Overview of Emissions on World-Harmonised and Non-road Cycles from the AECC Euro VI Programme

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on Heavy-duty Engine Emissions
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Association for Emissions Control by Catalyst AISBL

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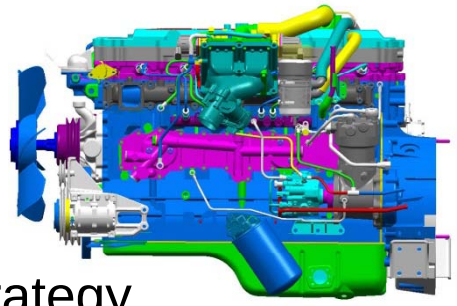
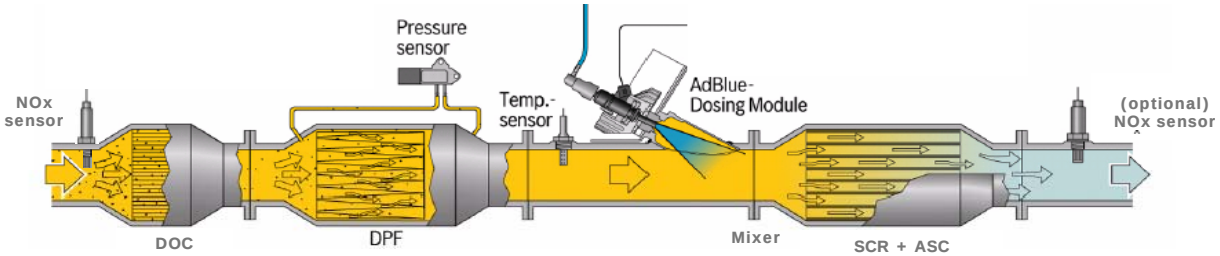
AECC heavy-duty Euro VI test engine

- 6 cylinder 7.5 litre engine designed for US2007
  - Common rail
  - Turbocharged
  - EGR
  - No modification to base engine calibration
  - No change to calibration or regeneration strategy.



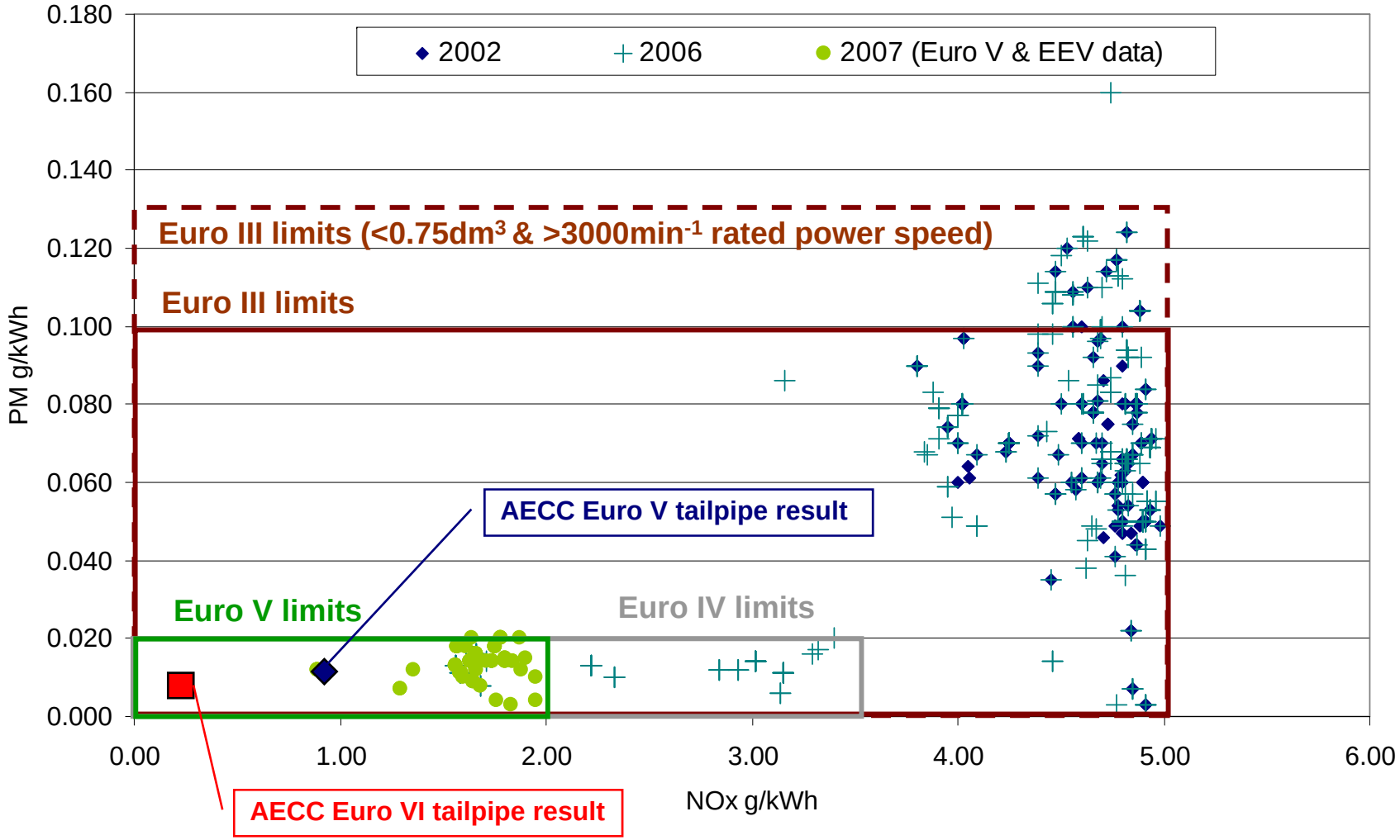
- AECC emissions control system + Bosch advanced airless urea dosing system
  - Basic urea dosing system calibration for the ESC, ETC and WHTC
  - No specific calibration for other cycles.



1m mixing length between injector and SCR face.

- No thermal management.

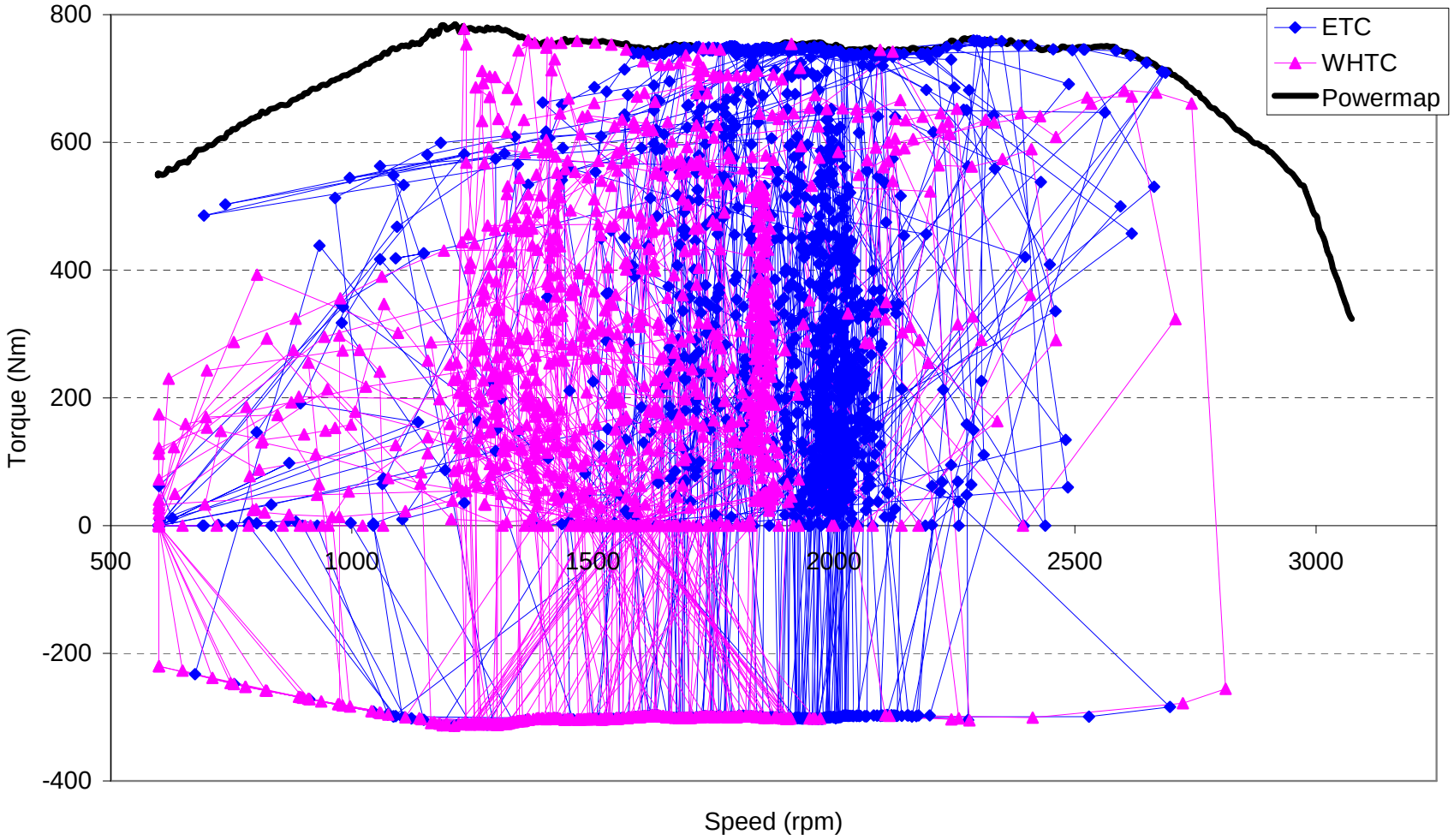
PM vs NOx (ESC test)



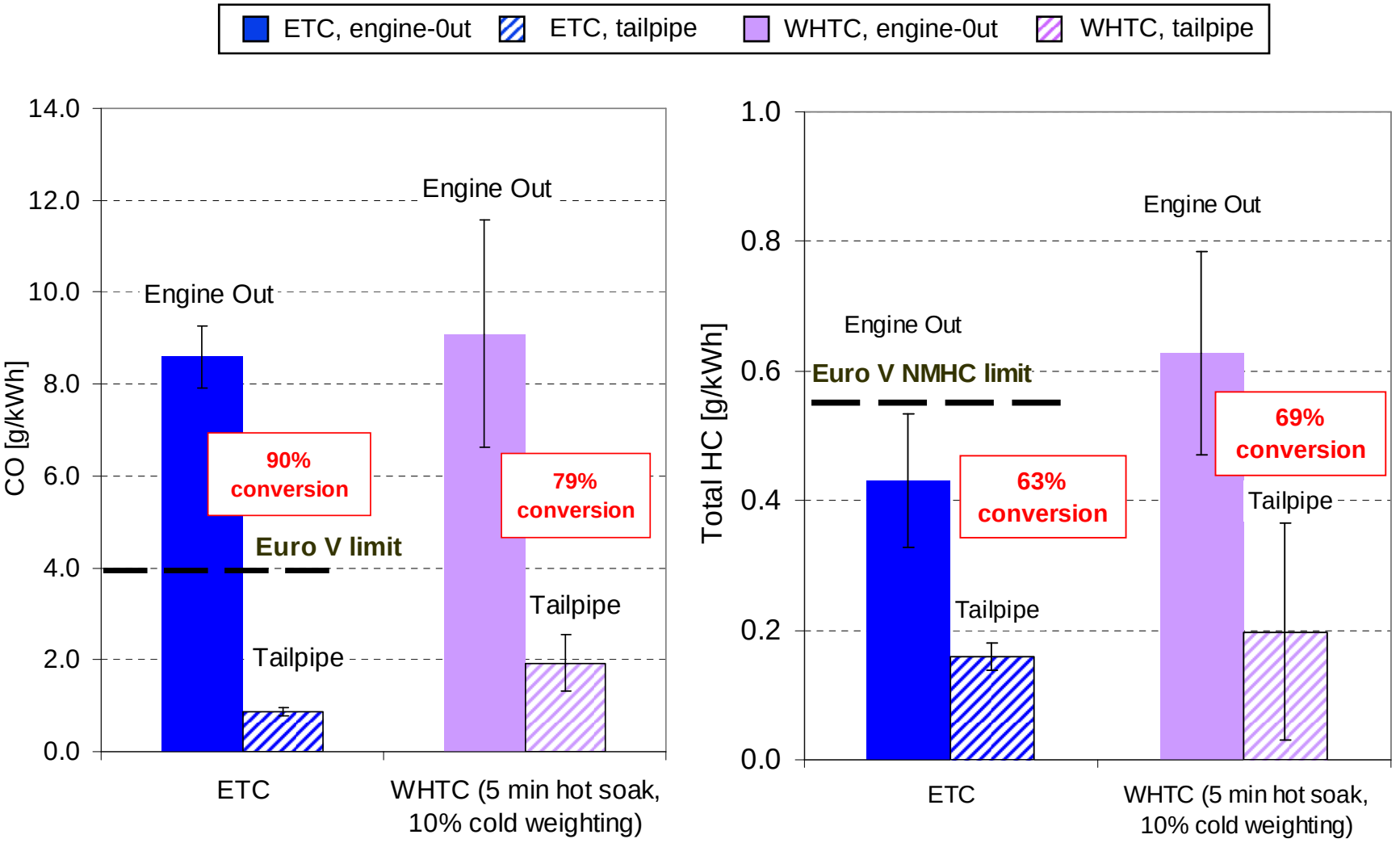
Source: KBA data, June 2002, January 2006, March 2007

ETC and WHTC cycle comparison

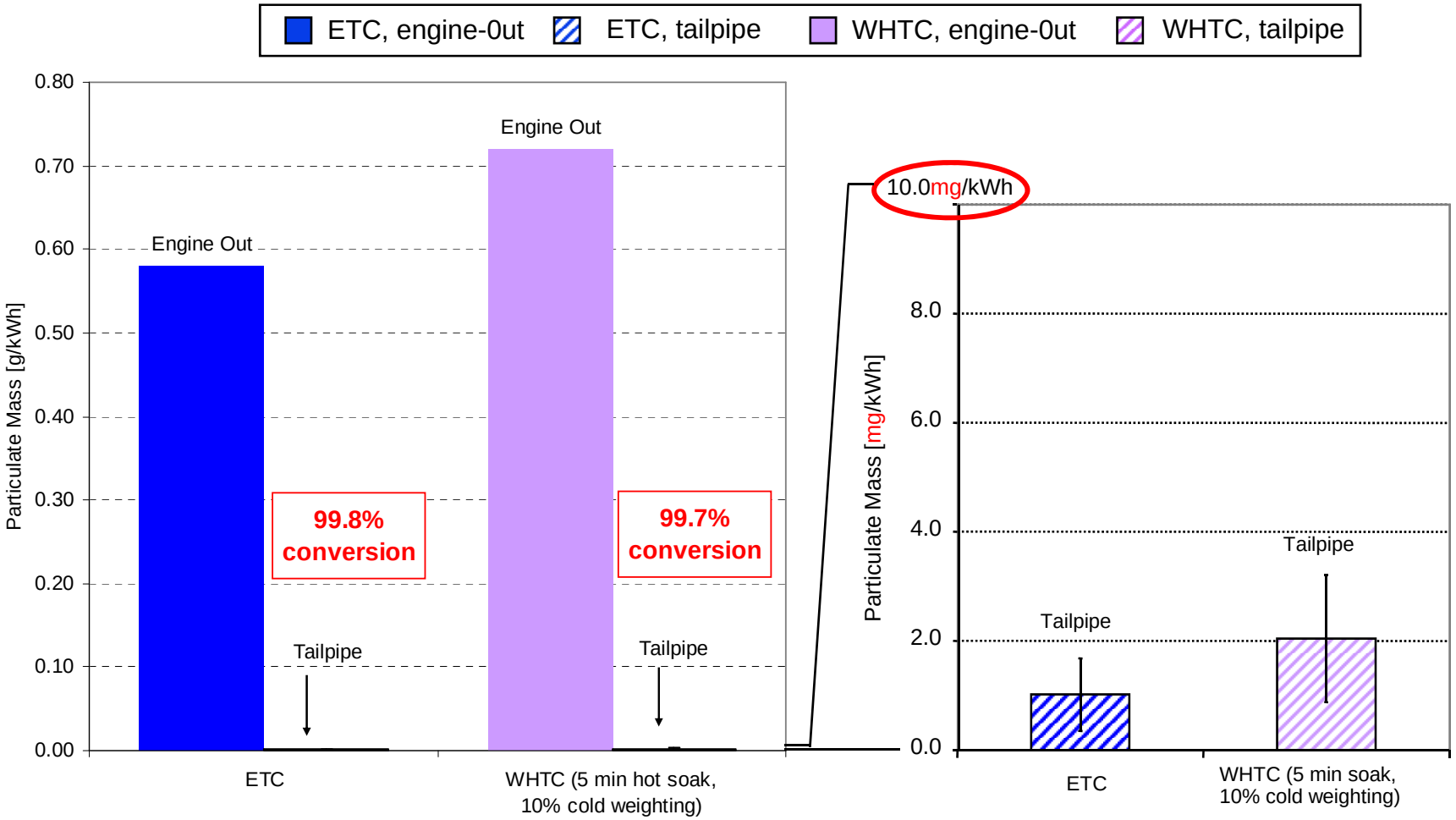
WHTC operates at lower speeds and loads than ETC.



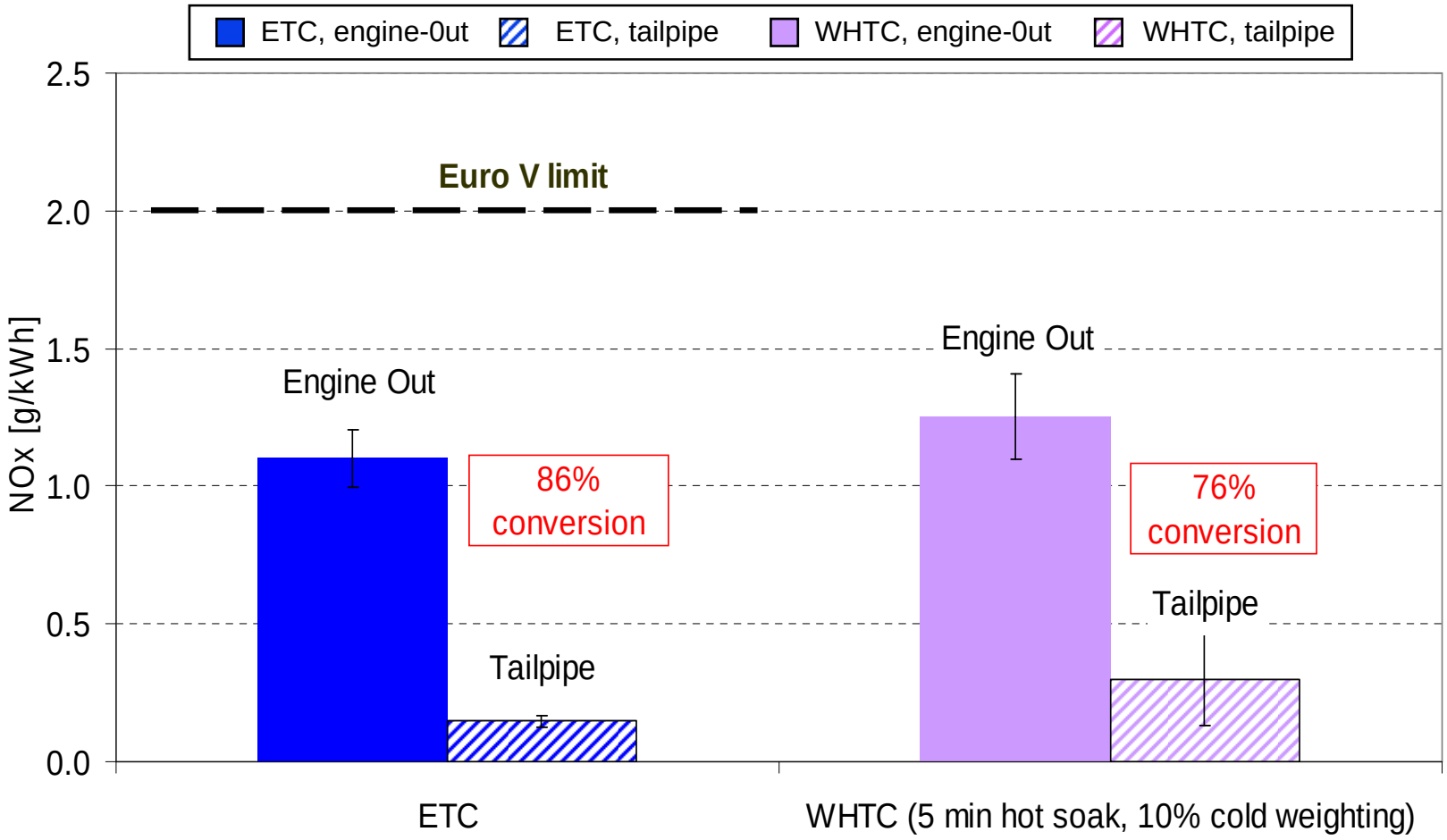
ETC and WHTC tests: CO & HC emissions for engine-out and tailpipe



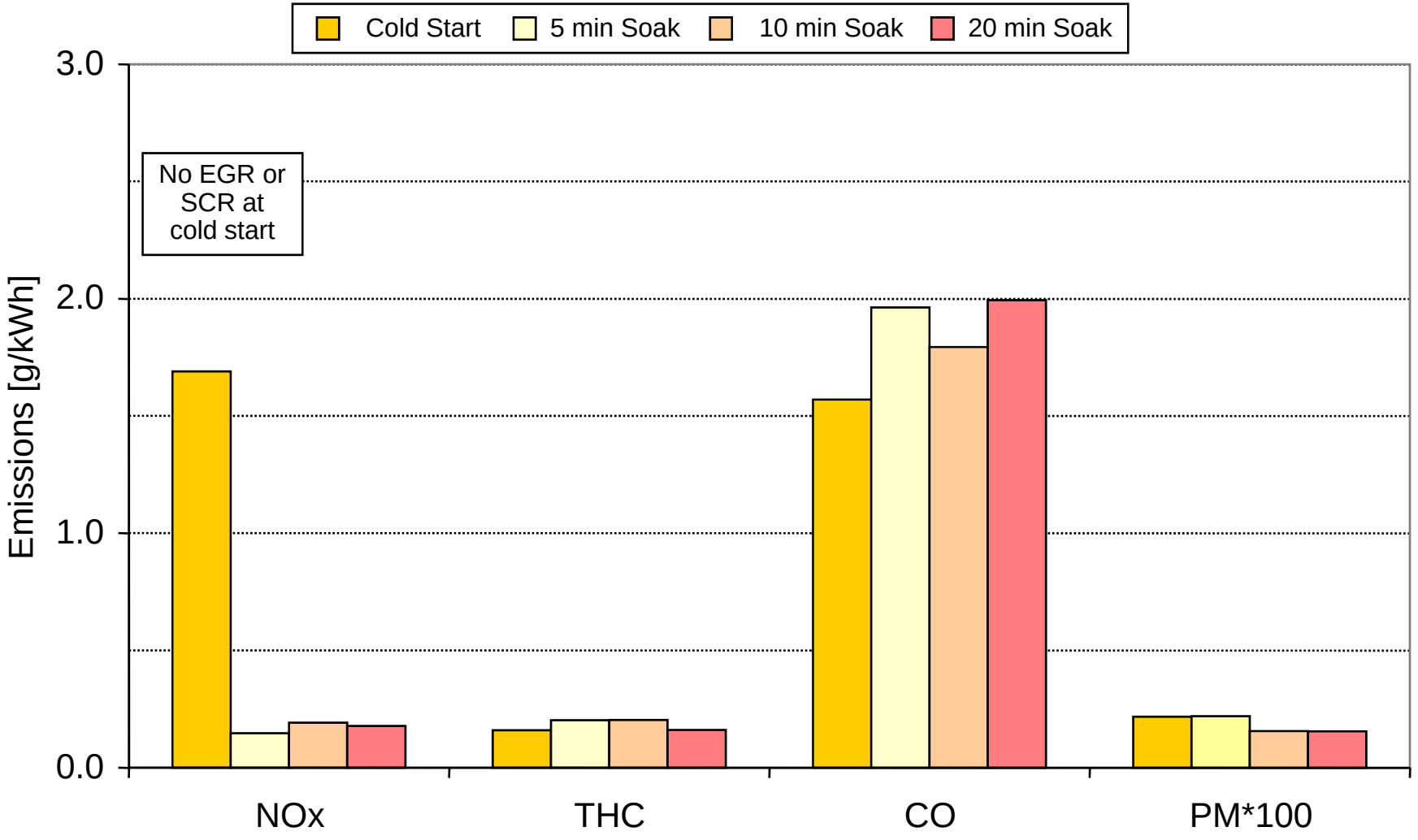
ETC and WHTC tests:
PM emissions for engine-out and tailpipe



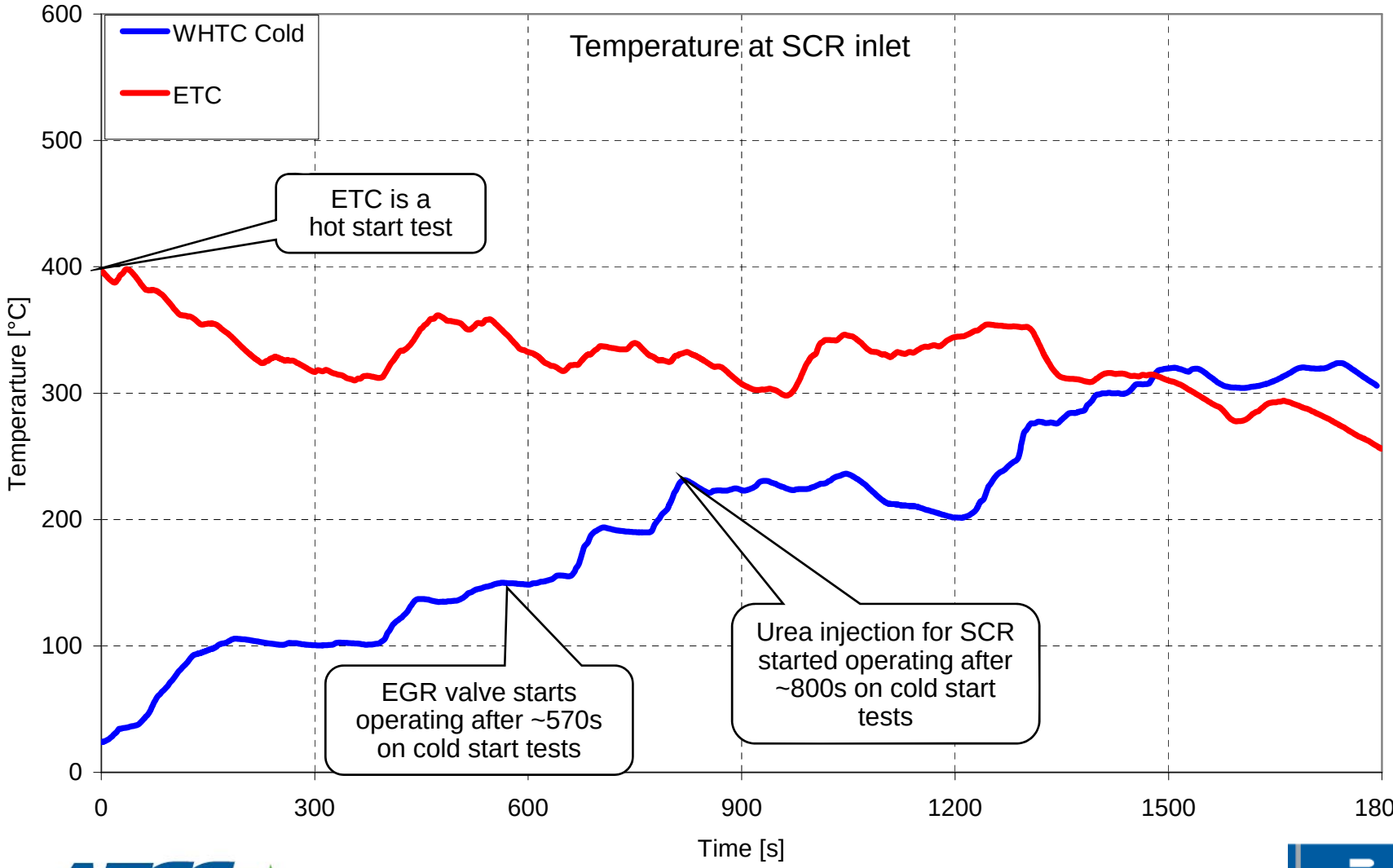
ETC and WHTC tests: NOx emissions for engine-out and tailpipe



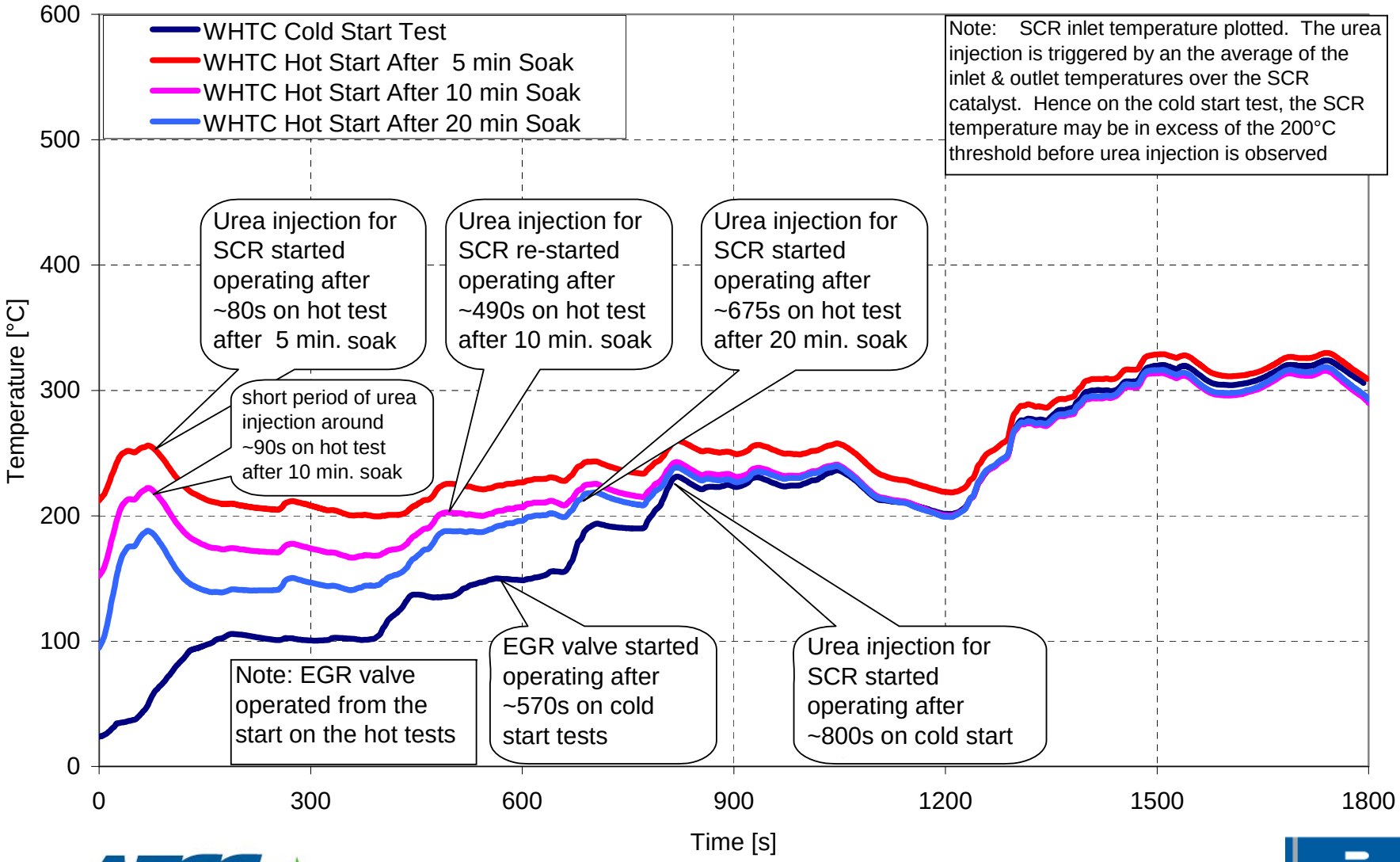
Tailpipe cold and hot start WHTC results showing effect of hot soak period



SCR temperatures for ETC and cold start WHTC



SCR temperatures for WHTC options



Summary of WHTC composite results

Test Procedure		Emissions [g/kWh]											
		THC			NOx			CO			PM		
		Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.
WHTC	cold	0.662	0.159	76%	2.338	1.689	28%	6.314	1.570	75%	0.594	0.002	99.6%
WHTC	**hot (5 min)**	0.624	0.202	68%	1.131	0.147	87%	9.403	1.962	79%	0.735	0.002	99.7%
10% cold	**weighted**	**0.628**	**0.198**	**69%**	**1.252**	**0.301**	**76%**	**9.094**	**1.922**	**79%**	**0.721**	**0.002**	**99.7%**
(EU-composite WHTC)													
WHTC	cold	0.662	0.159	76%	2.338	1.689	28%	6.314	1.570	75%	0.594	0.002	99.6%
WHTC	**hot (10 min)**	0.570	0.204	64%	1.232	0.191	84%	8.039	1.794	78%	0.735	0.002	99.8%
10% cold	**weighted**	**0.579**	**0.199**	**66%**	**1.343**	**0.341**	**75%**	**7.866**	**1.772**	**77%**	**0.721**	**0.002**	**99.8%**
WHTC	cold	0.662	0.159	76%	2.338	1.689	28%	6.314	1.570	75%	0.594	0.002	99.6%
WHTC	**hot (20 min)**	0.574	0.161	72%	1.193	0.178	85%	8.321	1.993	76%	0.735	0.002	99.8%
10% cold	**weighted**	**0.583**	**0.161**	**72%**	**1.308**	**0.329**	**75%**	**8.121**	**1.951**	**76%**	**0.721**	**0.002**	**99.8%**
14% cold	**weighted**	**0.586**	**0.160**	**73%**	**1.357**	**0.394**	**71%**	**8.034**	**1.933**	**76%**	**0.715**	**0.002**	**99.8%**

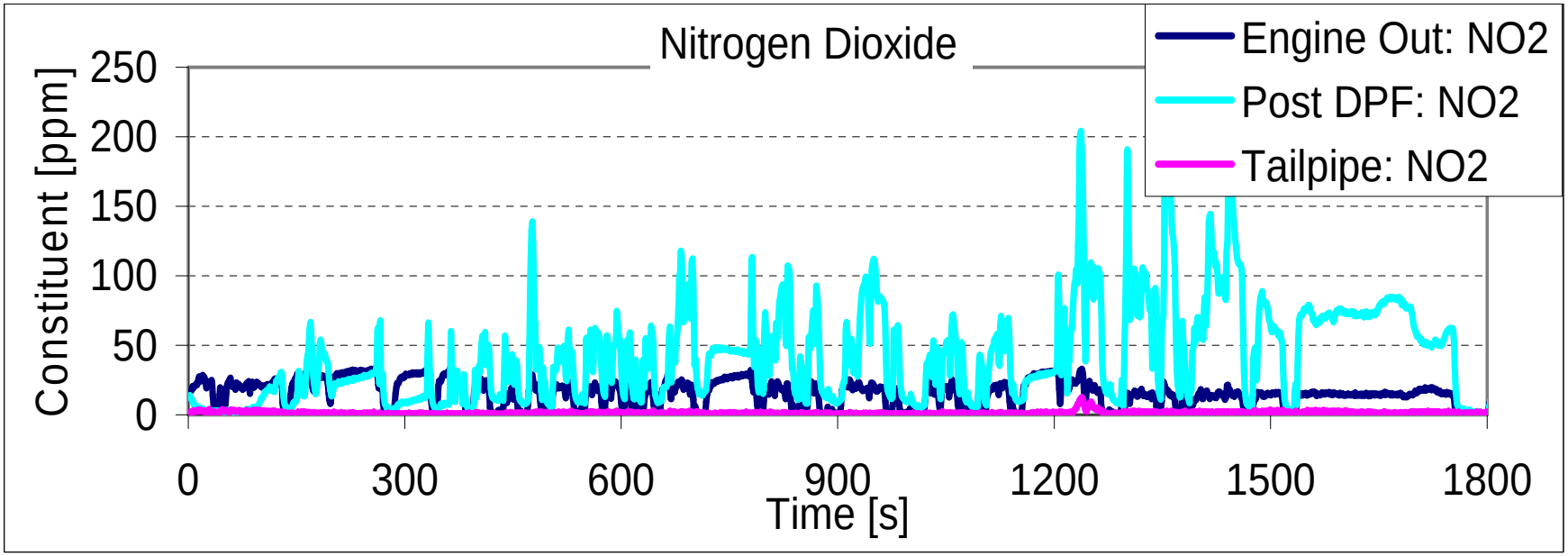
(US-composite WHTC)

Hot NOx conversion efficiencies ~85%.

PM reduction efficiencies >99.5%.

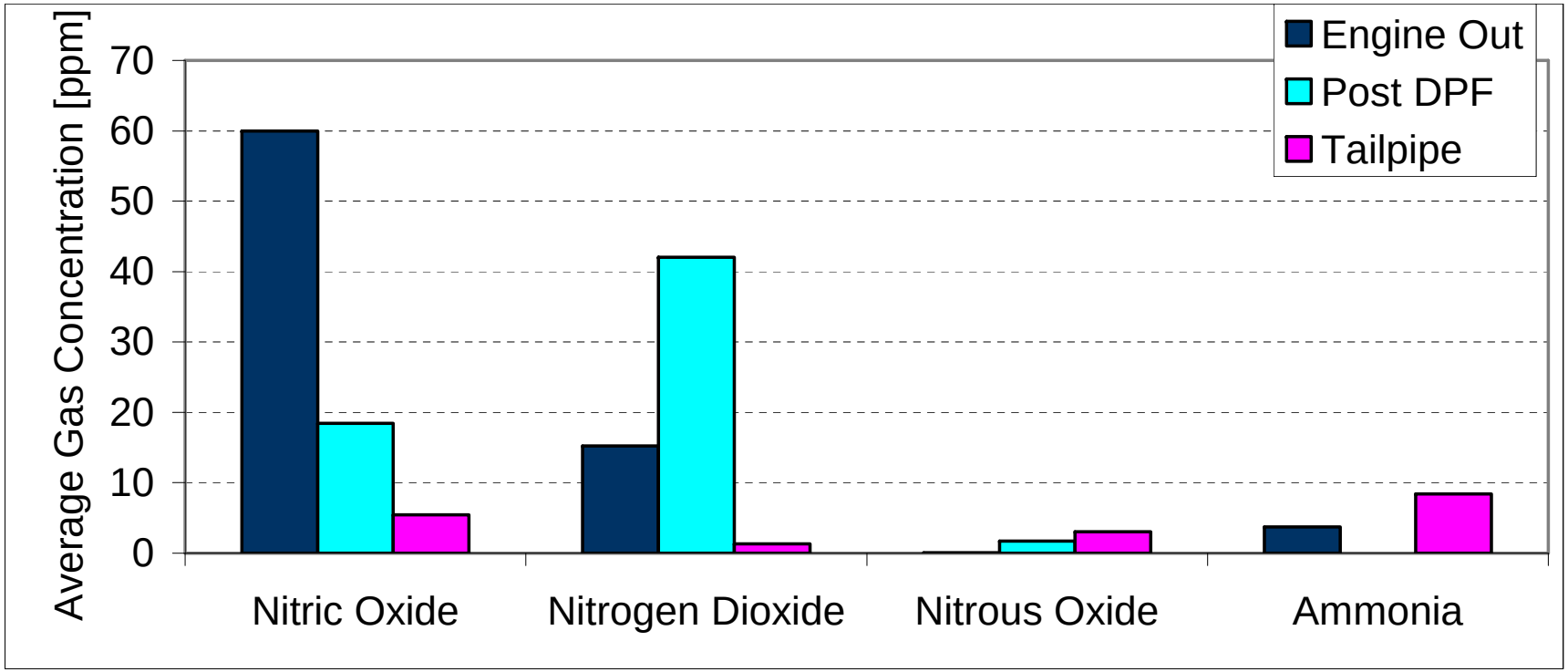
Continuous trace for NO_2 on the WHTC

World Harmonised Transient Cycle (WHTC)

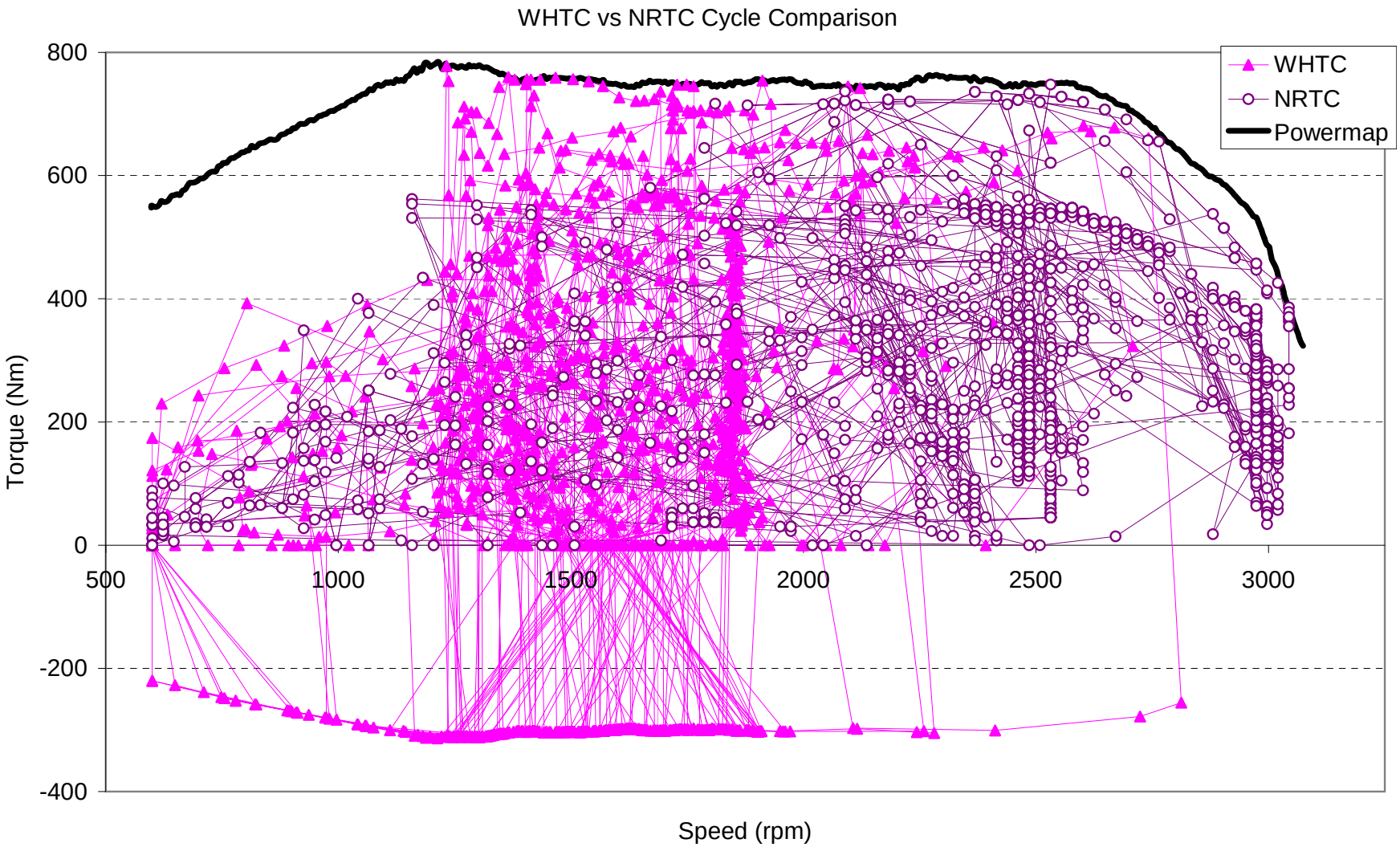


Profile of nitrogen species through the emissions control system

World Harmonised Transient Cycle (WHTC)

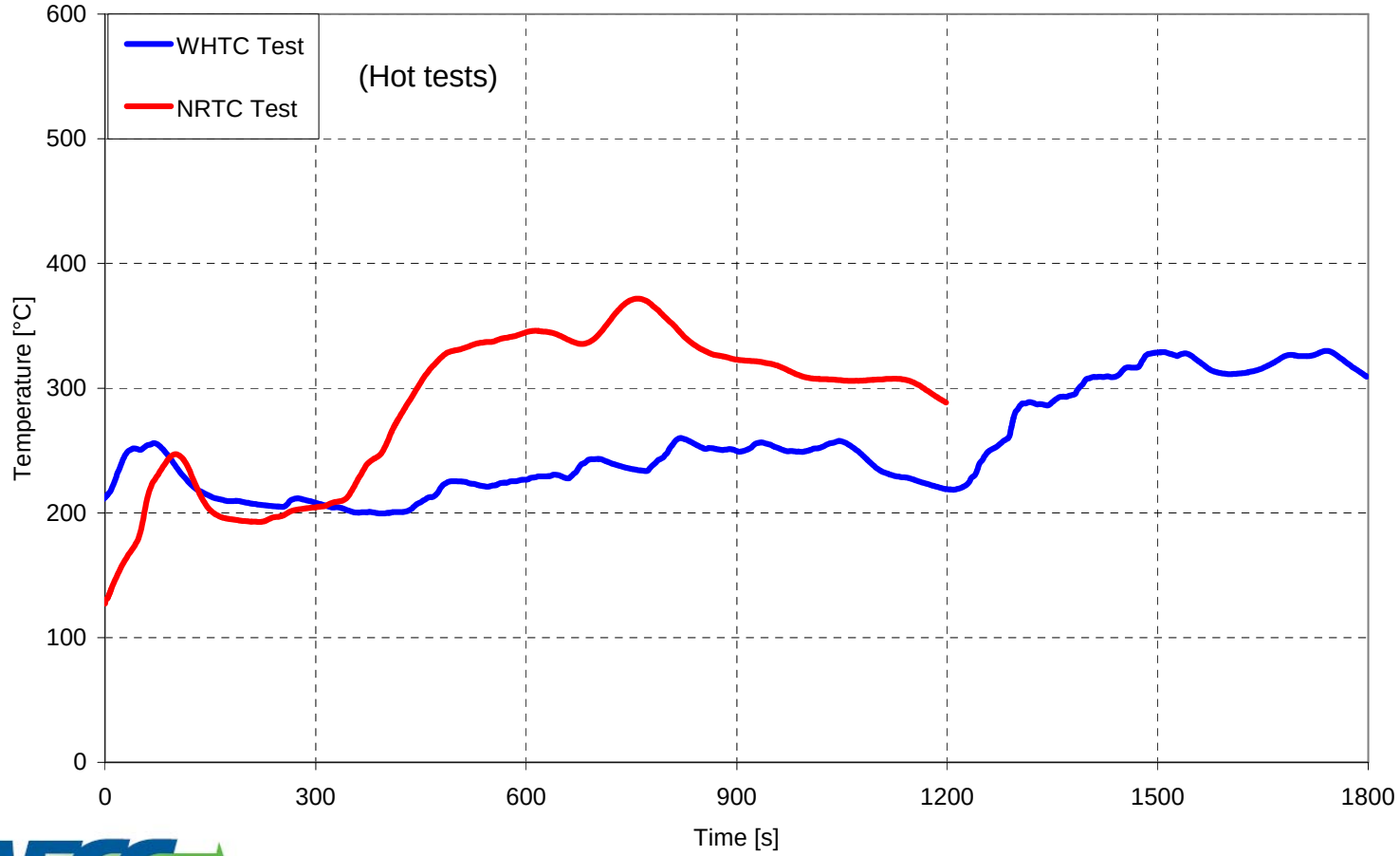


WHTC and NRTC cycle comparison

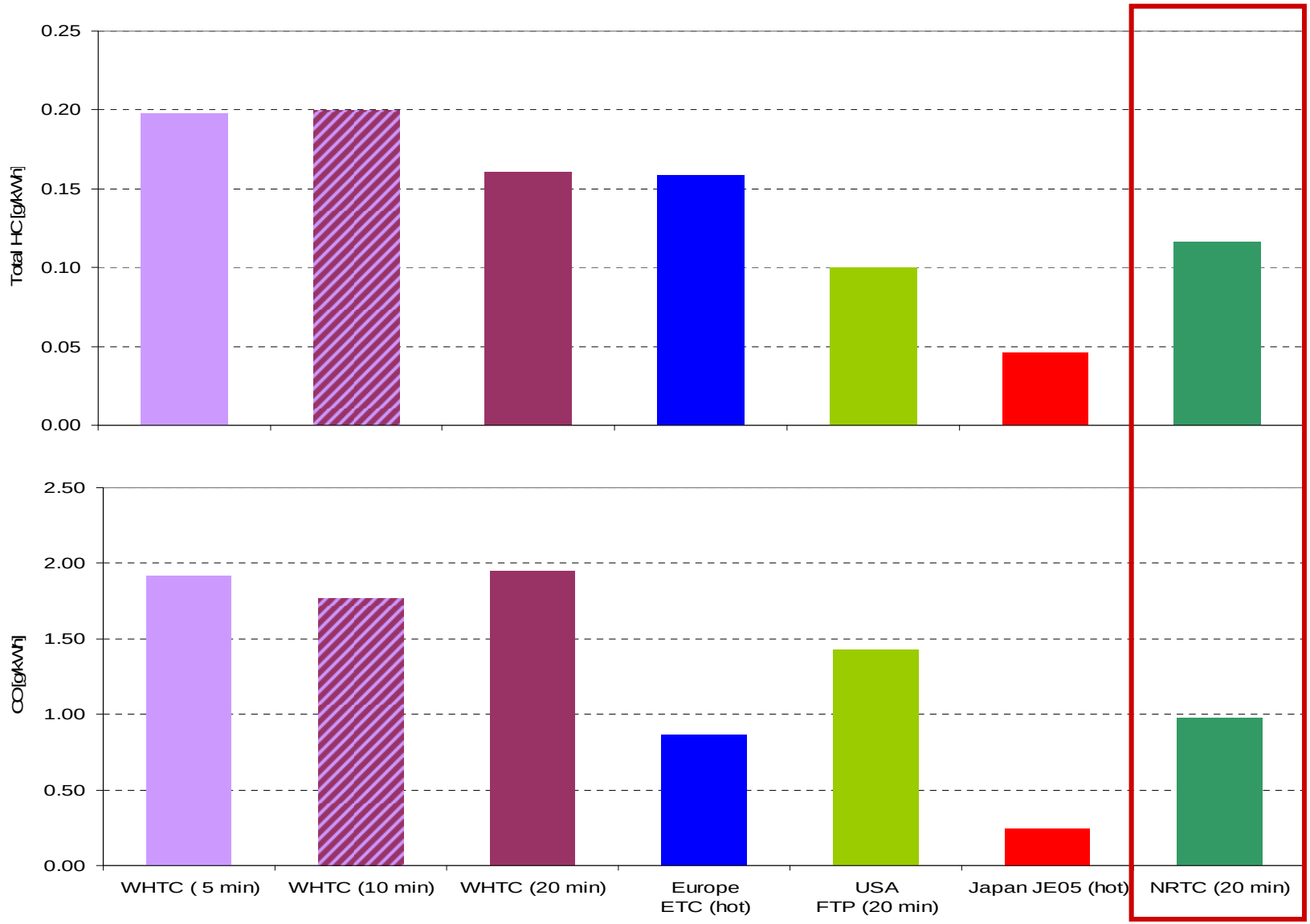


Non-Road Transient Cycle

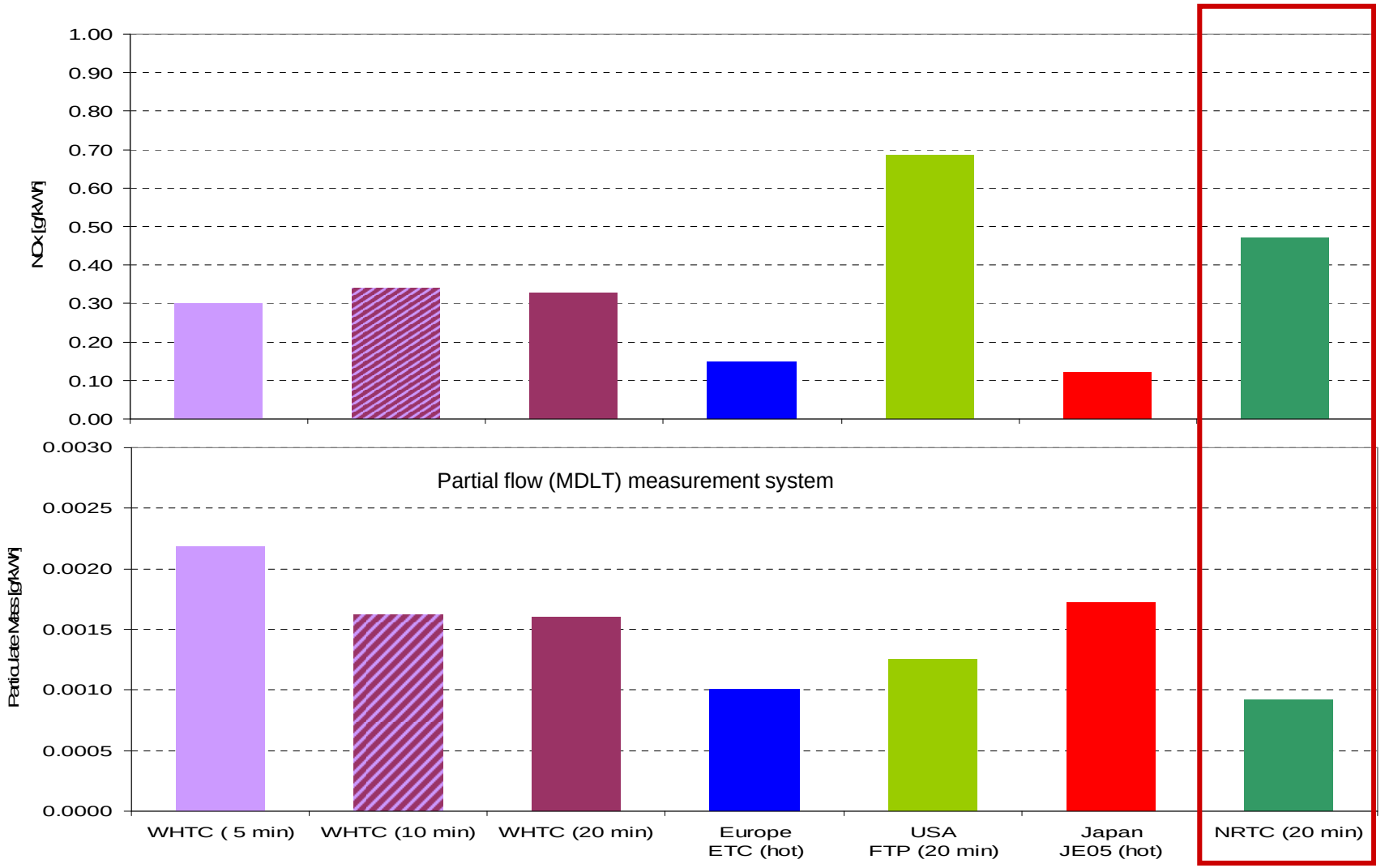
- Cold start weighting factors: EU is 10%; US is 5%.
- Soak time between the cold and hot tests is 20 minutes.
- Cold start: EGR and low SCR inlet temperature for first 300s.
- Hot tests: SCR inlet temperature reaches 200°C after 60s.



HC and CO for non-road transient cycle

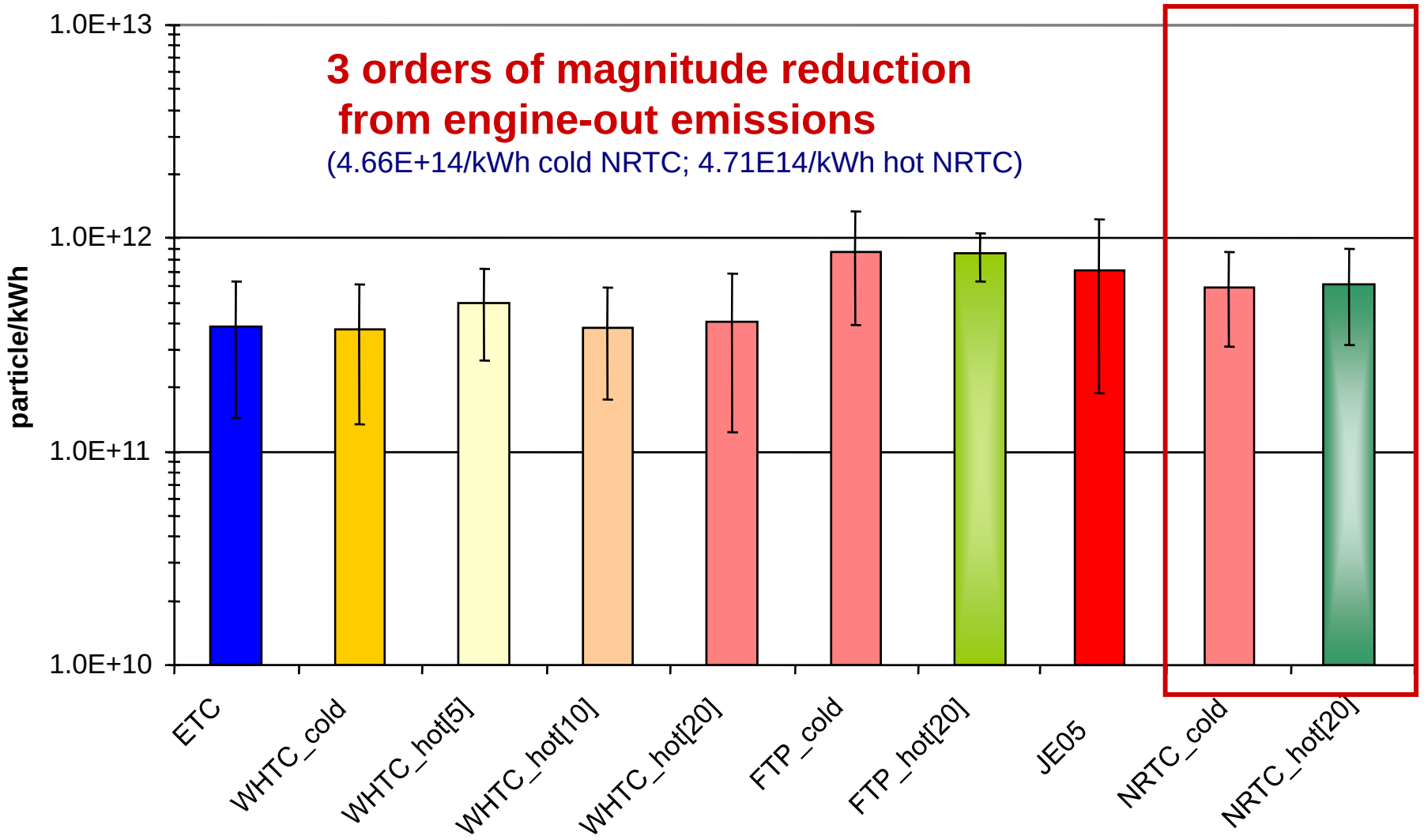


NOx and PM for non-road transient cycle



Note: PM limit for Stages IIIB & IV is 25mg/kWh. Average test result is <1mg/kWh

Particle numbers measurements over non-road transient cycle

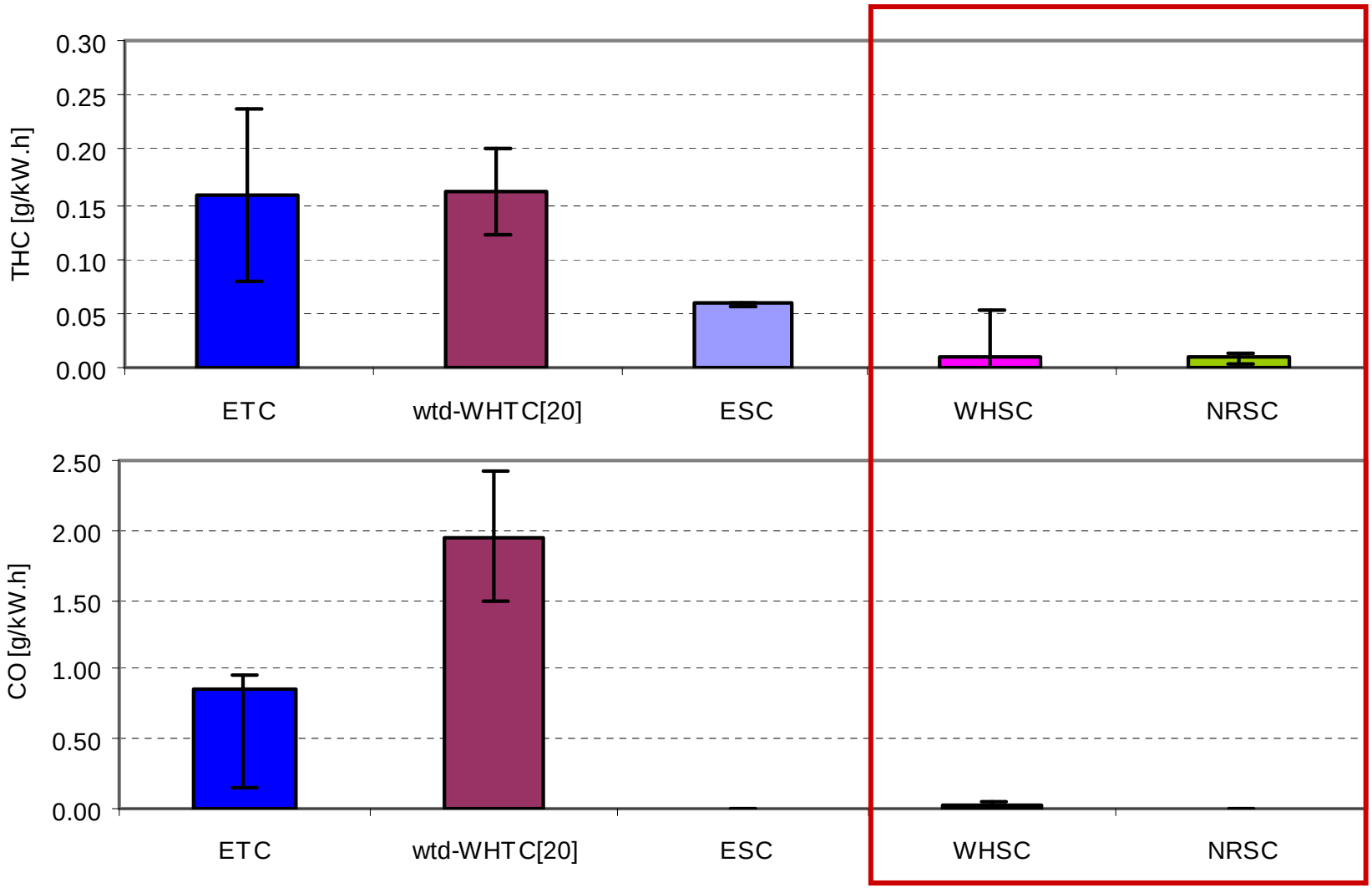


NRTC composite results

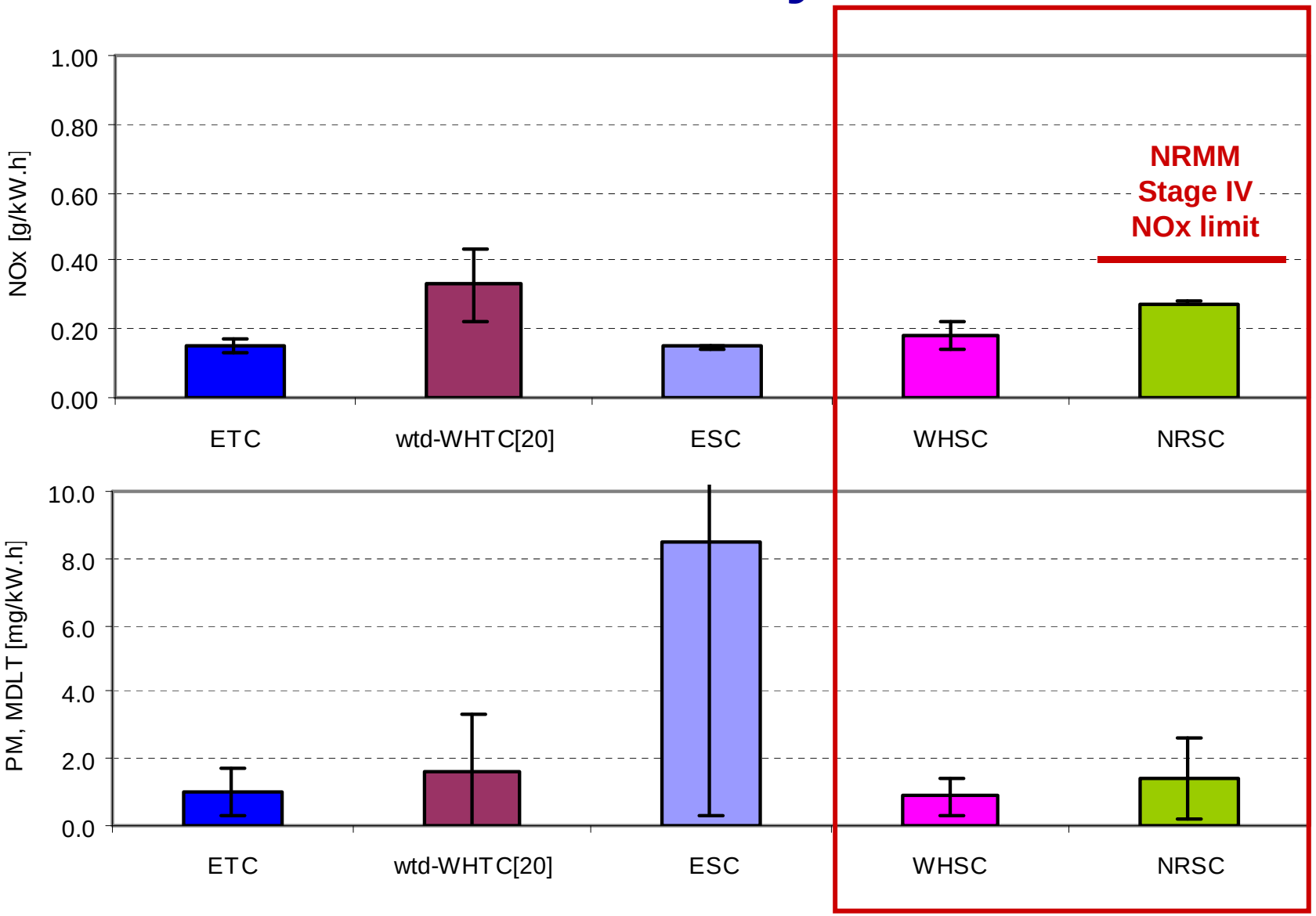
Test Procedure		Emissions [g/kW.h]											
		THC			NOx			CO			PM		
		Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.	Engine Out	Tail pipe	Conv. Effy.
NRTC cold	cold	0.584	0.070	88%	2.217	1.220	45%	4.380	0.719	84%	0.541	0.001	99.8%
NRTC hot	hot (20 min)	0.775	0.122	84%	1.486	0.388	74%	6.820	1.007	85%	0.505	0.001	99.8%
NRTC (EU)	10% cold wtd.	0.756	0.116	85%	1.559	0.471	70%	6.576	0.978	85%	0.509	0.001	99.8%
NRTC cold	cold	0.584	0.070	88%	2.217	1.220	45%	4.380	0.719	84%	0.541	0.001	99.8%
NRTC hot	hot (20 min)	0.775	0.122	84%	1.486	0.388	74%	6.820	1.007	85%	0.505	0.001	99.8%
NRTC (US)	5% cold wtd.	0.766	0.119	84%	1.523	0.429	72%	6.698	0.992	85%	0.507	0.001	99.8%

- No optimisation was undertaken.
  - No change to engine calibration from US2007 HD basis.
  - 'One-shot' system sizing: would be optimised for production.
  - Urea dosing was not optimised for non-road cycles.
  - No thermal management strategy to improve cold NOx emissions.

HC and CO for steady-state tests

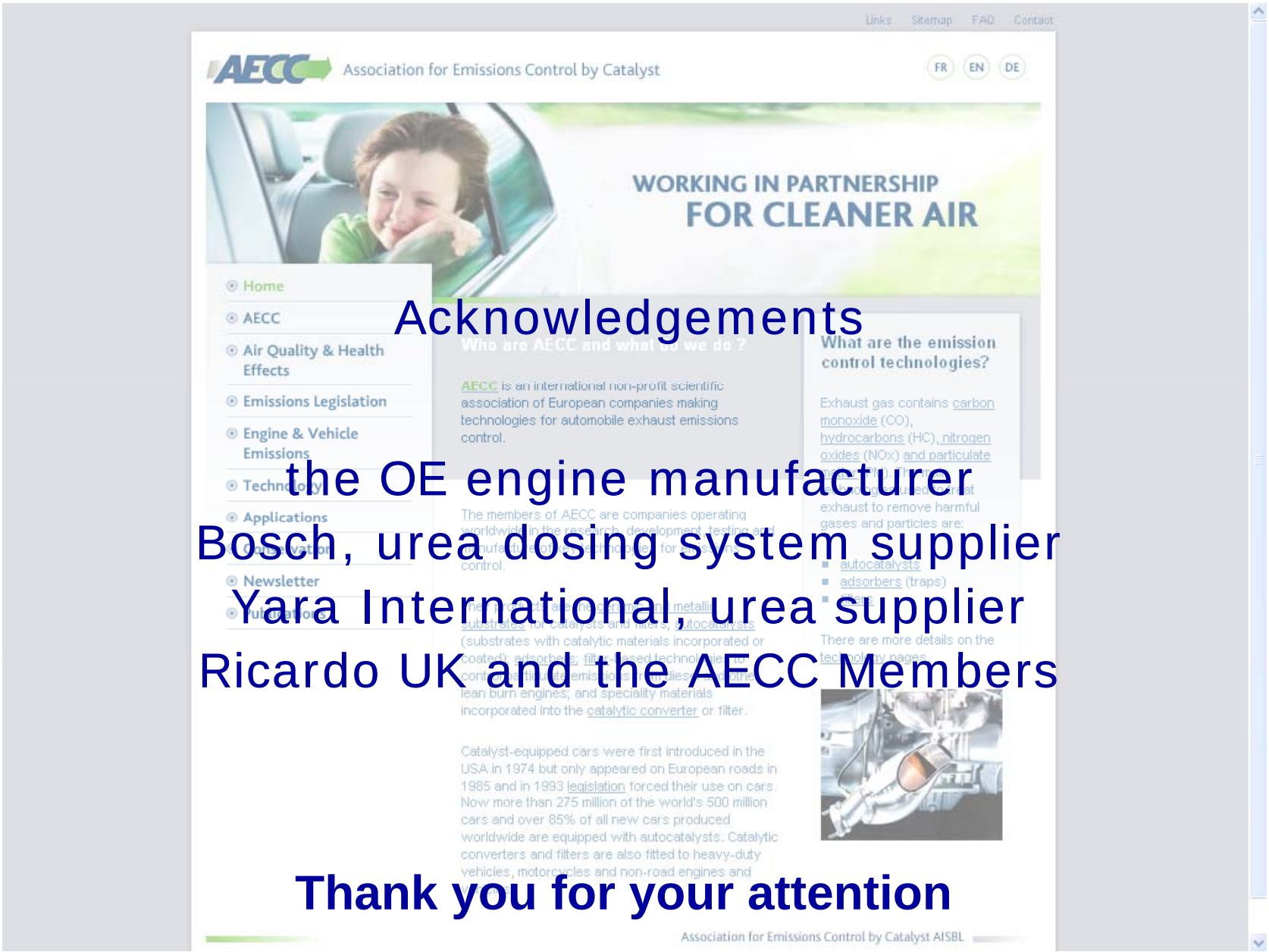


NOx and PM for steady-state tests



Summary

- Over the EU-composite World Harmonised Transient Cycle, NOx emissions were 0.3g/kWh and PM emissions were 2mg/kWh.
- NOx conversion efficiency over the hot-start WHTC was similar to that for the ETC (85%). Cold start efficiency was lower as the EGR did not operate until 570s and the system did not reach minimum urea injection until 800s on cold tests.
- The system was not fully optimised; there was no thermal management to assist cold start NOx emissions.
- The Non-Road Transient Cycle has higher speeds and loads than the WHTC, resulting in faster achievement of operating temperatures.
- Over the EU-composite Non-Road Transient Cycle, NOx emissions were 0.471g/kWh and PM emissions were 1mg/kWh.



Acknowledgements

the OE engine manufacturer

Bosch, urea dosing system supplier

Yara International, urea supplier

Ricardo UK and the AECC Members

Thank you for your attention