



HDV EU Regulation

Testing within Euro VI regulation

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Legislative Framework

- Control of the exhaust pollutant emissions of vehicles/engines under normal operational use
- Provide a legal framework that incentivise innovation and technological development:
 - Vehicle/engines/pollution control devices
 - Analytical instrumentations (PEMS)

Legislative Framework

- The so-called Euro VI emission standards are defined in Regulation (EC) No 595/2009 and the implementing Regulation (EC) 582/2011. They have become effective in 2013 for new type approvals and for all registrations in January 2014.
- Euro VI introduces a procedure for PEMS testing as a mandatory part of the type approval legislation in order to check the conformity of heavy-duty engines with the applicable emissions certification standards during the normal life of those engines: this is the so-called “In Service Conformity” (ISC) requirements.

EURO VI Emission Limits

	Limit values							
	CO (mg/kWh)	THC (mg/kWh)	NMHC (mg/kWh)	CH ₄ (mg/kWh)	NO _x ⁽¹⁾ (mg/kWh)	NH ₃ (ppm)	PM mass (mg/kWh)	PM number (#/kWh)
WHSC (CI)	1 500	130			400	10	10	8,0 × 10 ¹¹
WHTC (CI)	4 000	160			460	10	10	6,0 × 10 ¹¹
WHTC (PI)	4 000		160	500	460	10	10	⁽²⁾ 6,0 × 10 ¹¹

Note:

PI = Positive Ignition.

CI = Compression Ignition.

⁽¹⁾ The admissible level of NO₂ component in the NO_x limit value may be determined at a later stage.

⁽²⁾ The limit value shall apply as from the dates set out in row B of Table 1 of Appendix 9 of Annex I to Regulation (EU) No 582/2011.¹

EURO VI (revisions)

Character	NO _x OTL ⁽¹⁾	PM OTL ⁽²⁾	CO OTL ⁽³⁾	IUPR ⁽⁴⁾	Reagent quality	Additional OBD monitors ⁽⁵⁾	Power threshold requirements ⁽⁶⁾	Cold start and PM number	Implementation dates: new types	Implementation dates: all vehicles	Last date of registration
A ⁽⁷⁾ B ⁽⁸⁾	Row "phase-in period" of Table 1 or Table 2	Performance Monitoring ⁽⁹⁾	(N/A)	Phase-in ⁽¹⁰⁾	Phase-in ⁽¹¹⁾	(N/A)	20 %	(N/A)	31.12.2012	31.12.2013	31.8.2015 ⁽⁷⁾ 30.12.2016 ⁽⁸⁾
B ⁽¹²⁾	Row "phase-in period" of Tables 1 and 2	(N/A)	Row "phase-in period" of Table 2	(N/A)	Phase-in ⁽¹¹⁾	(N/A)	20 %	(N/A)	1.9.2014	1.9.2015	30.12.2016
C	Row "general requirements" of Table 1 or Table 2	Row "general requirements" of Table 1	Row "general requirements" of Table 2	General ⁽¹³⁾	General ⁽¹⁴⁾	Yes	20 %	(N/A)	31.12.2015	31.12.2016	31.8.2019
D	Row "general requirements" of Table 1 or Table 2	Row "general requirements" of Table 1	Row "general requirements" of Table 2	General ⁽¹³⁾	General ⁽¹⁴⁾	Yes	10 %	(N/A)	1.9.2018	1.9.2019	31.12.2021
E	Row "general requirements" of Table 1 or Table 2	Row "general requirements" of Table 1	Row "general requirements" of Table 2	General ⁽¹³⁾	General ⁽¹⁴⁾	Yes	10 %	Yes	1.1.2021 ⁽¹⁵⁾	1.1.2022 ⁽¹⁵⁾	

HDV - In-service conformity (ISC) testing

- In-service conformity testing – one of the cornerstones of the EU HDV type-approval framework
- A PEMS demonstration (“ISC”) test shall be performed at type-approval (limit off-cycle emissions)
- Purpose: verification of the performance of engine and emission control systems over their useful lifetime
- After TA of an engine family the manufacturer shall perform ISC testing on this engine family within 18 months from first registration of a vehicle fitted with an engine from that family (in service for at least 25,000 km).
- ISC is repeated at least every 2 years for each engine family periodically on vehicles over their useful life period.

EURO VI (D & E) - ISC

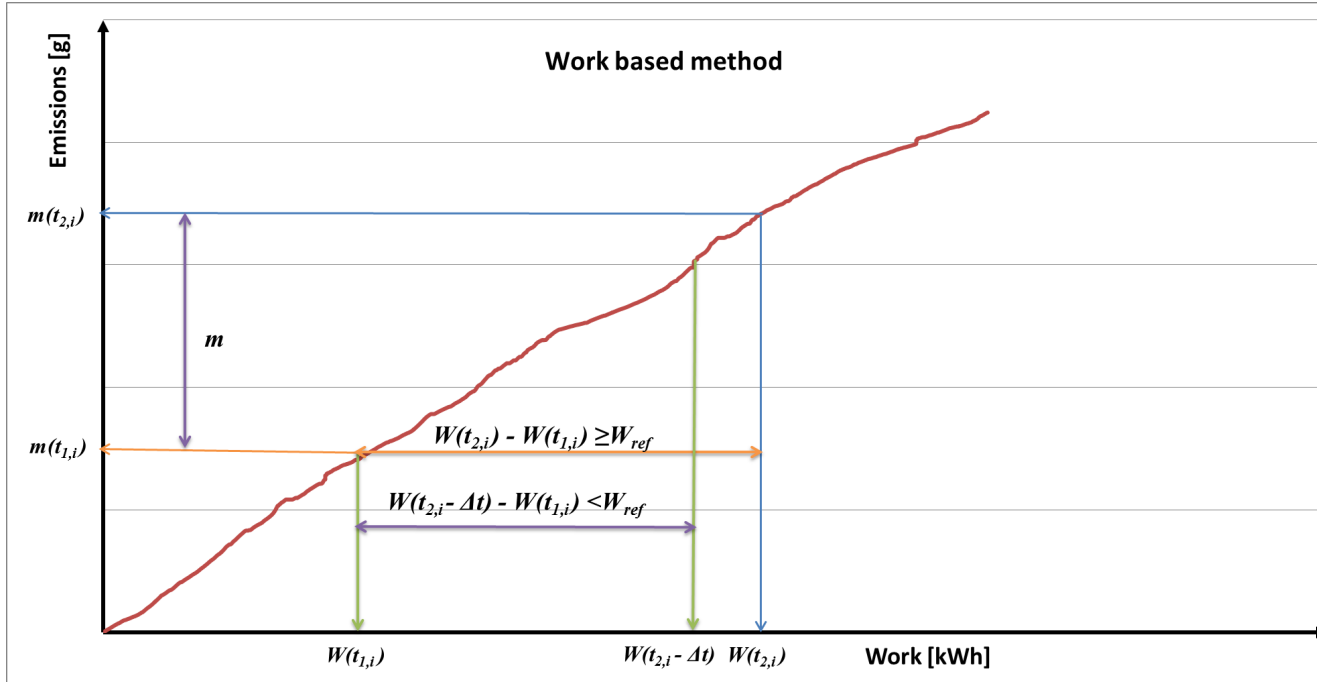
- **Euro VI D - ISC**

- Payload between 10 and 100 % of the max.
- Trip composition:
 - geographical coordinates
 - first acceleration method
- Average speeds in U/R/M (strict)
- The test duration: 4-8 WHTC Work or 4-8 CO₂ (kg/cycle) from WHTC
- $T_{\text{coolant}} \leq 303 \text{ K (30 °C)}$ at the beginning of test.
- Valid windows: windows $P_{\text{average}} \geq 10 \% P_{\text{max}}$ of the engine.
- One full valid window in the urban operation.

- **Euro VI E:**

- Euro VI D and ...
- Introduction in ISC of
 - Cold Start
 - PN
- AES Documentation Package
 - a full description of the inducement system
 - description of the anti-tampering measures considered
 - Declaration from manufacturers that vehicle is free of any defeat device

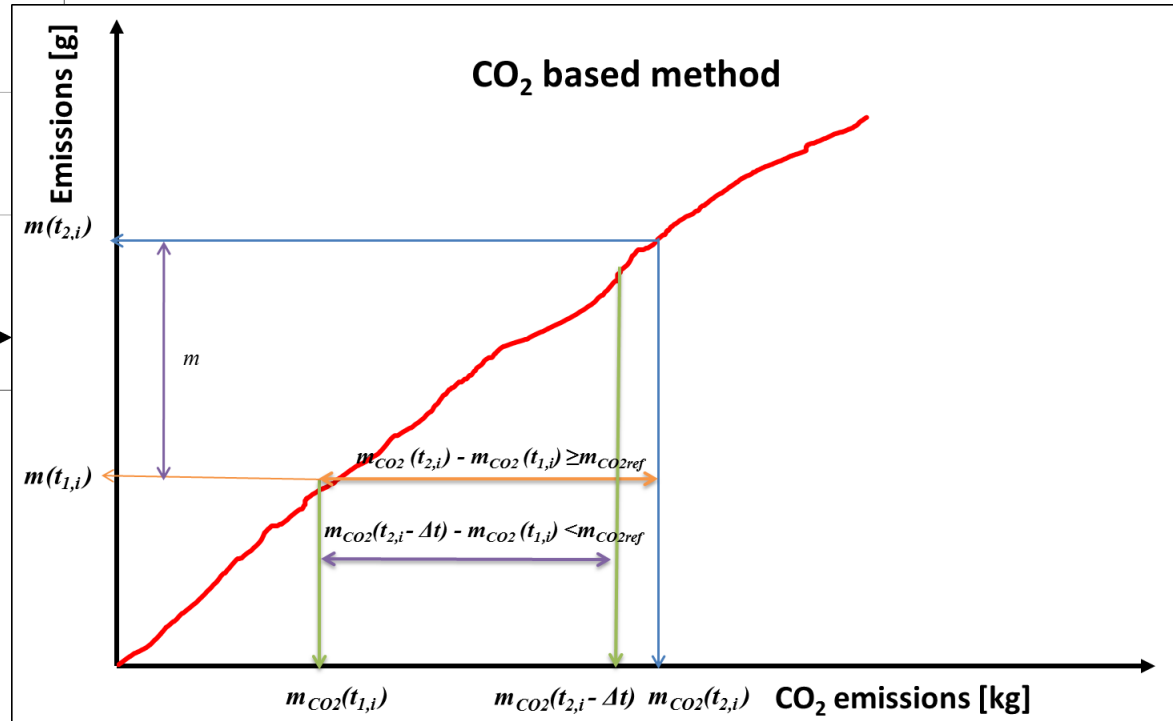
EURO VI (D & E) – ISC Methodology



$$CF = \frac{CF_I}{CF_C} \rightarrow CF_I = \frac{m}{m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i})} \quad (\text{in service ratio})$$

$$\rightarrow CF_C = \frac{m_L}{m_{CO_2,ref}} \quad (\text{certification ratio})$$

- Valid windows = windows whose duration $\leq D_{max}$ $D_{max} = 3600 \cdot \frac{W_{ref}}{0.1 \cdot P_{max}}$
- Percentage of valid windows shall $\geq 50\%$



$$e_{gas} = \frac{m}{W(t_{2,i}) - W(t_{1,i})}$$

$$CF = \frac{e}{L}$$

- e is the brake-specific emission of the component, g/kWh;
- L is the applicable limit, g/kWh.

- Valid windows = windows whose $\langle P \rangle \geq 10\% P_{max}$
- Percentage of valid windows shall $\geq 50\%$

EURO VI (D & E) – ISC Methodology

- The result of the test shall give sufficient confidence that the engines - if extracted from the vehicle – would comply with the applicable emissions limits on the type approval transient cycle (WHTC)
- The conformity factor (CF) of the ISC test is the 90th cumulative percentile of all the valid window's CF
- If
 - $CF_{\text{test}} \leq 1.5$ (gaseous pollutants)
 - $CF_{\text{test}} \leq 1.63$ (for PN and Euro VI E)

then Pass

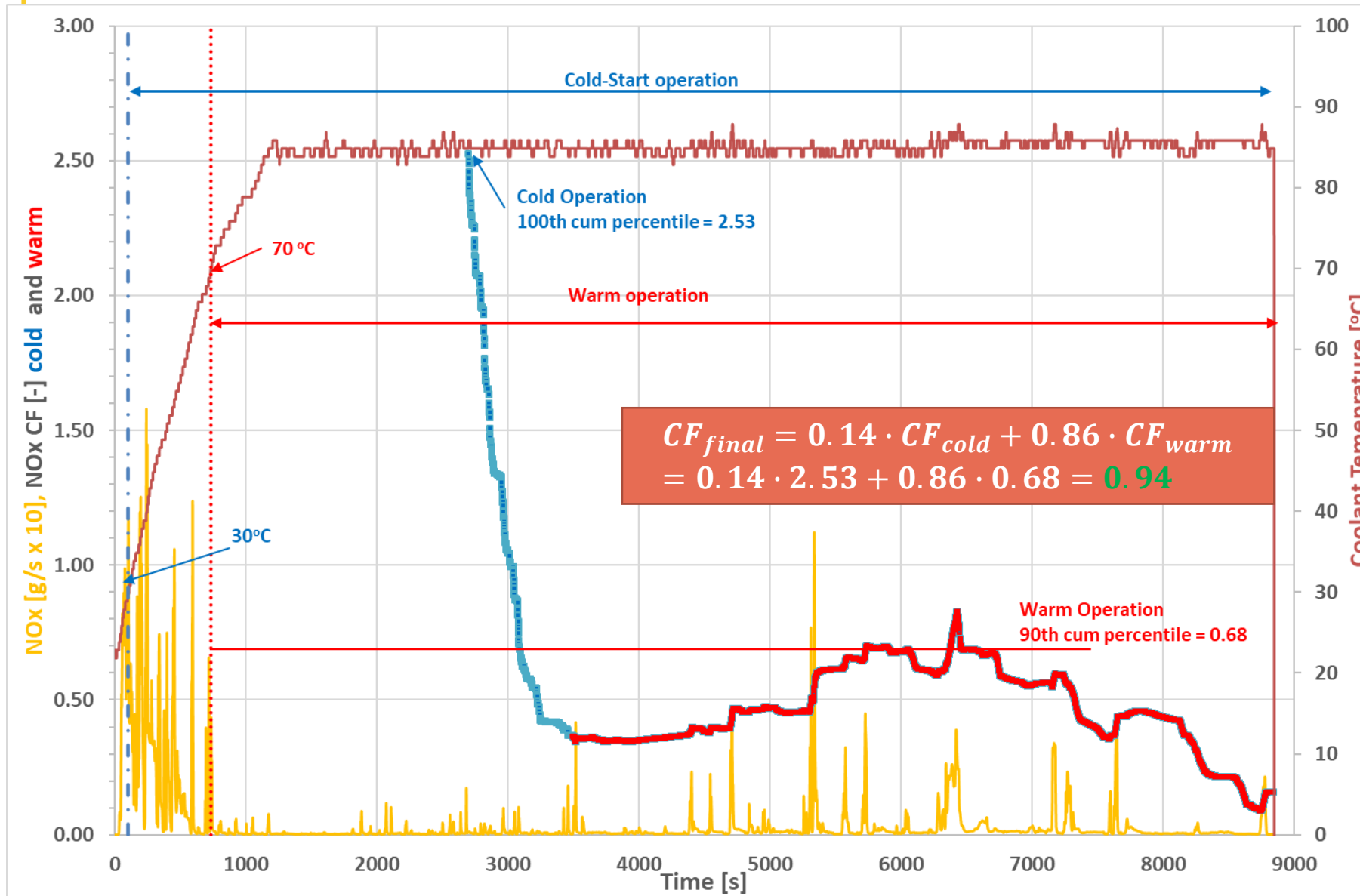
EURO VI E – ISC: Cold Start Introduction

- The final conformity factor for the test (CF_{final}) for each pollutant is calculated similarly as in the WHTC :

$$CF_{final} = 0.14 \cdot CF_{cold} + 0.86 \cdot CF_{warm}$$

- CF_{cold} is the conformity factor of the period of cold operation of the test, which shall be equal to the highest conformity factor of the moving averaging windows starting below 343 K (70 °C).
- CF_{warm} is the conformity factor of the period of warm operation of the test, which shall be equal to the 90th cumulative percentile of the conformity factors when the data evaluation is started after the coolant temperature has reached 343 K (70 °C) for the first time.

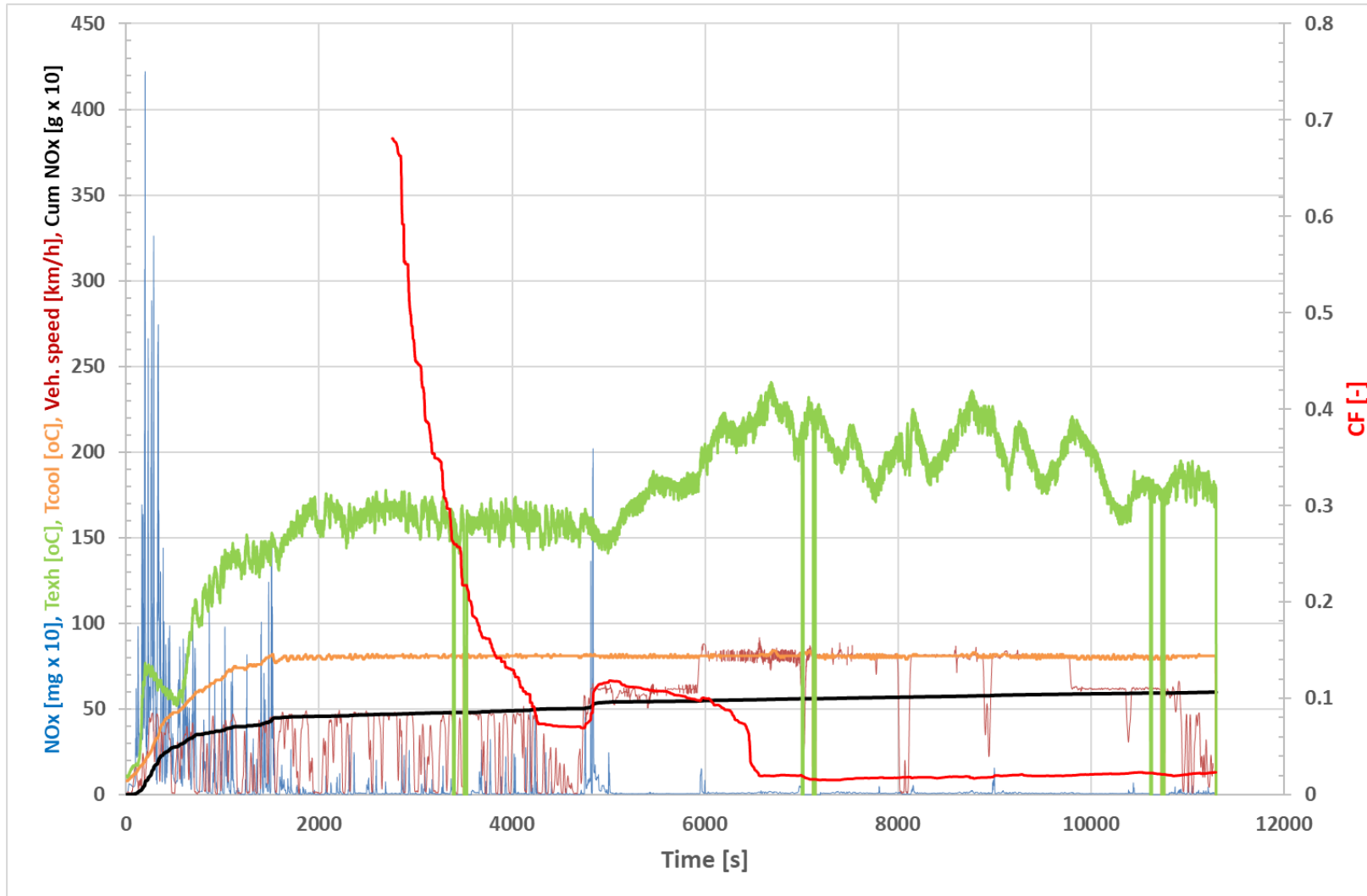
Cold-start in Euro VI E



N2 vehicle

- P = 184 kW
- Ref. work = 16.5 kWh

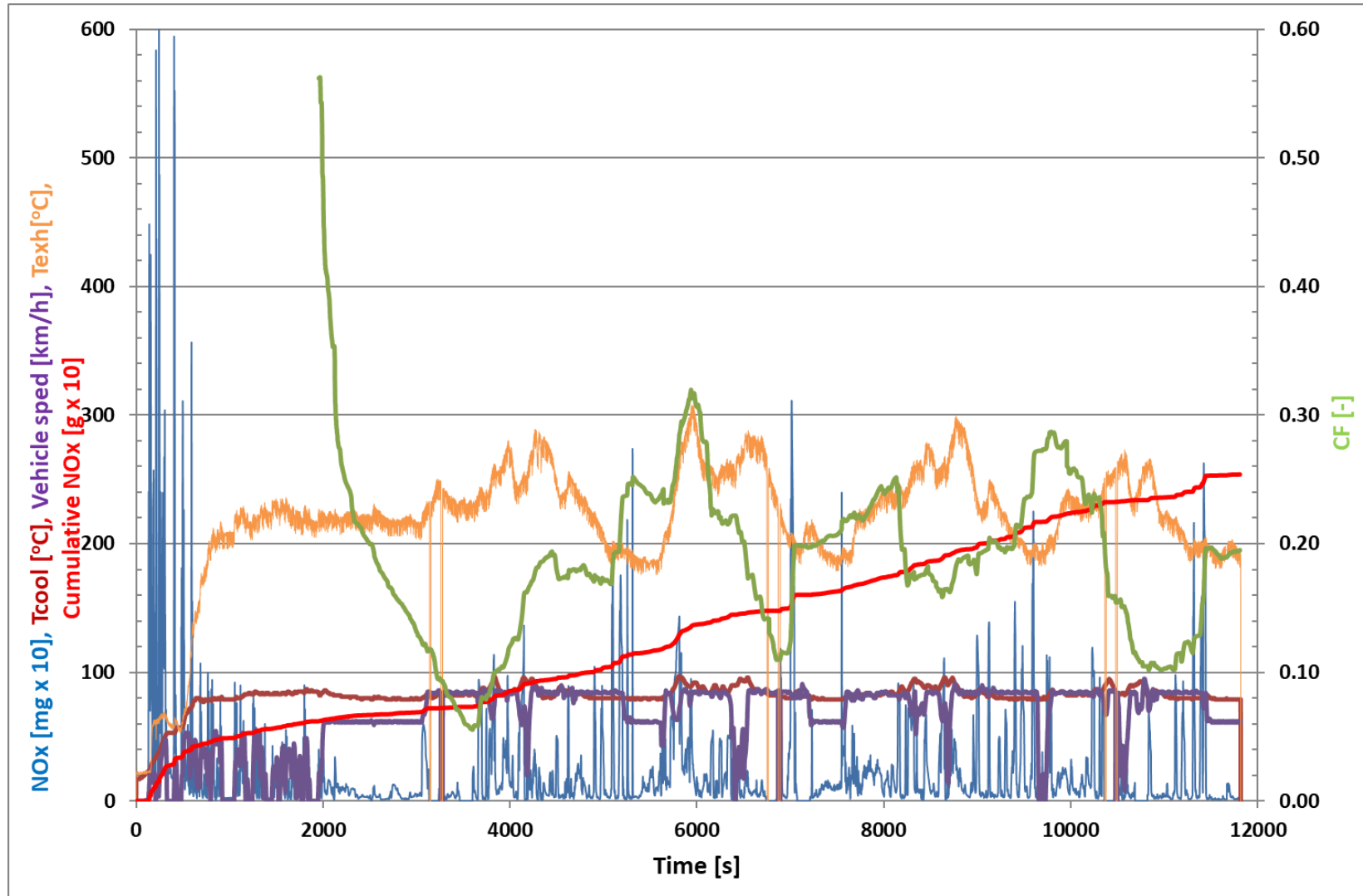
Effects of Euro VI (1)



N2: P = 170 kW
 Data processed without
 exclusions (i.e. cold-start is
 included)

Reference Quantity		Work
Reference Value	kWh	15.00
Threshold	%	10.00
Trip CO2 / WHTC CO2	[4-8]	5.90
Number of urban windows	>1	2012.00
Window Min. Power / Max. Duration	%/s	10.52
Window Max. Power / Min. Duration	%/s	30.33
Total number of windows		8537.00
Number of valid windows		8537.00
Percentage of valid windows	%	100.00
NOx_AVG	-	0.08
NOx_MIN	-	0.02
NOx_MAX	-	0.68
NOx_90% CUMULATIVE PERCENTILE	-	0.18

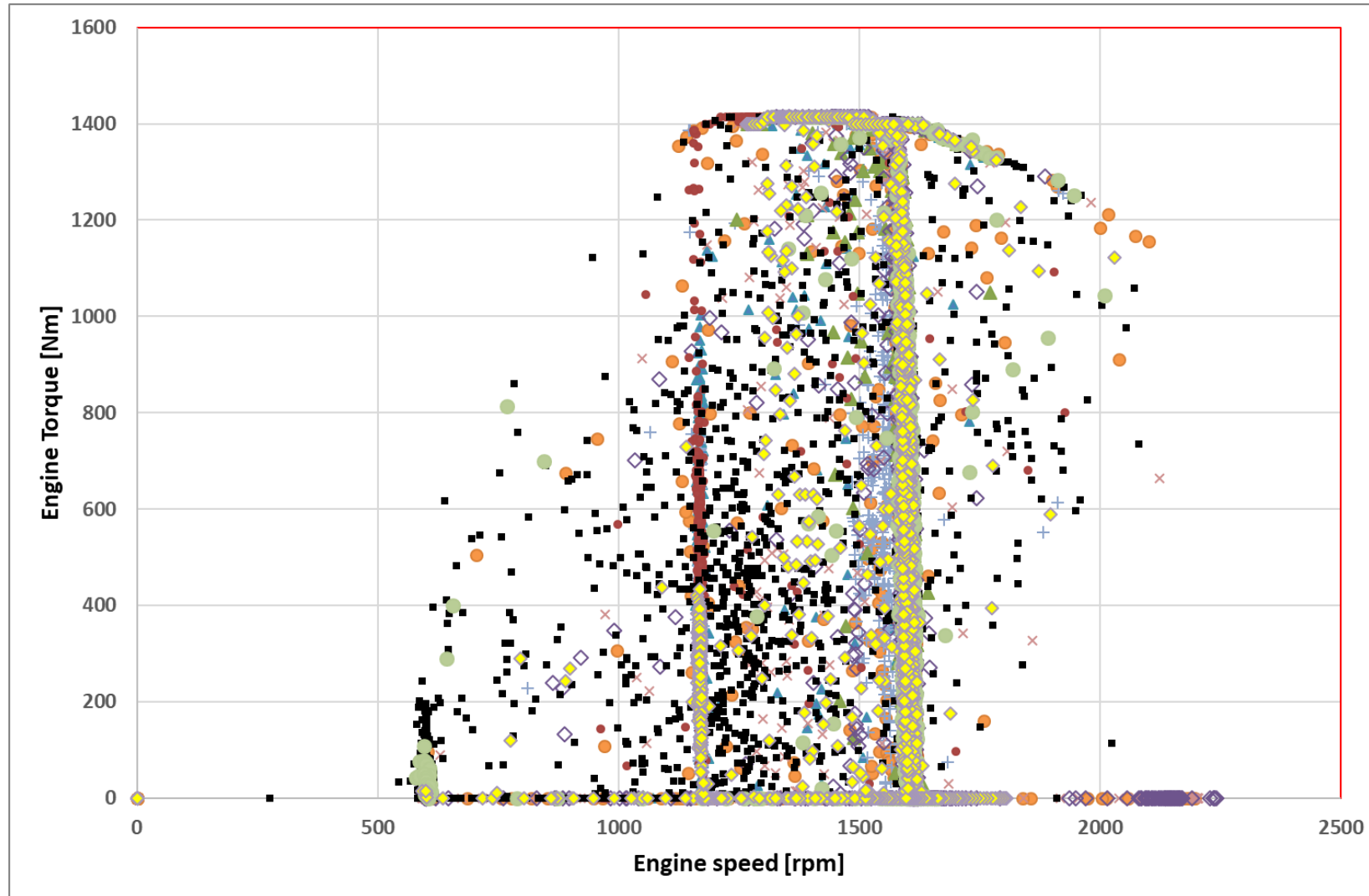
Effects of Euro VI (2)



Data processed without exclusions (i.e. cold-start is included)
N3: P = 260 kW

Reference Quantity		WORK
Reference Value	kWh	24.00
Threshold	%	10.00
Trip work / WHTC work	[4 - 7]	10.31
Number of urban windows	>1	41.00
Window Min. Power	%	17.27
Window Max. Power	%	51.46
Total number of windows		9855.00
Number of valid windows		9855.00
Percentage of valid windows	%	100.00
NOx_AVG	-	0.19
NOx_MIN	-	0.06
NOx_MAX	-	0.56
NOx_90% CUMULATIVE PERCENTILE	-	0.26

Explanation - Why



ISC tests a good
coverture of the
possible engine
operations

Summary

- There is a net improvement in the behaviour of EURO VI HDV as far as pollutant emissions is concerned.
 - Available data show significant drop of emission levels compared to EURO V/EEV[‡]
NO_x: -80% to -90%; PM and PN: <-90% ⁽¹⁾
 - It has led to a significant improvement of the real-world emission performance of Euro-VI trucks and buses ⁽²⁾.
 - Euro VI heavy-duty trucks and buses emit closer to certification limits (1–1.5×emission limits) than those certified to Euro IV (1.3–2.2×) and Euro V (1.9–3.9×) standards⁽³⁾.
- In-service conformity testing – remains the cornerstone of the type-approval framework
- The inclusion of cold-start and PN measurement in the ISC will further improve the behaviour of EURO VI HDV

[‡] “Enhanced Environmentally friendly Vehicle”.

⁽¹⁾ 11th Integer Emission Summit & AdBlue Forum-Europe 2015

⁽²⁾ 12th Integer Emission Summit & AdBlue Forum-Europe 2016

⁽³⁾ Anenberg, S. C., et al. (2017). "Impacts and mitigation of excess diesel-related NO_x emissions in 11 major vehicle markets." Nature 545(7655): 467-471.

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Thank you



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