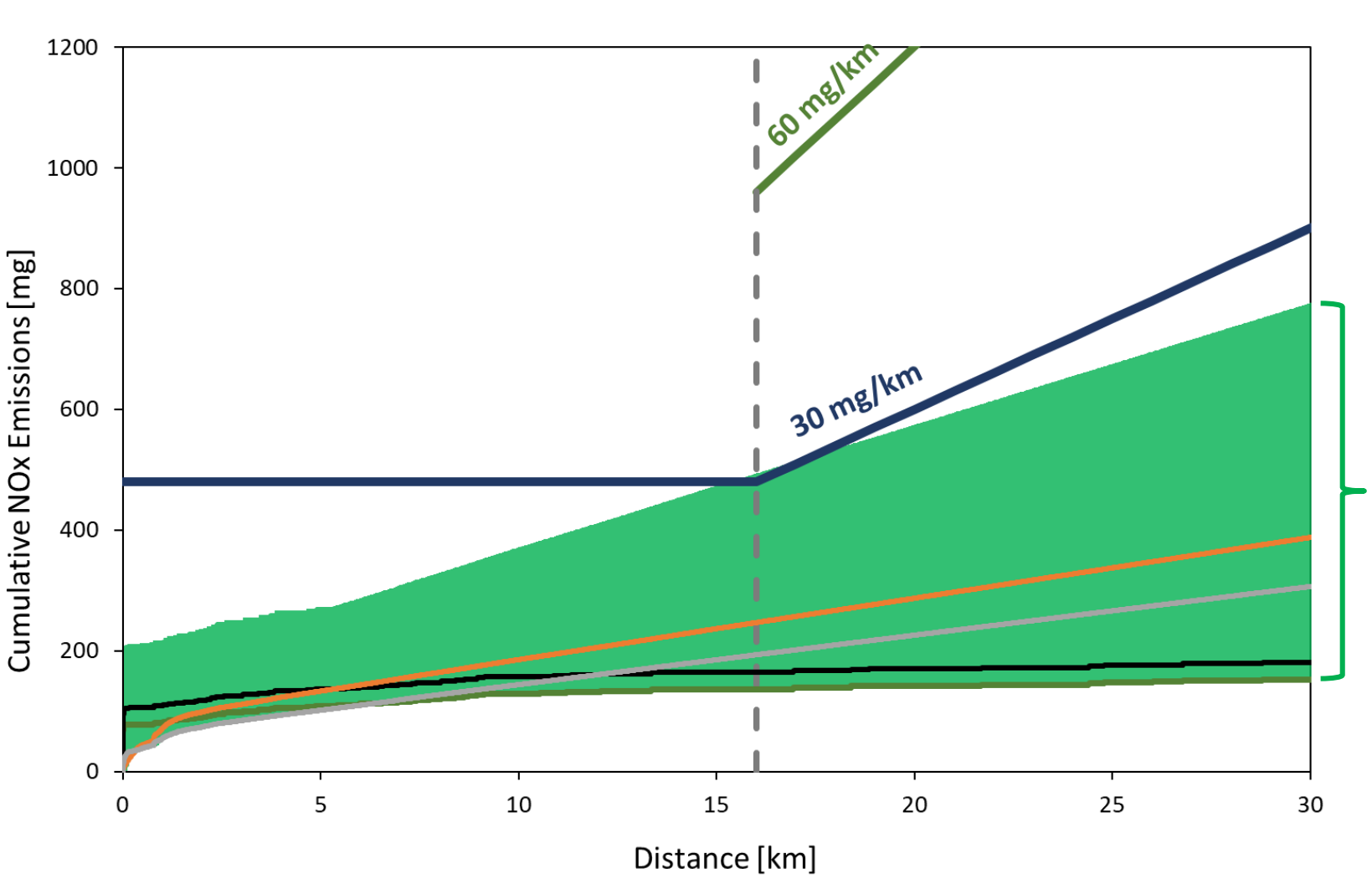
Reference distance investigation – NOx Scenario 1

- For a constant budget at 480 mg, if a lower reference test distance is selected, a higher limit should be applied e.g. 60 mg/km for a reference distance of 8 km.



Emission limit setting (Scenario 1) – NOx in normal driving

- Emissions performance from simulation data over moderate RDE tests at 23°C.

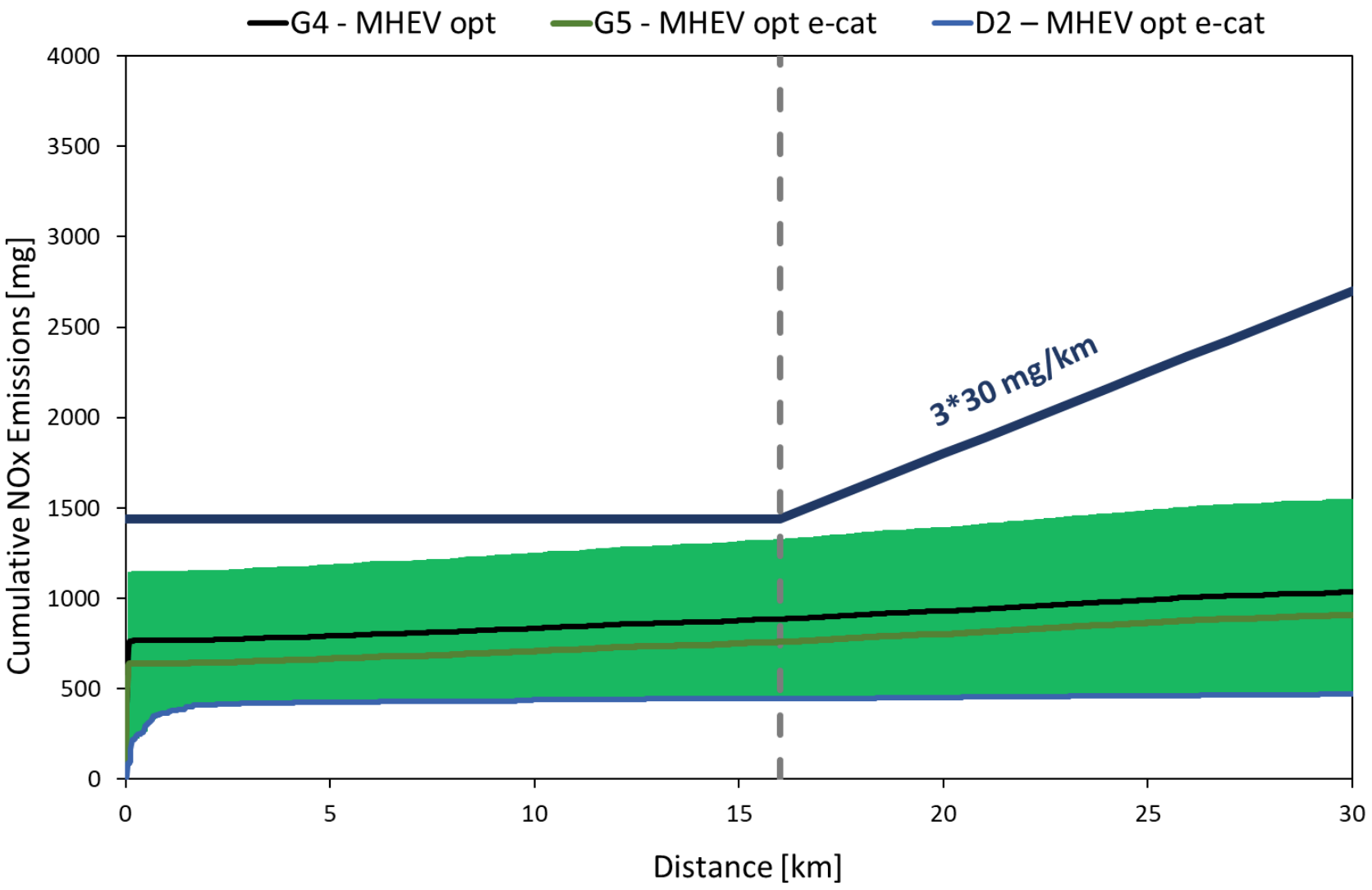


Emission limit area including margin for all boundary conditions within normal driving

Simulations performed using FEV's simulation tools

Emission limit setting (Scenario 1) – NOx in extended driving

- Emissions performance from simulation data on worst-case RDE tests at -10°C (*without trailer towing).



Simulations performed using FEV's simulation tools

Emission limit area including margin for all boundary conditions* within extended driving

Summary

- Based on emissions performance evaluation, Euro 7 technologies are within the “budget” for 16 km in both normal and extended conditions
- The proposed limits at 16 km were selected to account for all driving conditions within normal driving
- If shorter distance and the necessary margin should be both covered, a higher emissions limit is necessary

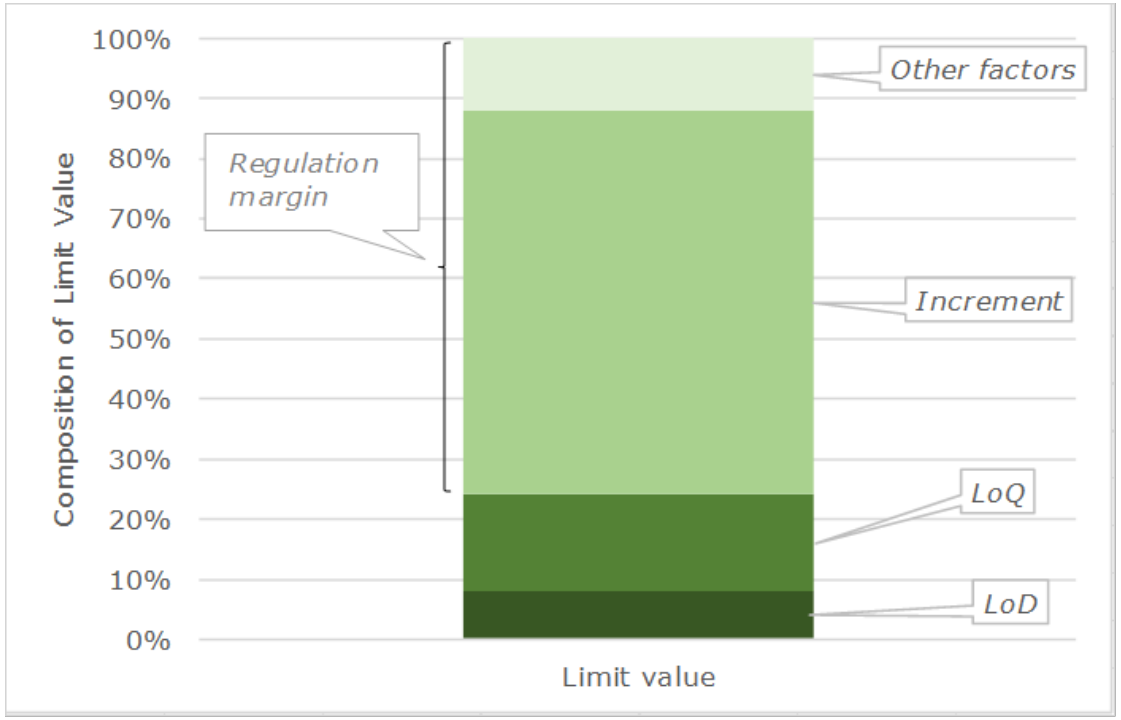
Limit setting methodology and measurement

- **The limit setting methodology** considers two main factors:
  1. Minimum limit value considering PEMS analyzer capabilities
  2. Achievable levels for EU7 vehicle technologies with emission (safety) margins

     → These margins also incorporate measurement uncertainty

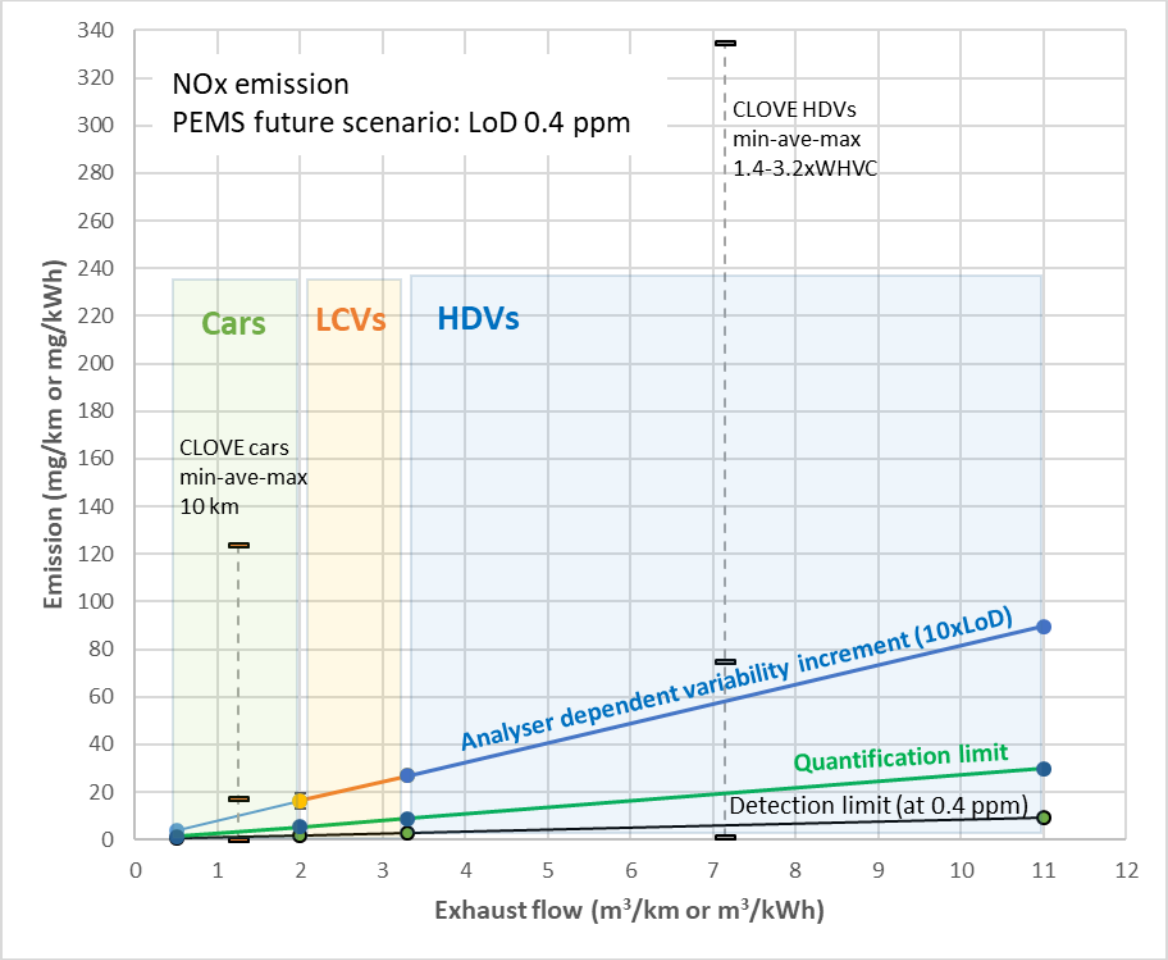
Limit-setting factors – Analyzer capabilities

- Limit setting factors



- Analyser dependent variability increment is 3-4 x LOQ (equivalent to 10 x LOD). This includes analyser-specific issues and reproducibility
  - Derived from the example of stack sampling: raw gas, exhaust flow meter etc

Analyzer capabilities, NOx as an example

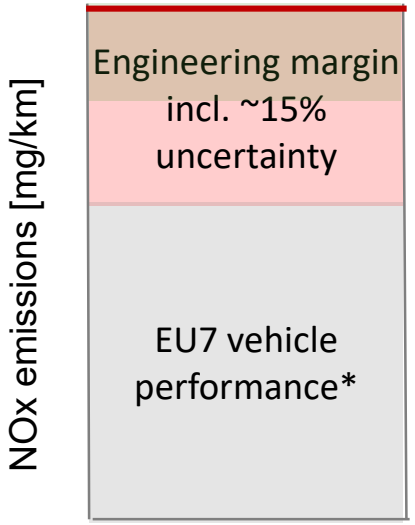


Note: "PEMS future scenario" LoD 0.4ppm used.

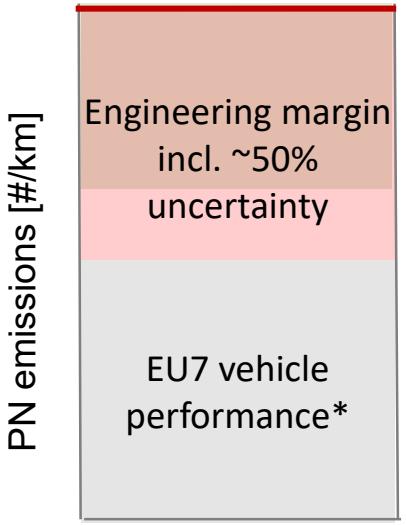
Proposed limit values integrate measurement uncertainty

- PEMS average uncertainty is included within the proposed limits for Type Approval
- The assessed capability levels of EU7 technologies for the emissions species, plus a safety margin (which includes the worst case future PEMS uncertainty), are below the proposed limit value

NOx proposed limit (scenario 1) =30 mg/km



PN proposed limit (scenario 1) = 1×10^{11} p/km

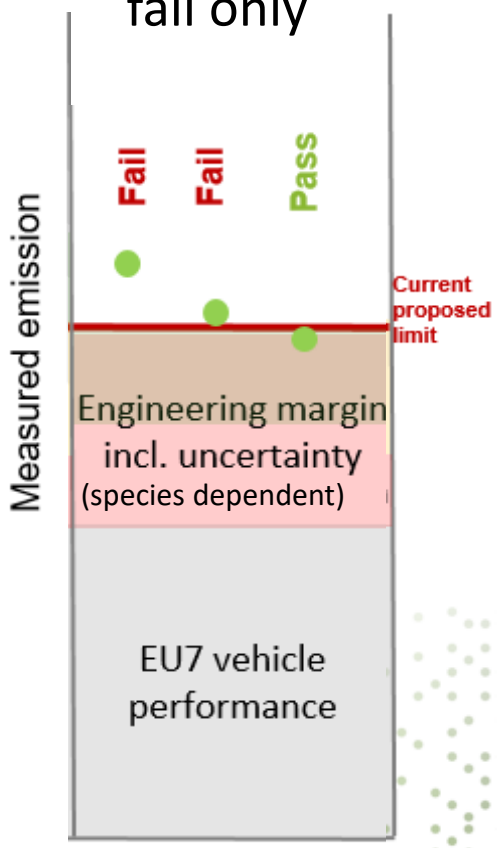


*Technology capability level

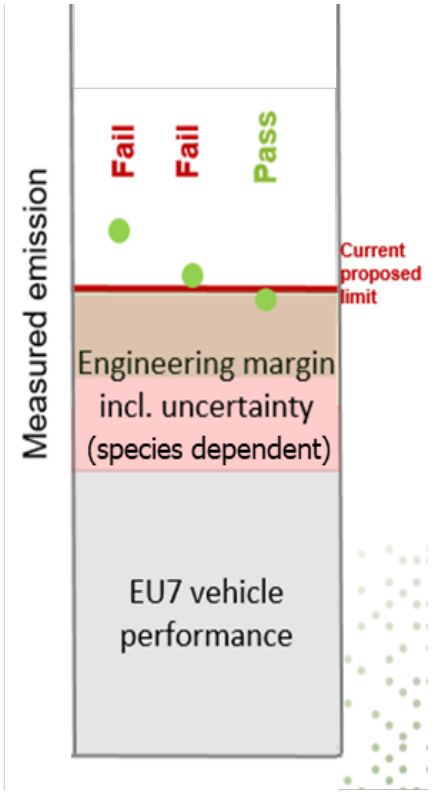
Proposal to revise test and validation approaches for Euro 7

- Type approval allows one test only
- ISC criteria to allow / force multiple repeat tests (follow matrix approach; later slide)
- MaS to require repeat test(s) if first test is within ± 10% of the limit; process TBC
- Requirements for accuracy, measurement ranges & zero gas impurities etc., to be applied to all analysers & components of the PEMS system. Requirements for internal lab verifications etc., to be set (TBC)
- Post-processing options for instantaneous PEMS data records below the detection limit to be considered
- Lab v PEMS comparison to be periodic (annual/6 monthly; TBC)
  - Comparison to be made between lab continuous raw analysers and PEMS continuous raw analysers
  - Data processing for lab and PEMS raw analysers to be identical
- Lab "certification" tests can still use the bagged dilute emissions method (e.g. CO_2), assuming bag fill times are adequate

Test is pass or fail only



ISC sampling scheme - Example



Commission Regulation (EU) 2018/1832

Figure B.2

Decision chart for the statistical procedure for vehicles based on types approved as of 1 January 2020 (where 'UND' means undecided)

Failed result count f	3	4	5	6	7	8	9	10
10								FAIL
9							FAIL	FAIL
8						FAIL	FAIL	FAIL
7					FAIL	FAIL	FAIL	FAIL
6				FAIL	FAIL	FAIL	FAIL	FAIL
5			FAIL	FAIL	FAIL	UND	UND	PASS
4		FAIL	FAIL	UND	UND	UND	UND	PASS
3	FAIL	FAIL	UND	UND	UND	UND	PASS	PASS
2	UND	UND	UND	UND	PASS	PASS	PASS	PASS
1	UND	PASS	PASS	PASS	PASS	PASS	PASS	PASS
0	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

Cumulative sample size n

Sampling scheme parameters:

- *Sequential sampling* to reach a decision
  - Number of vehicles to be tested (cumulative sample size, n):
  - from n = 3 (least requirement) to n = 10 vehicles (maximum)
- *Limit of accuracy (L_{test}%)* to characterize each test (event) as a "passed" or "failed" one
  - 'passed': $test\ accuracy\ \leq\ L_{test}$
  - 'failed': $test\ accuracy\ >\ L_{test}$
- *Decision-rules* within each sample size
  - Each failed-test result increase the 'f' count by 1
  - The decision-chart is then used to come to either an intermediate or to a final decision

Options for N_2O and CH_4 emission limits

- N2O considered as GHG and as air pollutant, primarily because there is growing evidence(*) that it contributes to stratospheric ozone depletion which increases cancer-inducing UVB radiation.
- CH4 considered as GHG. However, in regions where background CH4 is dominating and concentrations of other VOCs are very low, CH4 contributes significantly to the formation of tropospheric ozone(**).
- How to evaluate the above two substances: As air pollutants, as GHG or both? The obvious scientifically answer is both since we have no way to prioritise air pollution over climate change or vice versa. Two options:

  Option a. To limit N2O and CH4 individually.
  Option b. N2O and CH4 for calculation of CO2e for potential GHG certification

(*) e.g. Ravishankara et al., 2009, Portmann et al., 2012

(**) e.g. Fiore et al. 2002, Isaksen et al. 2014, Dingenen et al. 2017

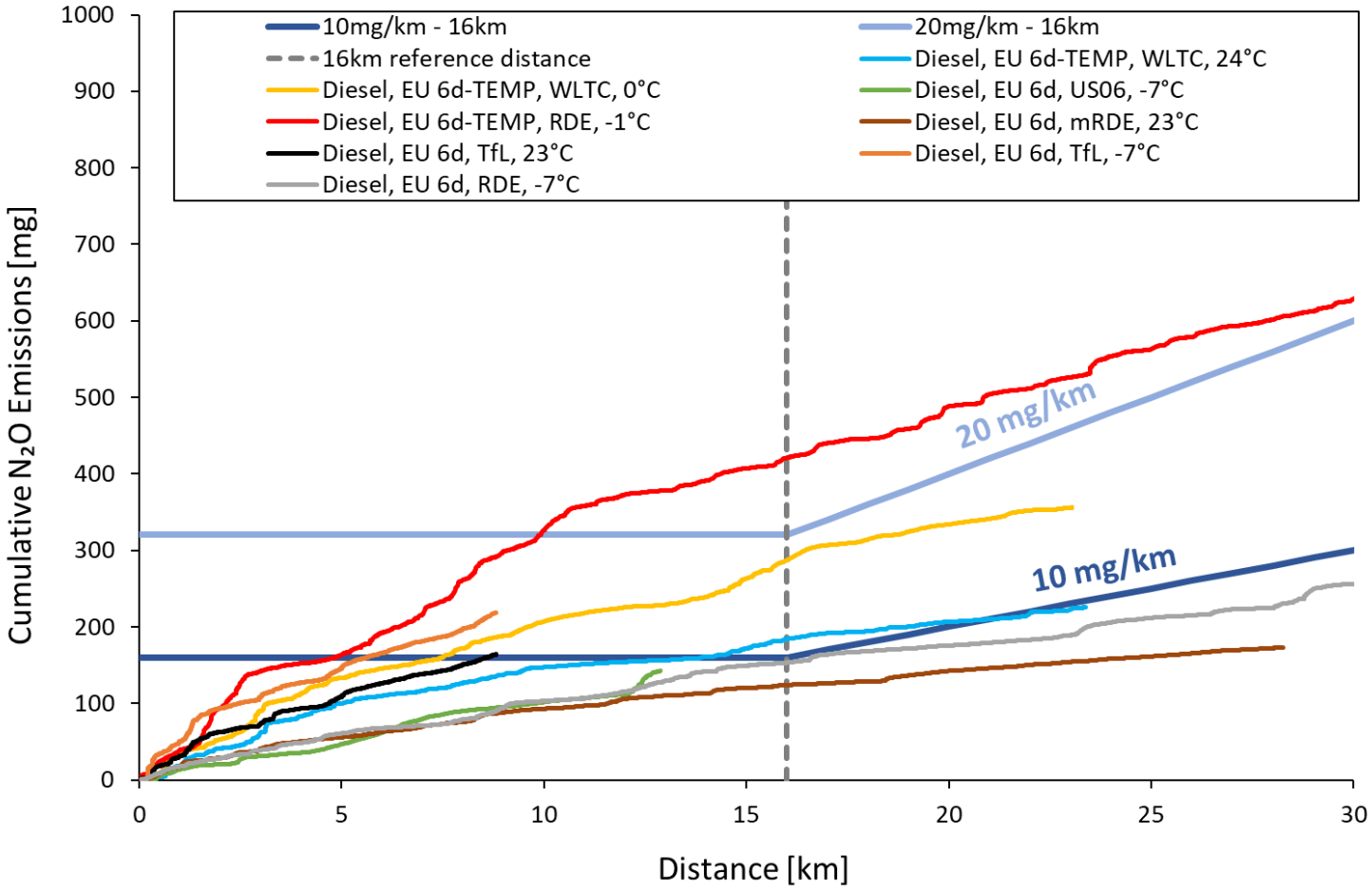
Options for N_2O and CH_4 emission limits

- Objectives for N_2O and CH_4 Euro 7 limits:
  - Both N_2O and CH_4 to be regulated as pollutants and not as GHGs
  - A cap to the emissions is needed to avoid high polluters currently identified in some cases

- Options for N_2O and CH_4 emission limit setting:
  - Either to apply the limit individually → Exact values per scenario in summary table
  - Or to add N_2O and CH_4 and use a combined limit. This combined limit could be lower than the sum of the above two, since it already provides the necessary room for adaptation from the OEMs, either for NG vehicles (CH_4 risk) or for diesel cars (N_2O risk)

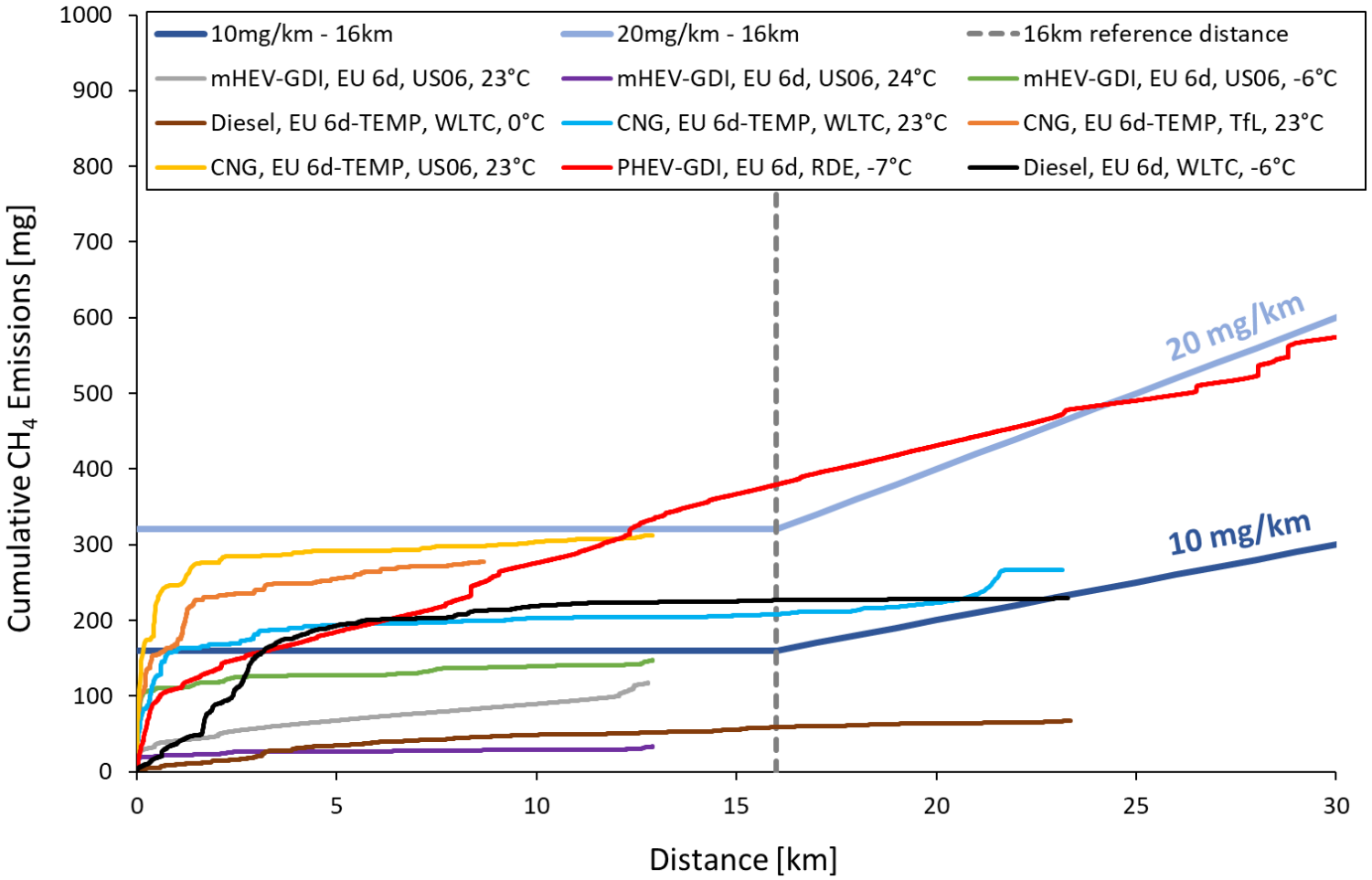
Emissions performance CLOVE database – N_2O

- Emissions performance of diesel vehicles over different test cycles and conditions (all within normal)



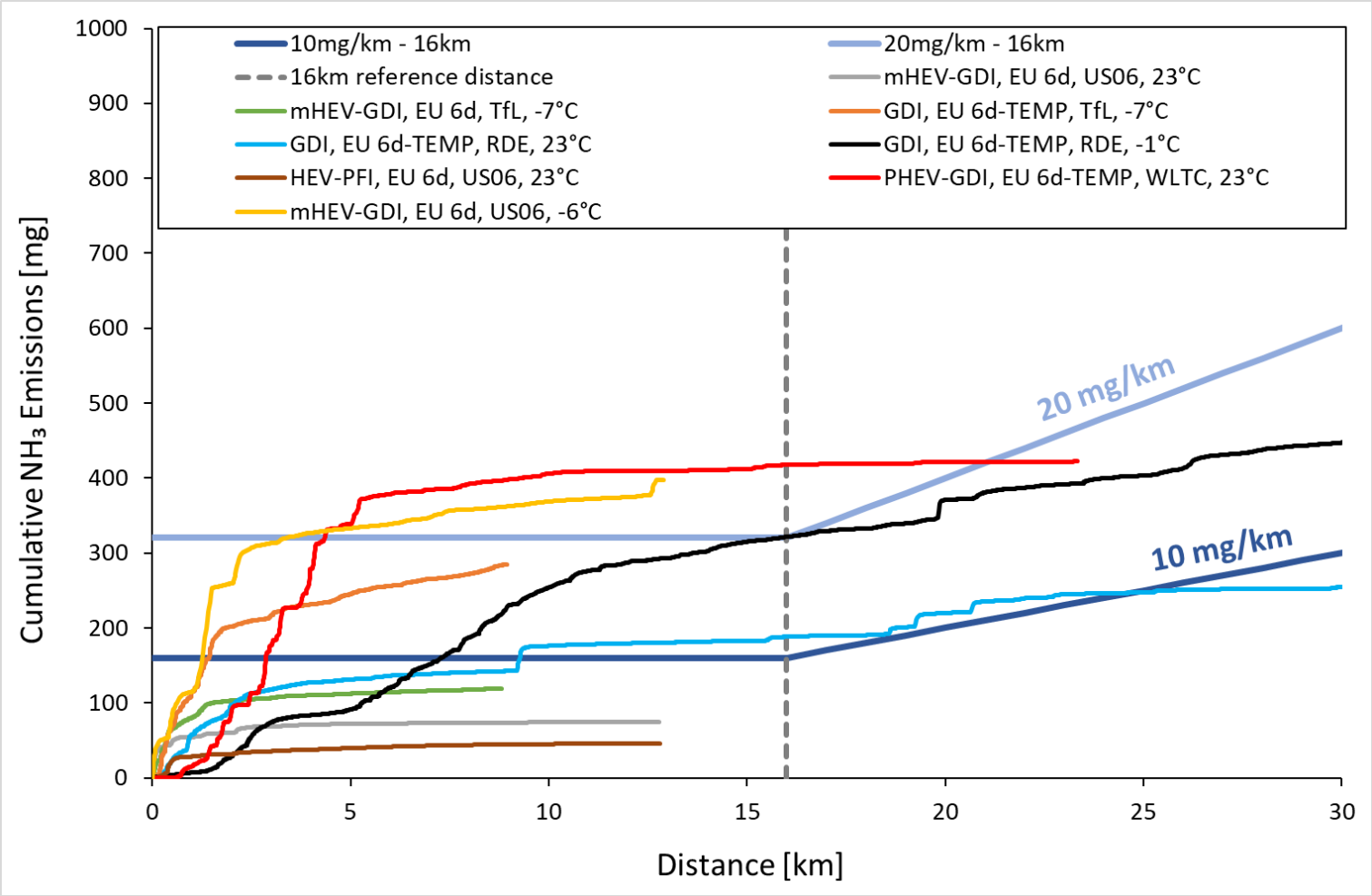
Emissions performance CLOVE database – CH_4

- Emissions performance of diesel, gasoline and CNG vehicles over different test cycles and conditions (all within normal)



Emissions performance CLOVE database – NH_3

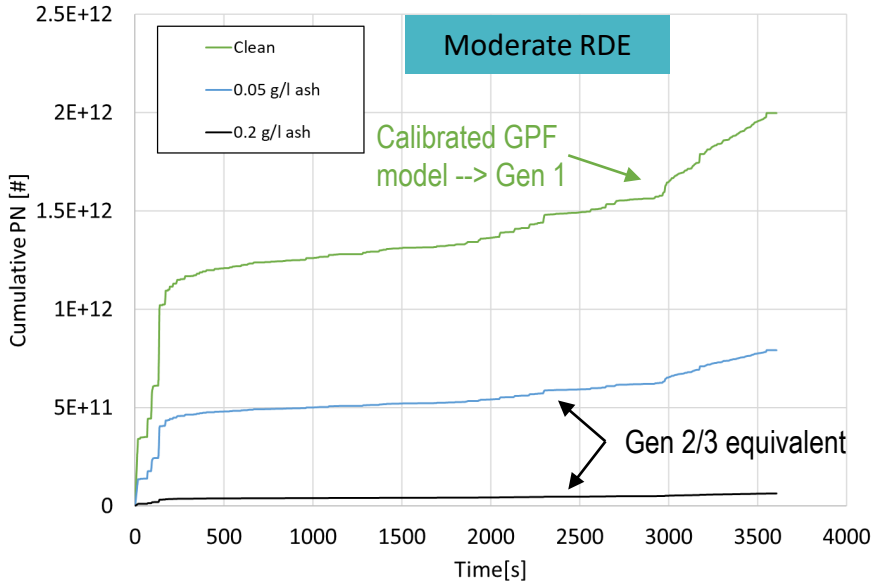
- Emissions performance of gasoline vehicles over different test cycles and conditions (all within normal)



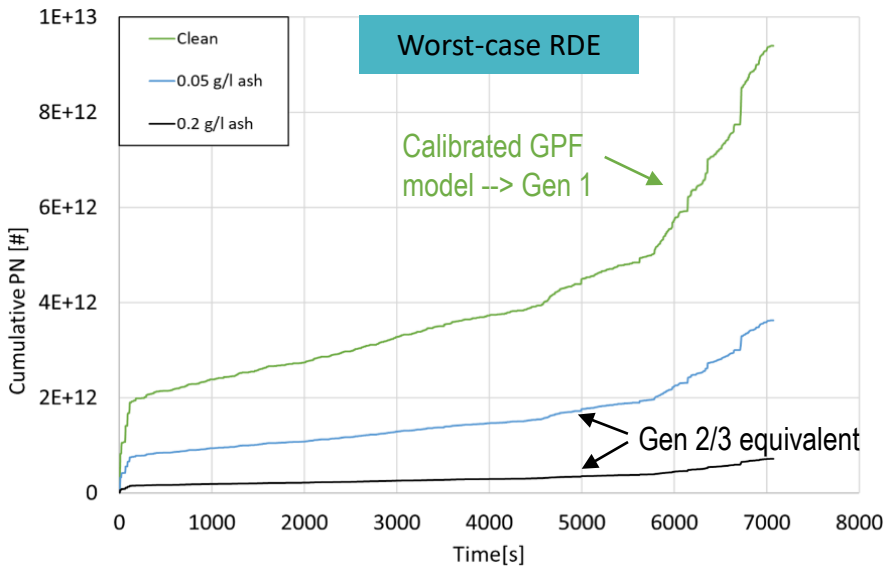
GPF filtration efficiency

GPF filtration efficiency

- Increased GPF filtration efficiency (in order to achieve proposed Euro 7 limits) can be achieved by:
  - New filter technology (new generation).
  - Accumulation of ash in the filter wall ("ashed" filter). "Negative deterioration" of filtration efficiency is expected due to continuous ash loading
- Results presented below refer to either different ash loadings or to 3 different filter technology generations



Ash state	PN emissions [p/km]
Clean	~4E+10
0.05g/l	~1.5E+10
0.2 g/l	~1.5E+09
Engine-out	1.6E+11



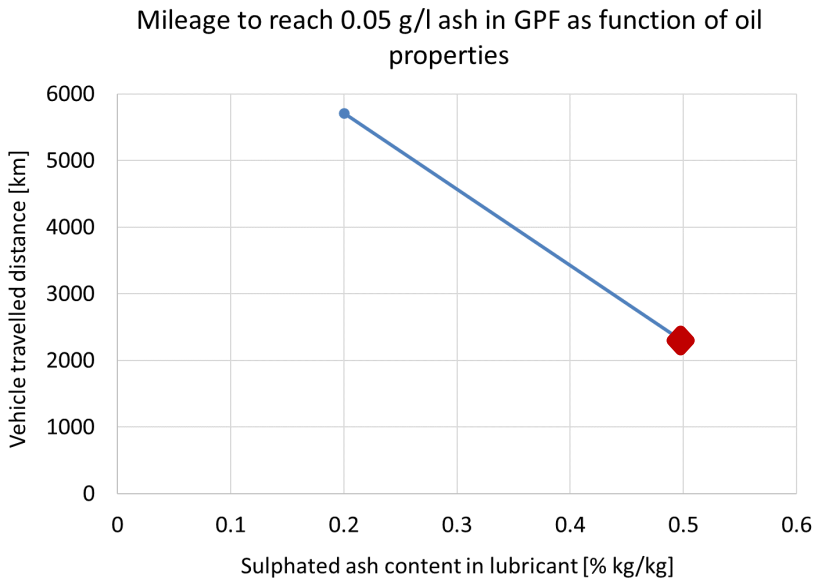
Ash state	PN emissions [p/km]
Clean	~9.4E+10
0.05g/l	~3.6E+10
0.2 g/l	~8E+09
Engine-out	2.5E+11

Simulations performed using
- FEV's simulation tools
- Exothermia suite

Ash accumulation with distance

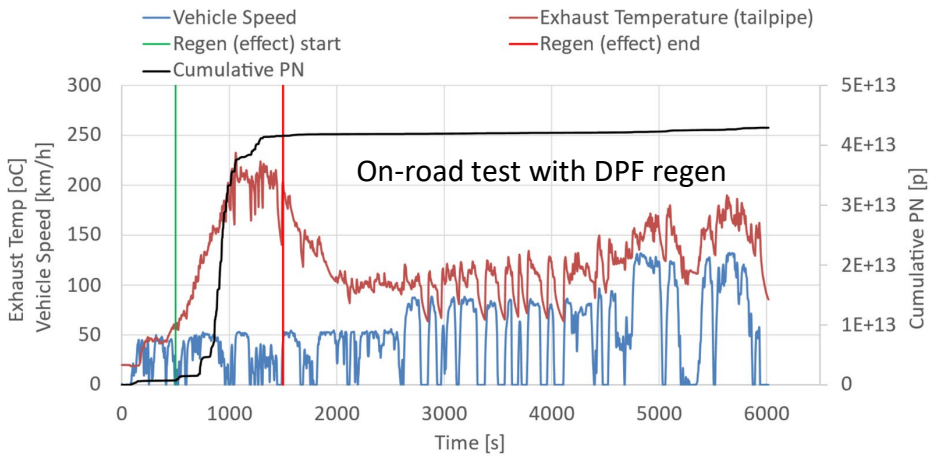
- Ash accumulation vs mileage is corelated based on engine oil consumption and oil ash content.
- Input data / assumptions:
  - Sulphated ash content of engine oil is 0.5% [kg/kg], as in ACEA European Oil Sequence 2016.
  - Engine oil consumption is 0.01 g/km. West et al. (SAE 2013-01-0884) suggest 0.015 to 0.09 g/km.
  - Ash recovery rate on GPF is 70%.
- This analysis indicates that accumulation of 0.05g/l of ash will be reached in less than 2500km.

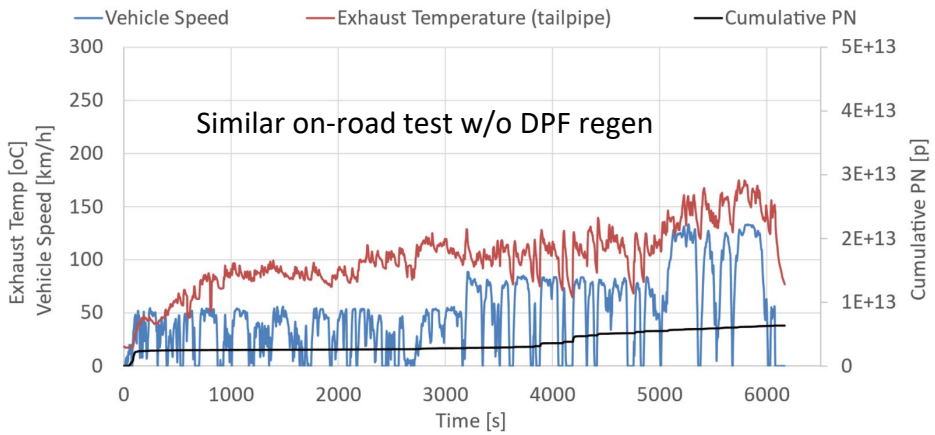
→ A minimum mileage of 3000km is proposed for Euro 7 valid testing



DPF Regeneration

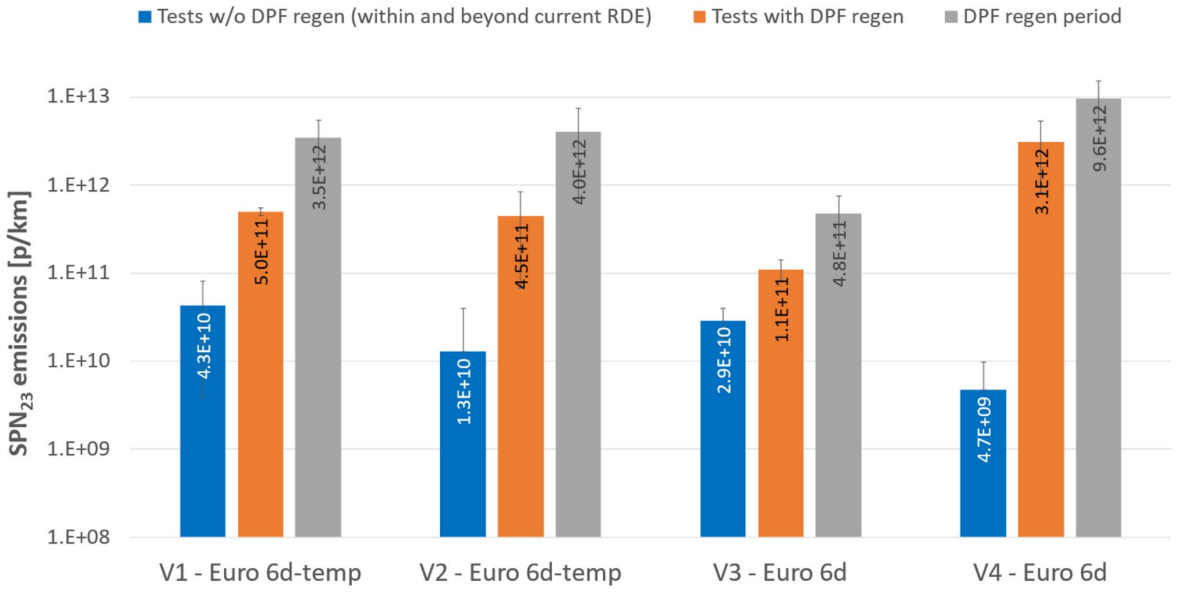
Current situation – findings from CLOVE database





Test/Phase	PN emissions [p/km]
Total test w/ DPF regen	5.4E+11
DPF regeneration period	4.9E+12
Total test w/o DPF regen	7.9E+10

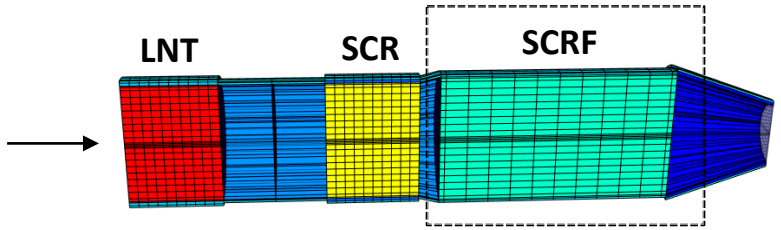
7:1

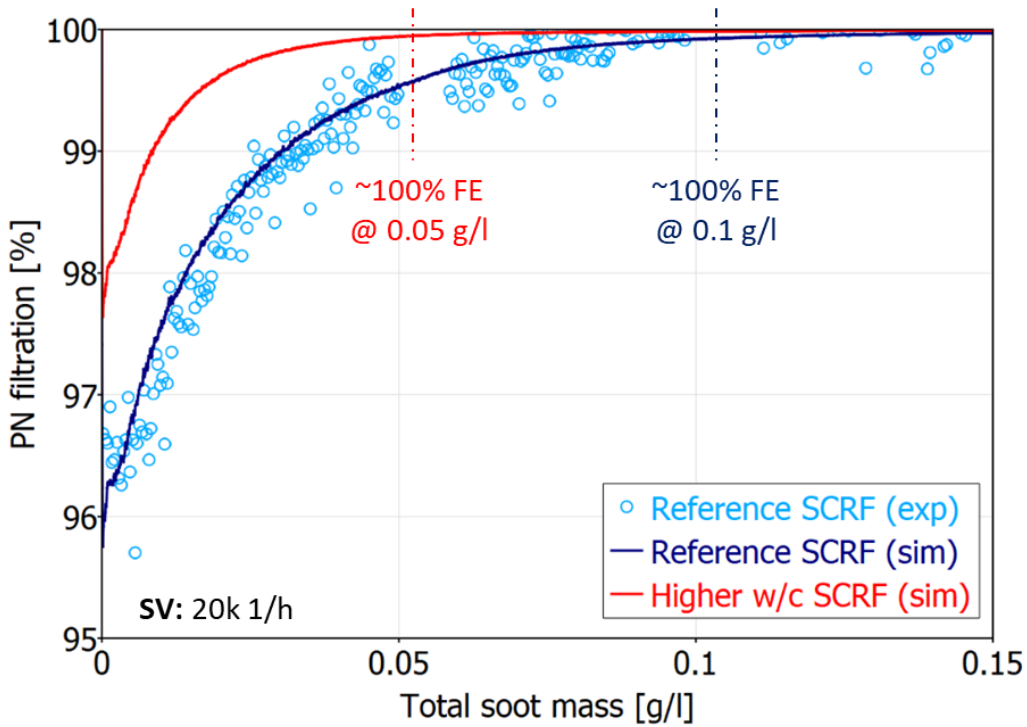


- Emissions on tests with DPF regeneration can be more than 2 orders of magnitude higher compared to tests without regen.
- Emissions during DPF regeneration period only are even higher
- Today these excess emissions are not covered by regulation
- Filtration efficiency of “clean” filters still an issue both in diesel (during and after regen) and GPF (passive regen)

Simulation exercise

- Assessment of tailpipe emissions over a cycle including DPF regeneration
- A reference SCRF and a higher washcoat SCRF are considered
- The reference SCRF FE is experimentally validated
- Input data: engine-out emissions (measurement) data over a WLTC test with regeneration



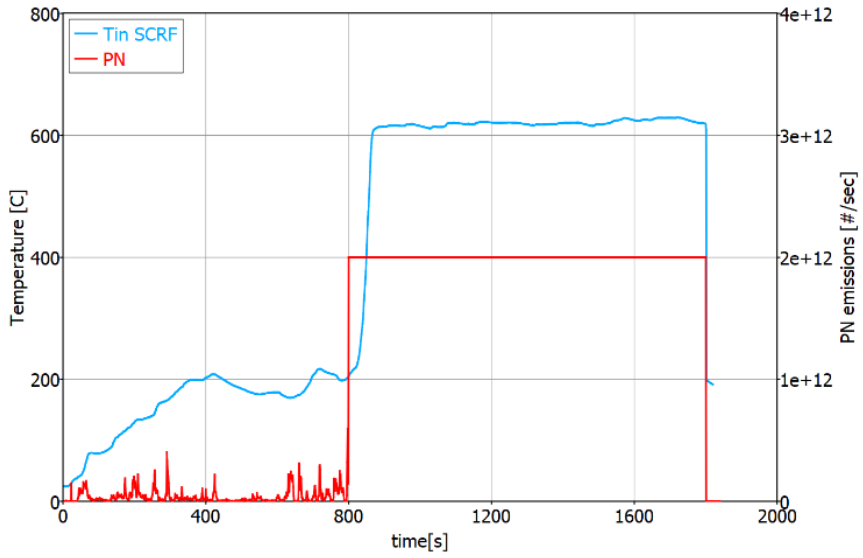


SCRF properties	Reference	Higher w/c
Volume [l]	3	
Washcoat loading [g/l]	90	>120
Substrate	Cordierite	
Wall structure	300cpsi/12mils	

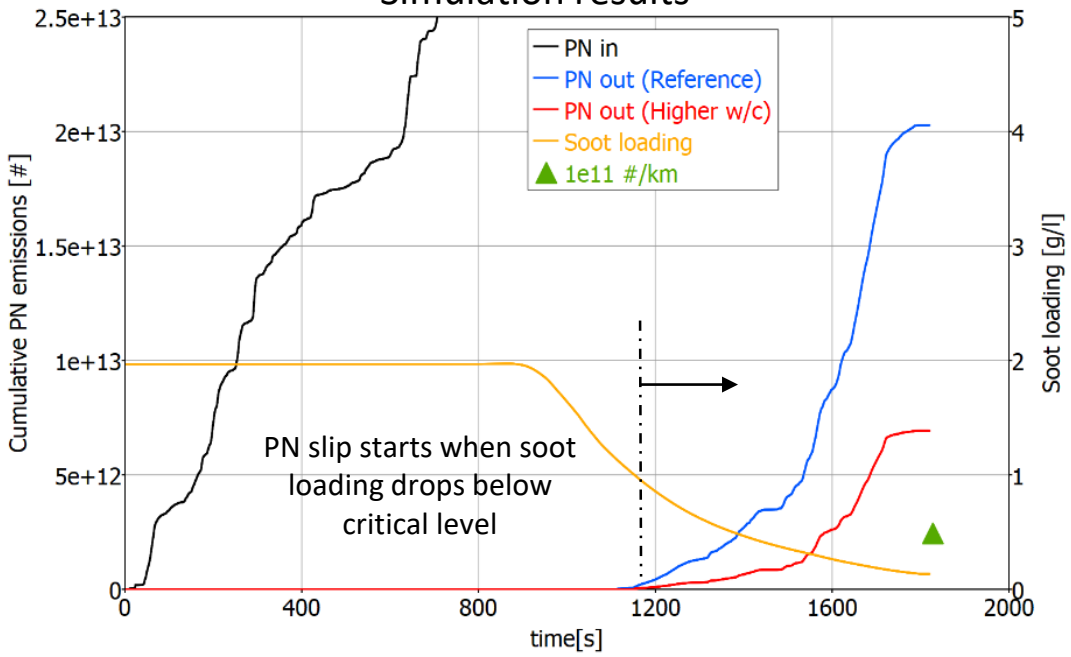
Simulations performed using Exothermia Suite

Simulation results

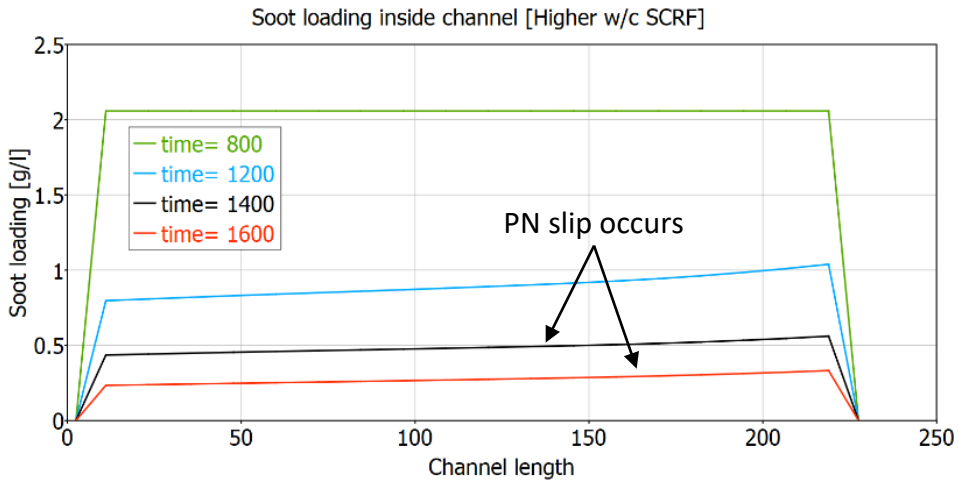
Scenario



Simulation results



- An active filter regeneration is (artificially) considered in WLTC cycle.
- T=600°C and 1000sec duration
- Increased EO PN emissions during regeneration.
- Simulation results with reference and higher washcoat SCRF

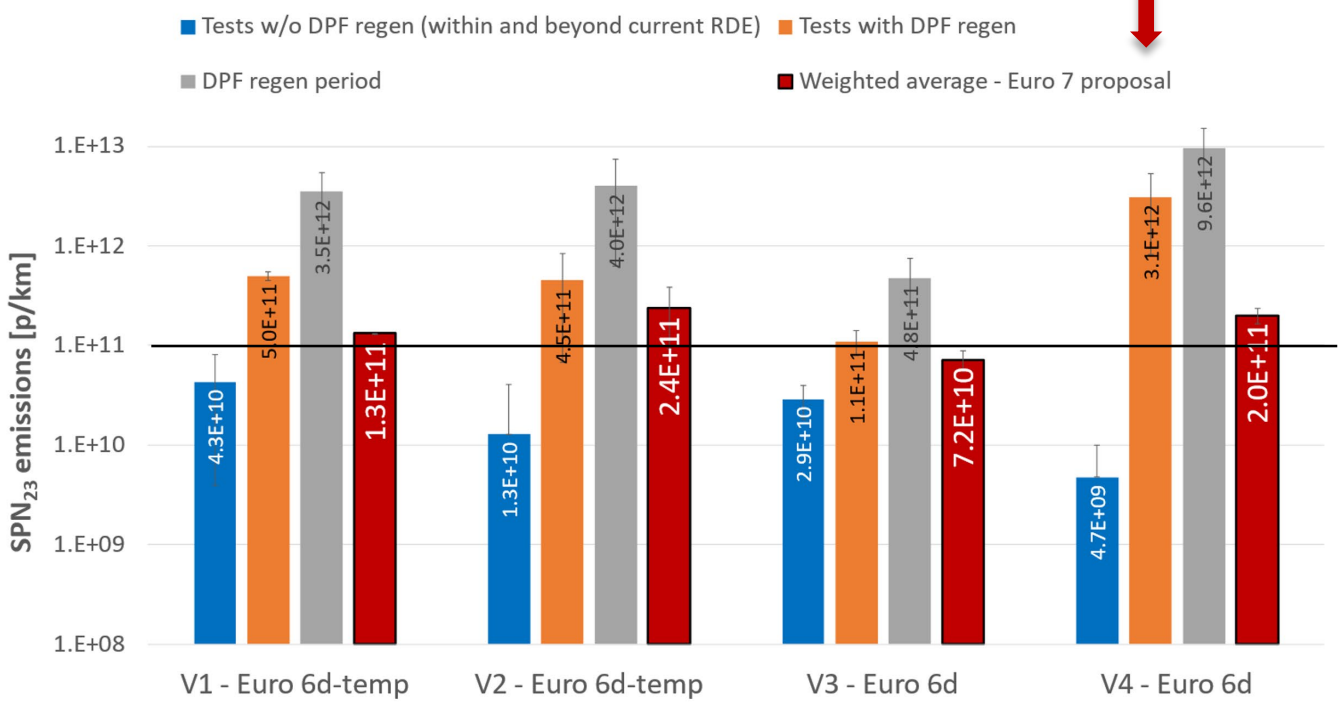


Inclusion of filter regeneration in Euro 7

- **Tests including a DPF regeneration are proposed to be valid tests in Euro 7**
- Extra PN emissions due to DPF regeneration will be considered based on regeneration interval. Proposed approach:
  - 2 tests: one including regeneration (full) and one without, >16 km each
  - Weighted average emissions:

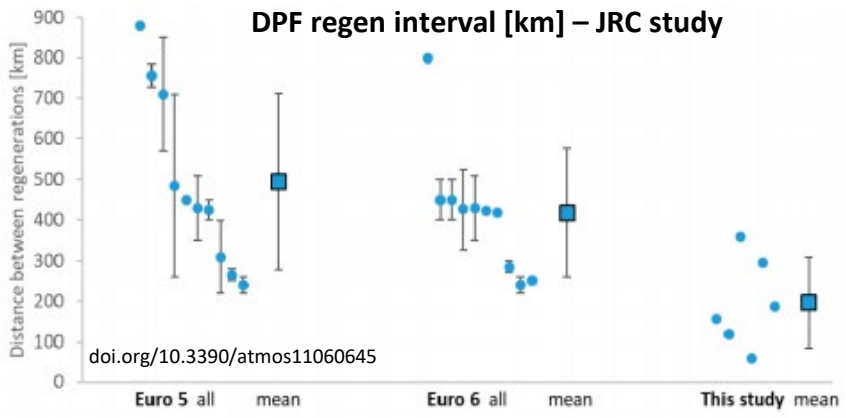
$$PN\left[\frac{p}{km}\right] = \frac{PN_{regen\_cycle}\left[\frac{p}{km}\right] * d_{regen\_cycle}[km] + PN_{w/o\_regen}\left[\frac{p}{km}\right] * (regen\_interval - d_{regen\_cycle})[km]}{regen\_interval\ [km]}$$

- Weighted average emissions of current vehicles in the range $7.2\times10^{10} – 2.4\times10^{11}$ p/km
- An improvement in DPF regeneration strategy and filtration efficiency of "clean" filters is needed in most cases to reach the target (1×10^{11} p/km)



DPF regeneration interval

- Determination of average regeneration interval (mileage from regeneration start till next regeneration start):
  - Derived by OBM system based on last ~10 regenerations
  - New vehicle start with a declared regeneration frequency from OEM. With every regeneration it will be updated
  - OEM shows to the tester regeneration start and end, as well as estimated end and estimated mileage until next regeneration start
  - Last 10 regenerations are stored in the ECU (vehicle mileage, duration of regeneration)
  - Average regeneration frequency could be easily checked by third party based on a data logger



CLOVE database vehicles	Regen interval [km]
V1 – Euro 6d-temp	440
V2 – Euro 6d-temp	200
V3 – Euro 6d	145
V4 – Euro 6d	400

Emissions limits for cars/vans for normal conditions of use

(All emission values for 160.000 km – further deterioration factors required for 240.000 km)

Pollutant	CO	NMOG	NO_x	PM	PN_{10}	NH_3	CH_4(*)	N_2O(*)	HCHO
Unit	mg/km	mg/km	mg/km	mg/km	#/km	mg/km	mg/km	mg/km	mg/km
Scenario 1									
Cars with and Vans	400	45	30	2	1×10^{11}	10	**20**	**20**	5
Vans with TPMLM>2500 kg & PWR<35 kW/t	600	45	45	2	1×10^{11}	10	**20**	**30**	**10**
Scenario 2									
Cars and Vans	400	25	20	2	1×10^{11}	10	10	10	5
	600	25	30	2	1×10^{11}	10	10	**15**	**10**

(*) Or a combined N2O + CH4 < sum of the proposed individual limits

Strengthening MIL (TCI)

AGVES 27 April 2021

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Developments: terminology TCI withdrawn

- The concept of TCI (Testing Conformity Indicator) was meant to express that new functionalities would be added to the MIL; new functionalities linked to readiness of a vehicle for ISC RDE testing
- However, the concept and its terminology caused confusion
- The terminology will be changed to the basic objective of the concept:

strengthening MIL functionality

Current situation

- Valid ISC RDE testing requires a vehicle to be in a proper state.

(2018/1832) Diagnosis of faults and any normal maintenance necessary in accordance with Appendix 1 shall be performed on vehicles accepted for testing, prior to or after proceeding with ISC testing. The following checks shall be carried out: OBD checks (performed before or after the test), visual checks for lit malfunction indicator lamps, checks on air filter, all drive belts, all fluid levels, radiator and fuel filler cap, all vacuum and fuel system hoses and electrical wiring related to the after-treatment system for integrity; checks on ignition, fuel metering and pollution control device components for maladjustments and/or tampering.

- Checks prior to a test require a (detectable) link to the OBD system, after procurement. Checks afterwards may invalidate test and increase test burden.
- Currently, even after repair/maintenance, fault codes still remain within the system and may disqualify vehicles from ISC testing.
- Currently no system in place to enforce repairs of high emitting vehicles.

Proposal: strengthen MIL functionality

- If MIL light is not activated and no problems are detected during visual inspection, the vehicle is deemed to be in a proper state for ISC RDE testing

If MIL is <u>not</u> activated, and checks and assessments have been performed properly, OEM will be accounted fully responsible for the test results

- Emissions related MIL activation requires driver/owner to undertake repair/maintenance. If no response within reasonable period, inducement will be activated (similarity with SCR/AdBlue inducement)

- MIL functionalities will be expanded with additional checks of the state of the vehicle and (a link to) an inducement system

Proposal: strengthen MIL functionality (2)

- Visual inspection and interview is still needed
  - Aerodynamic modifications that significantly influence driving resistance (e.g. roof racks and roof boxes) – testing will be assumed to be under extended conditions
  - Leaks in the exhaust line during PEMS measurement – repair before testing
  - Vehicle is adapted beyond its original state as described by the documentation (e.g. CoC) – correct before testing (e.g. replace tyres/rims)
  - Clear visual indications that the vehicle is not in a proper state of road worthiness – exclude from testing

- The vehicle selection criteria in 2018/1832 Annex II (point 5.7 and its appendix 1) will be simplified by removing all items that can be detected by the vehicle.
  - MIL should cover also events like mis-fuelling, racing, unauthorised repair, tuning/illegal software/manipulation/tampering/… After proper repair MIL shall be reset.

Additional feature: log functionality

- To support the assessment of the test specific information during the trip relevant for emissions performance will have to be logged (temporarily or permanently). E.g.
  - extended conditions occurring during test
  - regeneration events
  - vehicle in process of coming to malfunctioning decision in the case of OBM
  - …

FUEL EVAPORATION

Background (non-fuel) evap emissions

Sources

- Non-fuel hydrocarbon emissions from plastics, rubber and other polymers
- Found in tires, carpets, seats, paints, adhesives, etc.

Emission levels

- Usually highest with newly manufactured vehicles, but decrease relatively quickly over time
- Emission levels in the order of 0.2 – 0.3 g/day for a typical passenger car
- Generally higher for larger vehicles

Euro 7 evap limits

	PCs and LCVs < 2.5t TPMLM (N1 class I-II)	LCVs > 2.5t TPMLM (N1 class III)
Diurnal emissions limit	0.50 g/day (48 h test, worst of 2 days)	0.70 g/day (48 h test, worst of 2 days)
	0.30 g/day (48 h test, worst of 2 days)	0.50 g/day (48 h test, worst of 2 days)
Refuelling emissions (ORVR)	0.05 g/L	
Leak threshold	0.5 mm (~0.02 inch) diameter	

Testing conditions

	Testing conditions	Comments
Preconditioning	• Reduce drive time • Soak and drive temperature between 25 and 38°C	• Enforce more frequent purging • Exact temperature not defined to prevent tuning of purging strategy
SHED test	• 48-h diurnal test (+hot soak) remains as is	• Emission limit applies to worst of two days (+hot soak)
Running losses	• No test and hence no limit during certification	• Running losses effectively controlled by the technology used to achieve lower diurnal emissions
ISC and MaS	• Diurnal emissions (and indirectly also running losses) checked during ISC and MaS	
OBD leak detection	• Checked during PTI, ISC, MaS	
Background emissions	• Baking of entire vehicle or of individual components	• SHED test run with used tyres

On behalf of the CLOVE consortium: **Thank you!**