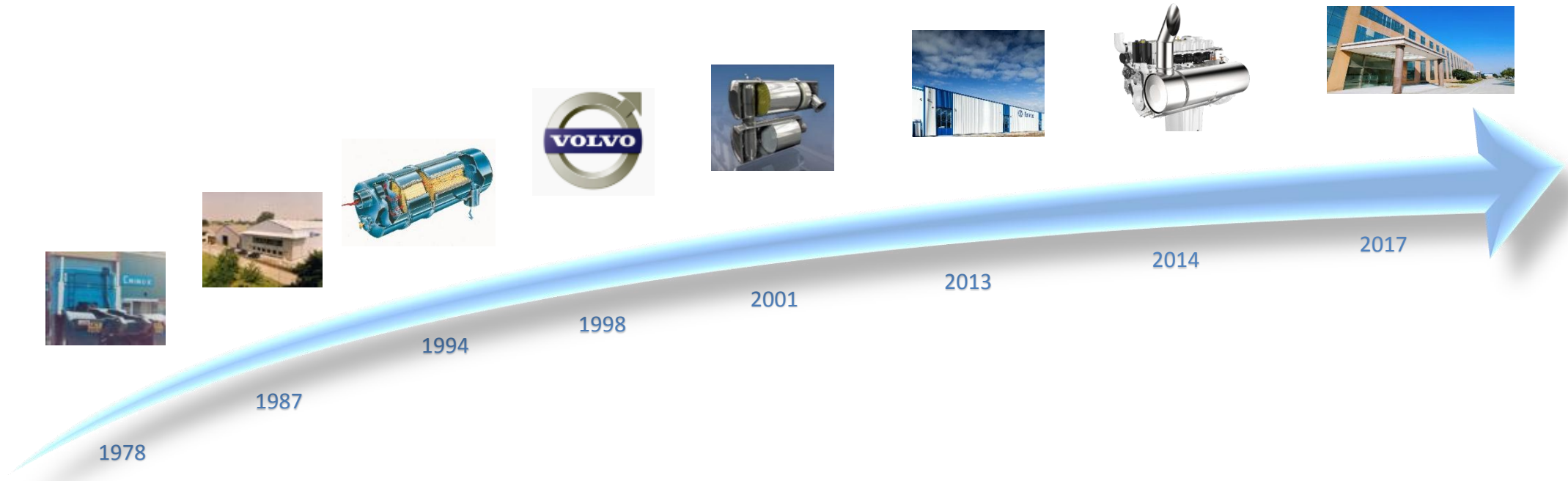


Retrofitting to Real World Euro VI



Carlos Vicente
Retrofit Sales Director

Eminox - 40 years of evolution in EATS !



OEM Customers



Retrofit Customers



Global Retrofit

Over 20 years in emission control
15 years' experience in SCRT®



CRT®: 80,000+

London LEZ

Paris

German E-Zones

Swedish E-Zones

Belgium

Chile



SCRT®: 4,500+

UK

Paris

Belgium

Barcelona

Sweden E-Zones

Denmark

Hong Kong



UK Retrofit SCRT[®] market :

All schemes allow retrofit Euro VI solutions to tackle NO2 exceedance

2017

2018

2019

2020

2021

2022



Transport for London = 5000 buses £80m project

Clean Bus Fund = £40m Bus retrofit

Clean Air Zones x 29 cities £220m funding

London ULEZ

London Phase II ULEZ M25



Clean Air Zones



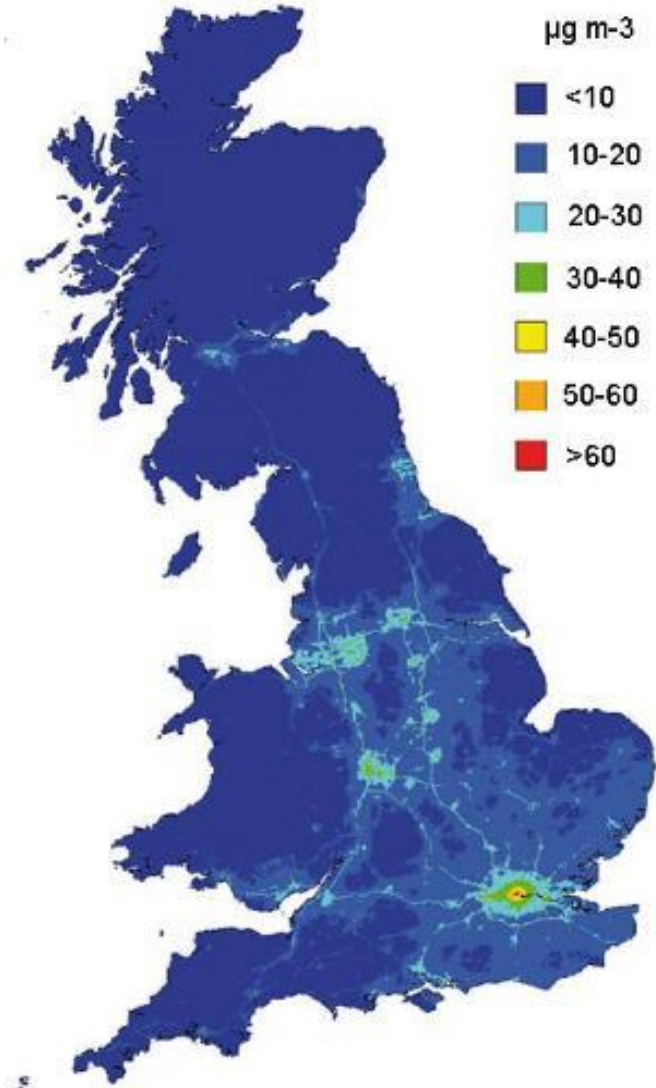
Final Air Quality Plan published July 2017

Detailed plans to be produced by 29 Local Authorities

Basildon District Council	Coventry City Council	Leeds City Council	Nottingham City Council	Southampton City Council
Bath and North East Somerset Council	Derby City Council	Manchester City Council	Rochford District Council	Stockport Metropolitan Borough Council
Birmingham City Council	Fareham Borough Council	Middlesbrough Borough Council	Rotherham Metropolitan Borough Council	Surrey Heath District Council
Bolton Metropolitan Borough Council	Gateshead Metropolitan Borough Council	New Forest District Council	Rushmoor Borough Council	Tameside Metropolitan Borough Council
Bristol City Council	Greater London Authority	Newcastle City Council	Salford Metropolitan Borough Council ⁴¹	Trafford Metropolitan Borough Council ⁴²
Bury Metropolitan Borough Council	Guildford Borough Council	North Tyneside Council	Sheffield City Council	

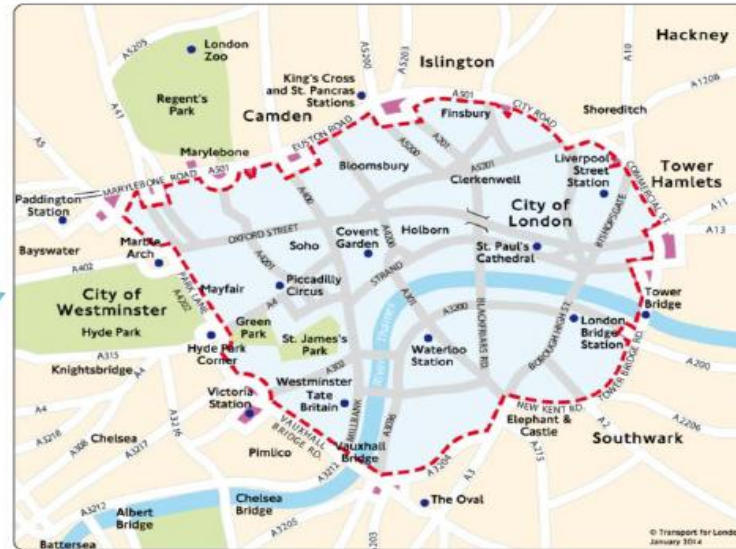
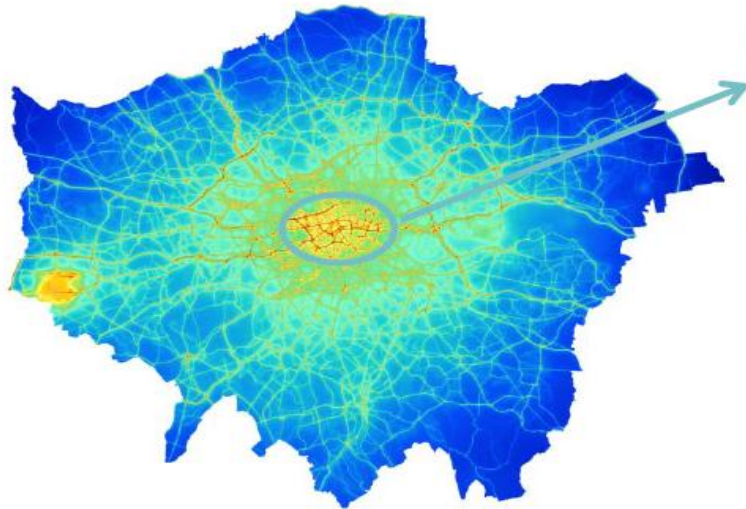
Draft Plans for consultation by March 2018

Final plans by December 2018



London = Biggest NO2 exceedance in UK !

The ULEZ is the same as the Congestion Charge zone

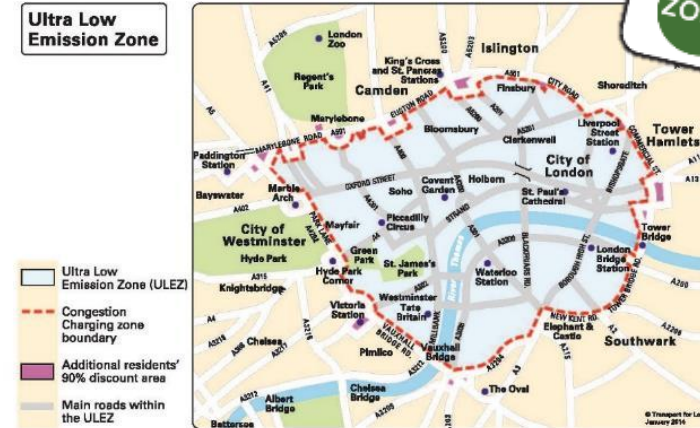


EVERY JOURNEY MATTERS

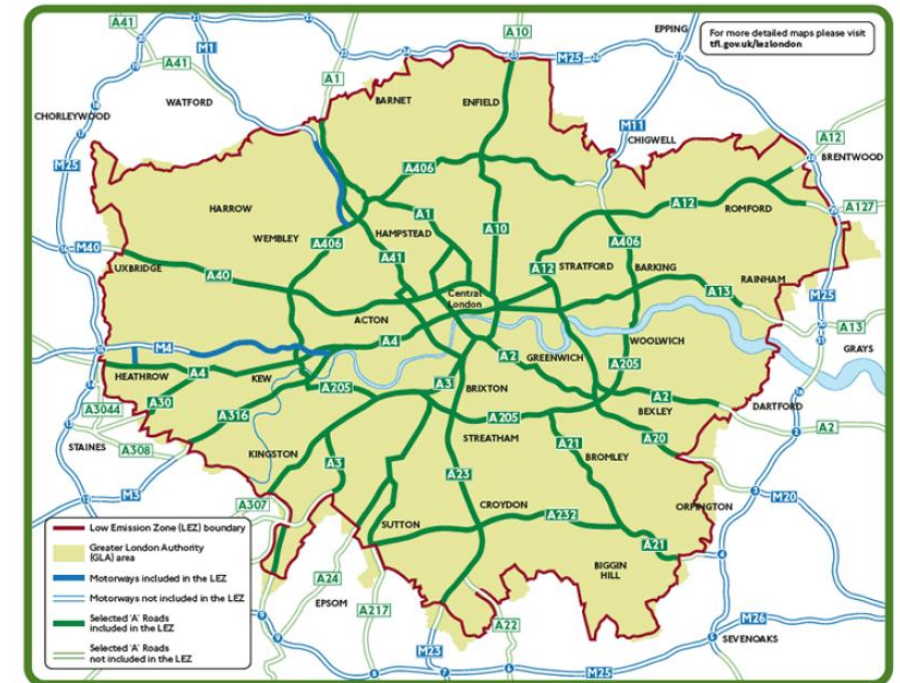
London Ultra Low Emission Zone & TfL

Central London ULEZ

- Confirmed date: **8 April 2019**
- Area as congestion charging zone
- £100/day** £1000/day penalty



- Expansion - Phase II Greater London expected for bus, coach and truck from **26 October 2020**
- TfL - 5000 buses retrofit programme Euro VI
- Vehicles retrofitted to Euro VI (CVRAS) or TfL MLTB**



Clean Air Zones

- Plan for Clean Air Zones or ‘equally effective measures’
- Original **5 Clean Air Zones** to be introduced by **2020**
 - Birmingham
 - Leeds
 - Nottingham
 - Derby
 - Southampton
- **Additional zones** to be introduced by **2021**
- All zones likely to focus on buses, possibly coach & other heavy duty vehicles
- **Clean Vehicle Retrofit Accreditation Scheme (CVRAS) approved technologies will be compliant**



Government Support for Retrofit

£40m Clean Bus Technology Fund

- Announced in September 2017
- Local Authorities can bid for up to £3m for local projects
- **Only for Clean Vehicle Retrofit Accreditation Scheme (CVRAS) approved technologies**

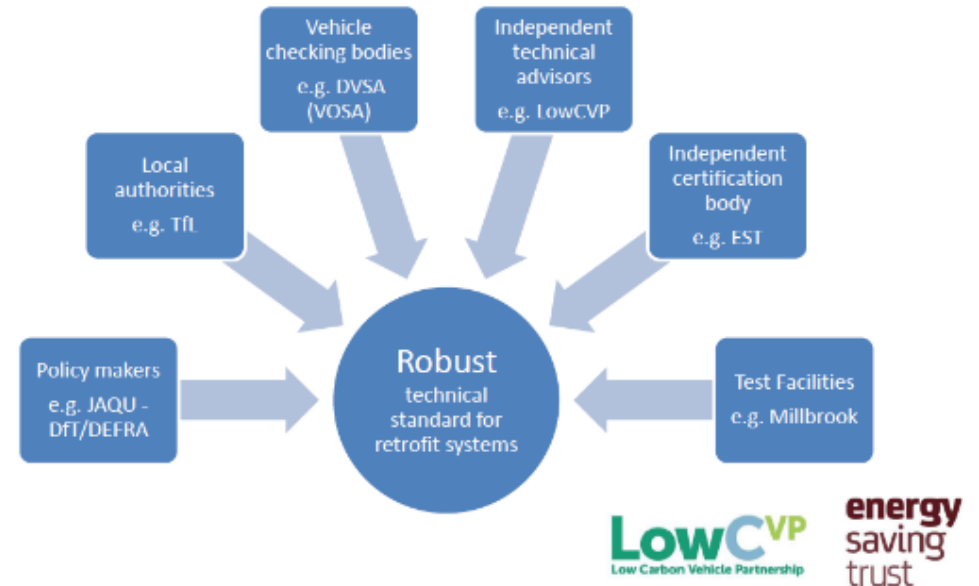
£220m Clean Air Fund

- For local authorities in England
- Focus on additional measures to minimise impact on local people/businesses
- With existing funding focused mainly on buses :-
DEFRA consulted on what support is needed for retrofit in other sectors (RCV Coach etc)
- Consultation closed 5 January 2018 <https://consult.defra.gov.uk/airquality/additional-measures/>



CVRAS: Clean Vehicle Retrofit Accreditation Scheme

- Approval Standard for CAZ and ULEZ in UK
- Scheme was published on 3 August
- So far only scheme fully released is for bus
 - Coach, Truck & RCV in progress
- UK approved test cycles
- Company and technology accreditation required

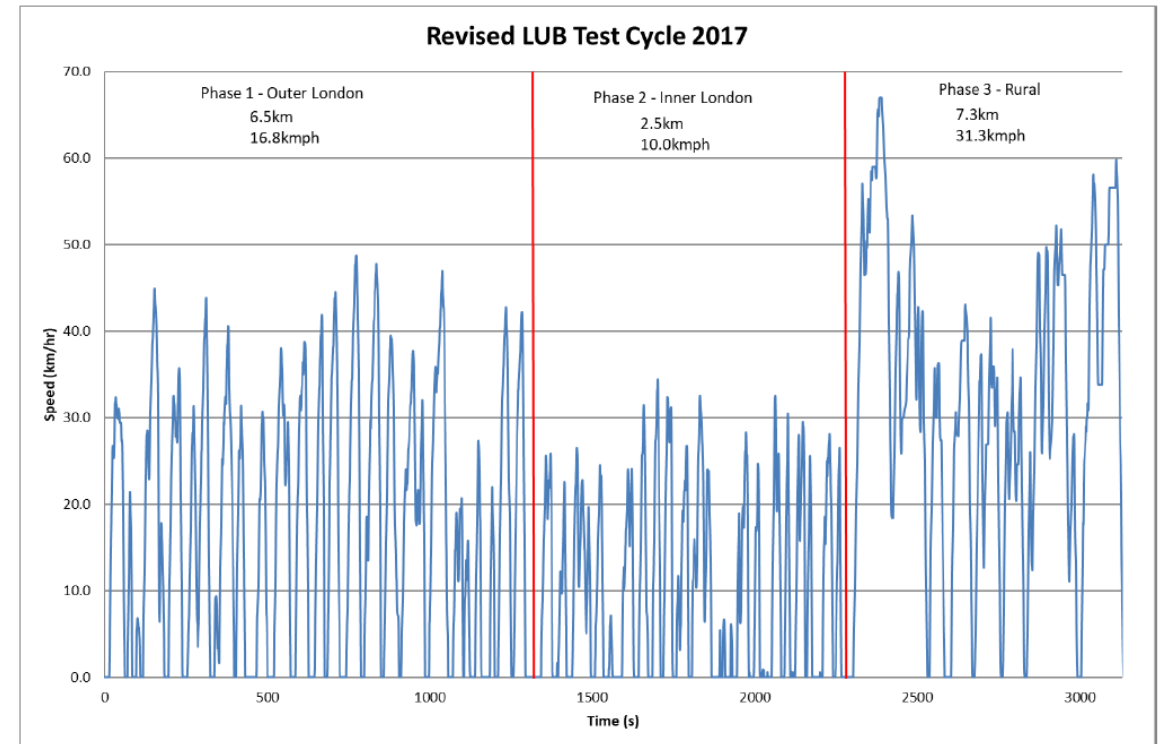


<http://www.energysavingtrust.org.uk/business/transport/clean-vehicle-retrofit-accreditation-scheme-cvras>

CVRAS: Clean Vehicle Retrofit Accreditation Scheme

- Same emission targets as TfL + new national drive cycle for buses

Exhaust emission parameter		Maximum permitted limit
Primary emissions		
Mixed oxides of nitrogen	NO _x	500mg/km
Nitrogen dioxide	NO ₂	100mg/km
Particulate matter (PM)	PM	10mg/km
Number of particles (PN)	PM	6 x 10 ¹¹ /km
Secondary emissions		
Nitrous oxide/methane	N ₂ O/CH ₄ (as CO ₂ e)	< 5% of CO ₂
Carbon dioxide	CO ₂	< 1% increase
Ammonia	NH ₃	10ppm average 25ppm peak
In service		
Mixed oxides of nitrogen	NO _x	



CVRAS: Clean Vehicle Retrofit Accreditation Scheme

CVRAS Status – yellow tbc

Vehicle	Test cycle	Test Limits	Service Limits	System Approvals	Vehicle approvals	Registered database
Bus – 25% laden	Dyno RLUB Confirmed	500mg NOx 5% CO _{2e} 100 mg NO ₂	>80% incl average daily conversion	Eminox Green Urban ?		
Coach – 50% laden (100% pax)	Dyno LUC Proposed	500mg NOx 5% CO _{2e} 100 mg NO ₂	Monitoring or OBD	Baumot Eminox		
Truck – N2N3 50% laden Or dyno max	Dyno LUT Track LHAC	500mg NOx 5% CO _{2e} 100 mg NO ₂	Monitoring or OBD			
Van – N1 50% laden? Or ref weight	Dyno LUT or WLTP	250mg NOx 3% CO _{2e} 100 mg NO ₂	Monitoring or OBD			
Taxi – 1 pass or ref weight	Dyno PCO CENEX or WLTP	250mg NOx 3% CO _{2e} 100 mg NO ₂	Monitoring or OBD	Aminex Autogas lpg		

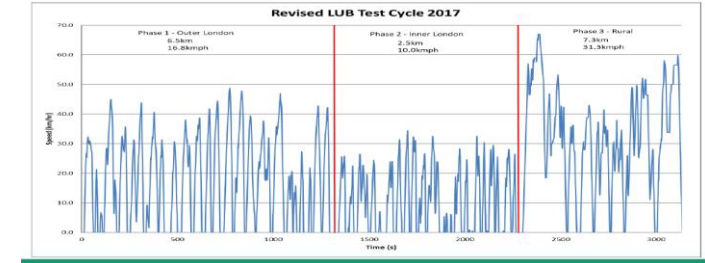
Do we want to make Coach and Truck any different limits to Bus or keep all the same at 5% CO_{2e} and 100mg NO₂?

Van and Taxi, can argue that WLTP cycle is most appropriate for Euro 6 equivalence, however we have real-world cycles for each?

PCO is worst case and may give higher NOx

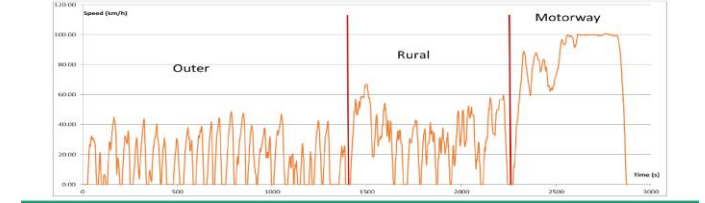
Buses Vehicle Emission Testing Procedure

- Test procedure – Clean Vehicle Retrofit Accreditation Scheme/TFL Bus test
- Real world cycle – Revised LowCVP UK Bus (RLUB) Cycle. (Rural at end)
- Test to be undertaken at a vehicle laboratory using a chassis dynamometer
- Test conditions: 50% of seated passenger load (or 25% of total)
- Measurements: NO, NO₂, NOx, N₂O, CO₂, CH₄, PM, PN, THC plus NH₃



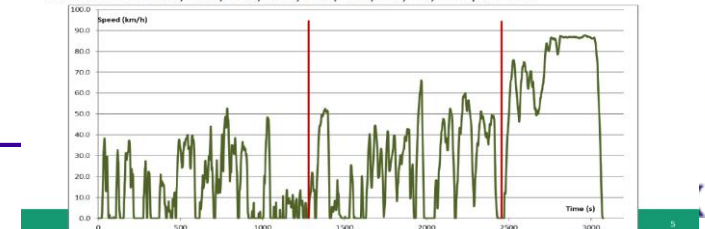
Coach Vehicle Emission Testing Procedure

- Test procedure – Clean Vehicle Retrofit Accreditation Scheme
- Real world cycle – LowCVP UK Coach (LUC) Cycle.
 - Outer London Bus, + Rural Bus, + Motorway
- Test to be undertaken at a vehicle laboratory using a chassis dynamometer
- Test conditions: 50% of GVW load (or 100% of total passengers) up to max Dyno inertia
- Measurements: NO, NO₂, NOx, N₂O, CO₂, CH₄, PM, PN, THC plus NH₃



Trucks Vehicle Emission Testing Procedure

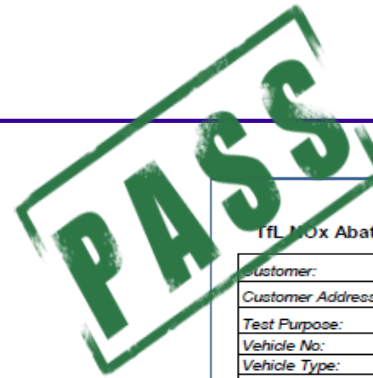
- Test procedure – Clean Vehicle Retrofit Accreditation Scheme
- Real world cycle – LowCVP UK Truck (LUT) Cycle.
 - Abbreviated TFL AM urban peak, + WHVC (WHVC urban and rural combined into single phase)
- Test to be undertaken at a vehicle laboratory using a chassis dynamometer
- Test conditions: 50% of payload up to max Dyno inertia – Track PEMS Test additionally for Large HGV exceeding Dyno capability
- Measurements: NO, NO₂, NOx, N₂O, CO₂, CH₄, PM, PN, THC plus NH₃



Clean Vehicle Retrofit Accreditation Scheme

- Chassis dyno testing at Millbrook required by engine type
- In service validation via telemetry to confirm > 80% reduction

Exhaust Emission Parameter		Limits	Reduction performance
Primary emissions			
Mixed oxides of nitrogen	NO _x	500mg/km	>80% reduction
Nitrogen dioxide	NO ₂	100mg/km	
Particulate Matter (mass)	PM	20mg (or 10mg) /km	
Particulate Matter (count)	PN	6x10 ¹¹ /km	
Secondary Emissions			
Nitrous oxide/Methane	N ₂ O/CH ₄ as CO ₂ e	<5% (or 3%) of CO ₂	Average Peak
Carbon dioxide	CO ₂	< 1% increase	
Ammonia	NH ₃	10ppm	
		25ppm	



TFL NOx Abatement Summary Sheet - MLTB Cycle							MILLBROOK		
Customer:	Eminox Ltd								
Customer Address:	Miller Road, Corringham Road Industrial Estate, Gainsborough, Lincolnshire, DN21 1QB								
Test Purpose:	TFL development and testing								
Vehicle No:	LJ13 FDP								
Vehicle Type:	Volvo BSH			DYNAMOMETER SETTINGS					
Engine:	Euro V Diesel Hybrid			INERTIA	14,632 kg				
Transmission:	Auto			F*	555.93 N				
Fuel Type:	Pump Diesel			F*	-7.9750 N/kmh				
Fuel Batch No:	N/A			F*	0.41900 N/kmh ²				
Millbrook Project No:	PT0120-018-01			F*	-0.0019520 N/kmh ³				
Test No. 6282, 6285, 6288	Engine Summary								
Date	17/02/2017		NOx	NO ₂	N ₂ O	CH ₄	CO ₂ **	CO ₂ eq	NH ₃
	Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (max)
	Analyser:		MODAL	MODAL	FTIR (Eng)	FTIR (Eng)	BAG	Calculated	FTIR (Eng)
Phase 1	Outer London		11.895	1.369	N/A	N/A	919.3	0.00	N/A
Phase 2	Inner London		15.546	2.251	N/A	N/A	1223.3	0.00	N/A
	Combined result		12.908	1.614	N/A	N/A	1003.6	0.00	N/A
Test No. 6282, 6285, 6288	Tailpipe Summary								
Date	17/02/2017		NOx	NO ₂	N ₂ O	CH ₄	CO ₂	CO ₂ eq	NH ₃
	Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (max)
	Analyser:		MODAL	FTIR	FTIR (Tail)	FTIR (Tail)	MODAL	Calculated	FTIR (Tail)
Phase 1	Outer London		0.240	0.030	0.102	0.000	916.5	30.4	8.70
Phase 2	Inner London		0.473	0.055	0.123	0.000	1168.3	36.6	4.14
	Combined result		0.305	0.037	0.108	0.000	986.3	32.1	8.70
	Change vs Baseline		-97.6%	-97.7%			-1.7%		Pass
	Targets								
	Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (Avg)
	Analyser:		BAG	FTIR			MODAL	Calculated	FTIR
Target			0.5g/km	0.1g/km			Within +1% of Baseline result (+2% accuracy)	Less than 5% of total CO ₂ emissions	10ppm or lower
Relative Limit			0.500	0.10			1033.7	5%	10.0
Combined result			0.336	0.04			986.3	3.15%	3.0
			67%	37%			95.4%		30%
Pass/Fail			Pass	Pass			Pass	Pass	Pass
**Baseline CO2 Result taken from ML02016265, ML02016266, ML02016267. Three test conducted using same calibration, not performed consecutively. Based on Millbrook's in house validation of CO2 <=2% these three test results result in a failure on repeatability due to CO2 repeatability of 3.45%									
CO2 equivalence factors: CO2 : 1 - N2O : 298 - CH4 : 25									
Compiling Engineer:			DATE: 20/02/2017			Approving Engineer:			DATE: 21/02/2017

Approved Technology for CVRAS

SCRT[®] retrofit technology for Euro VI emissions levels

Retrofit



Plus :-

On Board Diagnostics integration

Real time Telemetry data

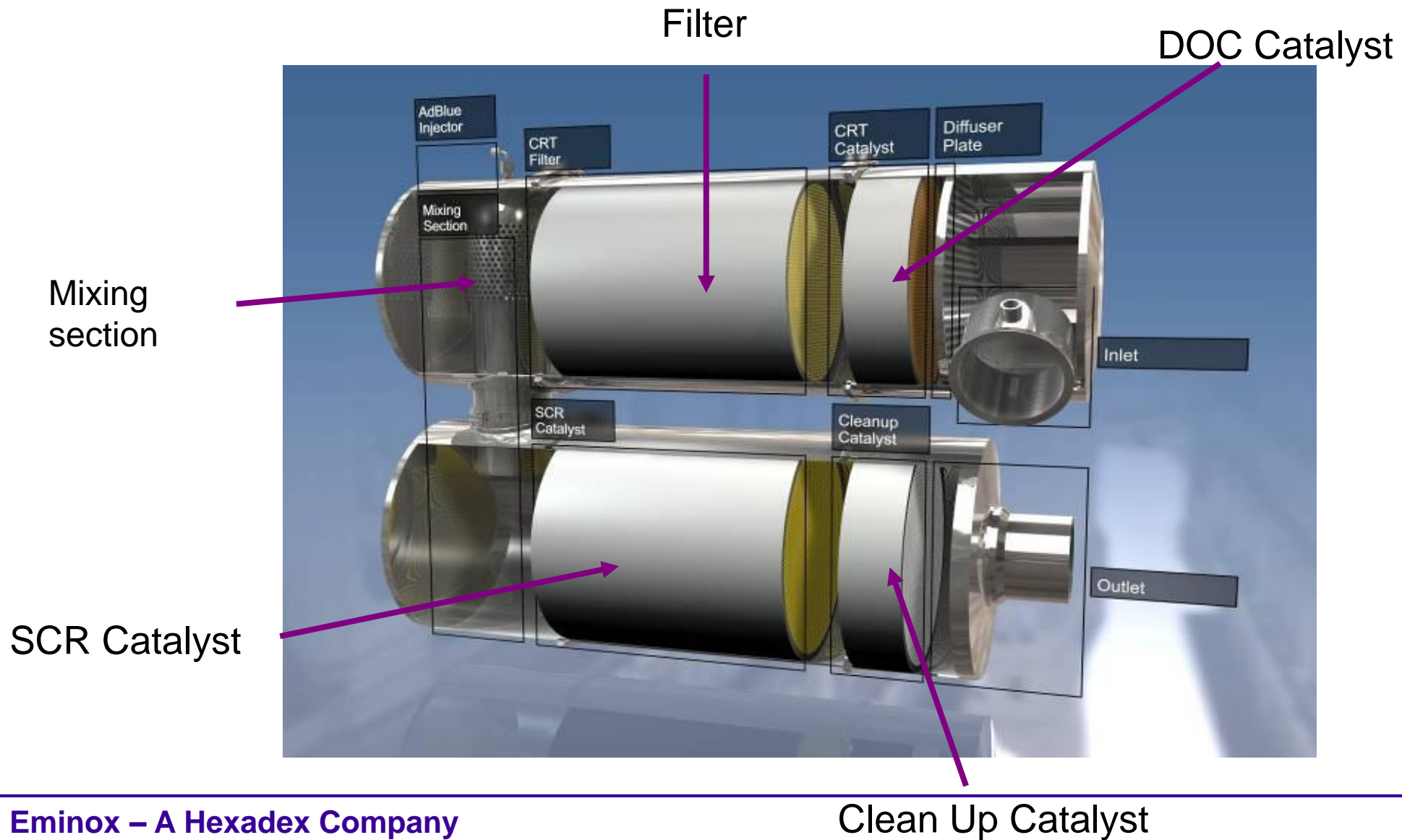


CRT and SCRT are registered trademarks of Johnson Matthey plc

Eminox – A Hexadex Company



SCRT® System Schematic



Eminox SCRT® system development process:-

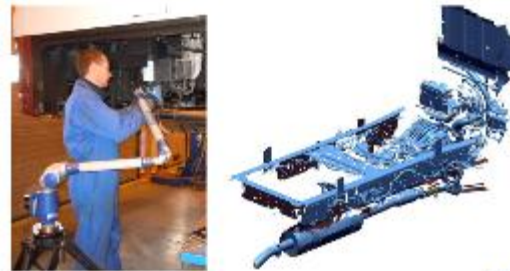
Each system variant needs to be :-

- Designed
- Optimised
- Tested
- Proof fitted
- Field Trials

Prior to volume supply

SCRT® System Overview - Development process

- We utilize 3D Laser scanning technology to make a model of the bus chassis

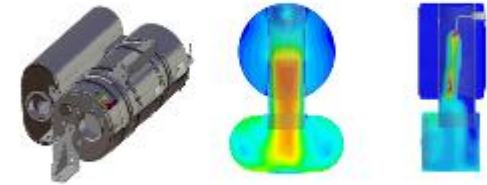


Clean Vehicle Technology

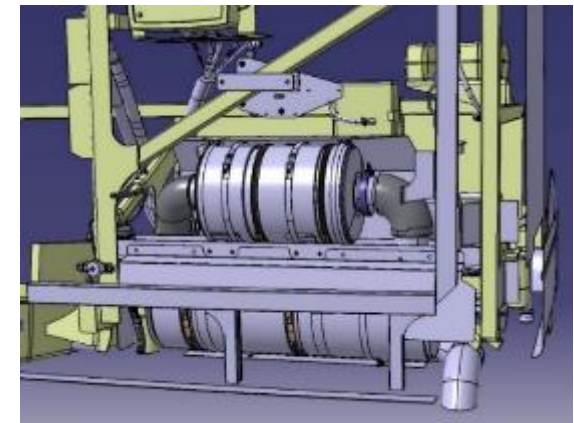


SCRT® System Overview - Development process

- We use CFD to model velocity, urea injection and mixing prior to series production

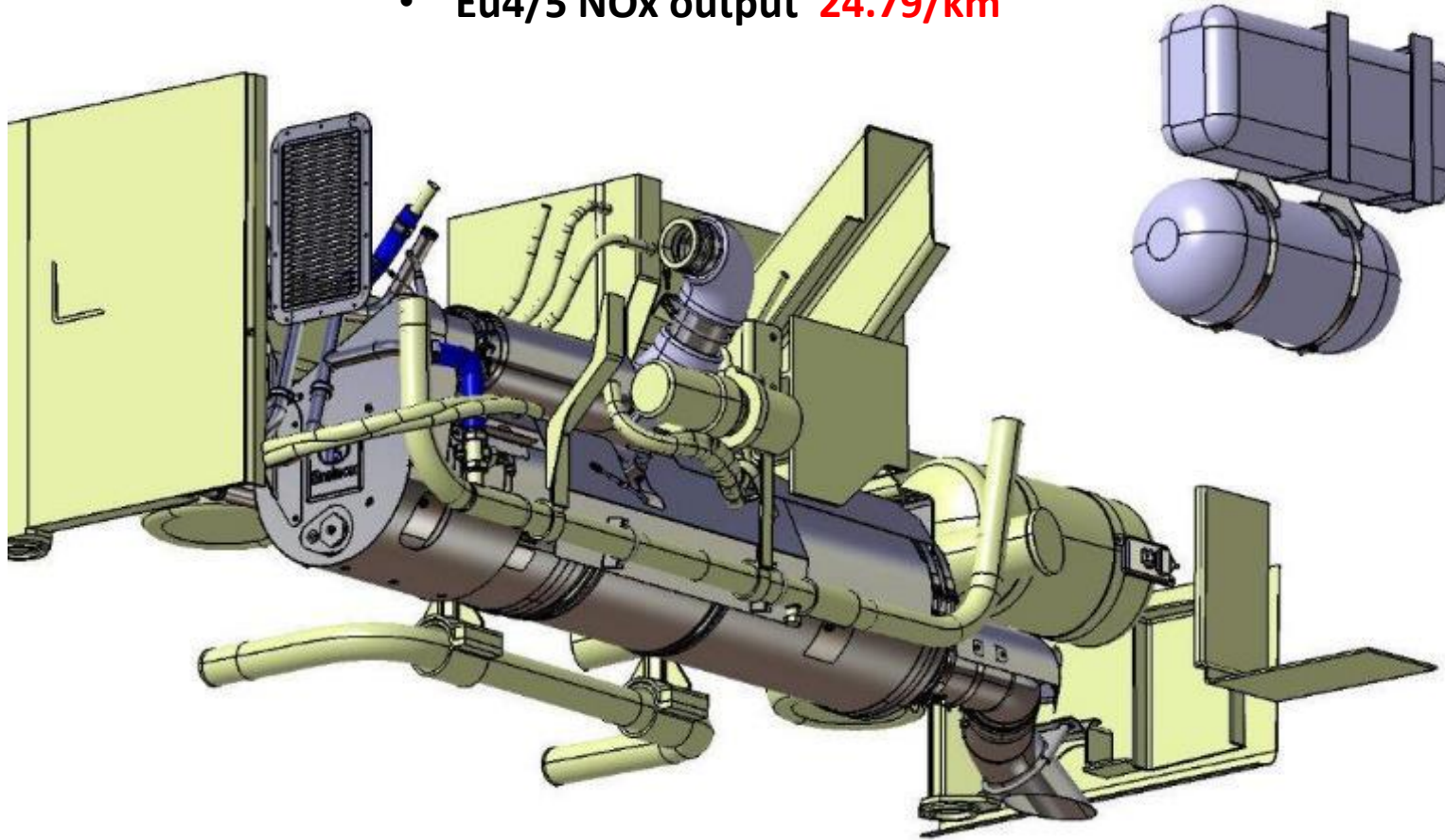


Clean Vehicle Technology



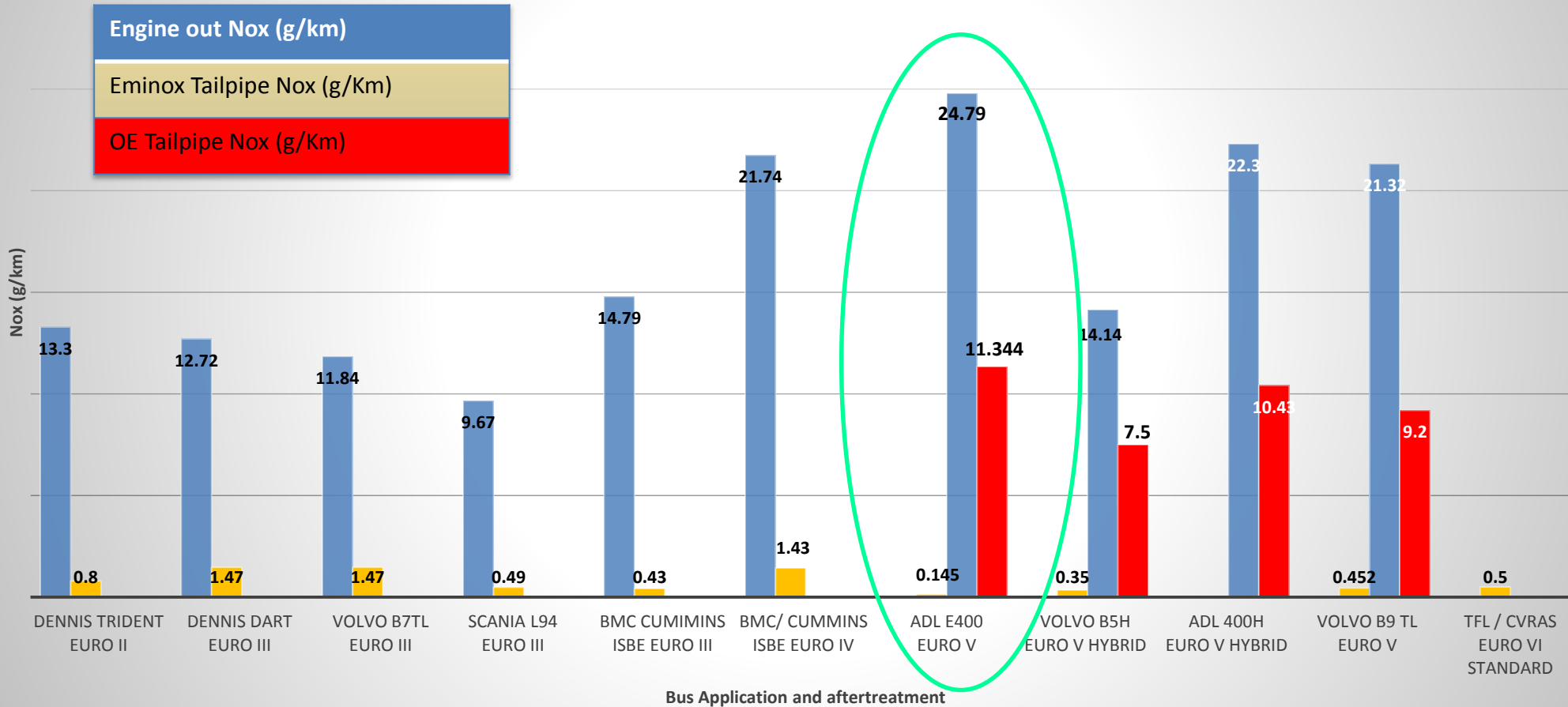
Much higher engine out NOx levels from newer vehicles (Cummins 6.7L)

- Eu3 NOx output **11g/km**
- Eu4/5 NOx output **24.79/km**



Eminox Retrofit SCRT Emissions Improvements - 99.5% reduction

Comparison of Engine out NOx v Tailpipe NOx on Euro II, III, IV and V vehicles over MLTB cycle



SCRT Euro V to IV = validated at Millbrook

TFL NOx Abatement Summary Sheet - MLTB Cycle		MILLBROOK	
Customer:	Eminox Ltd		
Customer Address:	Miller Road, Corringham Road Industrial Estate, Gainsborough, Lincolnshire, DN21 1QB		
Test Purpose:	TFL NOx Abatement Testing		
Vehicle No:	YX12 FPE		
Vehicle Type:	ADL E400	DYNAMOMETER SETTINGS	
Engine:	Diesel Euro V to Euro VI retrofit	INERTIA	14403 kg
Transmission:	Auto	F*	88.97 N
Fuel Type:	Diesel	F*	0.3610 N/kmh
Fuel Batch No:	N/A	F*	0.38530 N/kmh *
Millbrook Project No:	PT0120-020-01	F*	-0.0020330 N/kmh *



Test No. 6539, 6540, 6541		Engine Summary						
Date	05/06/2017	NO _x	NO ₂	N ₂ O	CH ₄	CO ₂	CO ₂ eq	NH ₃
Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (max)
Analysed:		MODAL	MODAL	FTIR (Eng)	FTIR (Eng)	BAG	Calculated	FTIR (Eng)
Phase 1	Outer London	22.630	0.749	N/A	N/A	1124.2	0.0	N/A
Phase 2	Inner London	30.566	3.471	N/A	N/A	1538.8	0.0	N/A
Combined result		4.791	2.232	N/A	N/A	1239.5	0.0	N/A

Test No. 6539, 6540, 6541		Tailpipe Summary						
Date	05/06/2017	NO _x	NO ₂	N ₂ O	CH ₄	CO ₂	CO ₂ eq	NH ₃
Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (max)
Analysed:		MODAL	FTIR(Tail)	FTIR (Tail)	FTIR (Tail)	BAG	Calculated	FTIR (Tail)
Phase 1	Outer London	0.117	0.012	0.240	0.000	1111.1	71.6	7.34
Phase 2	Inner London	0.217	0.007	0.198	0.000	1488.3	59.2	6.67
Combined result		0.145	0.010	0.229	0.000	1210.9	68.2	8.28
Change vs Baseline		-99.4%	-99.5%			-2.3%		Pass

Targets							
	NO _x	NO ₂	PM	PN	CO ₂	CO ₂ eq **	NH ₃
Units:	g/km	g/km	g/km	µg/km	g/km	g/km	ppm (Avg)
Analysed:	BAG	FTIR(Tail)	Filter Weight	PMP	BAG	Calculated	FTIR
Target	0.5g/km	0.1g/km	0.01g/km	6.00E+11/km	Within +1% of Baseline result (+2% accuracy)	Less than 5% of total CO ₂ emissions	10ppm or lower
Relative Limit	0.5	0.1	0.0	6.00E+11	1278.7	5%	10.0
Combined result	0.165	0.010	0.0063	4.82E+11	1210.9	5.33%	3.11
Pass/Fail	33%	10%	63%	77%	5.2%		31%
Pass/Fail	Pass	Pass	Pass	Pass	Pass	Fail	Pass

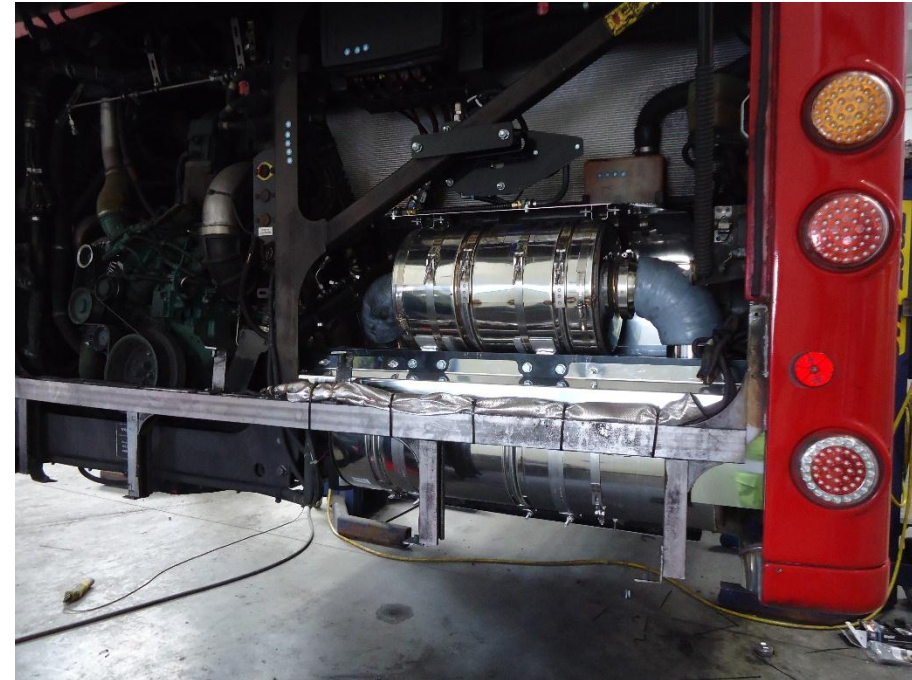
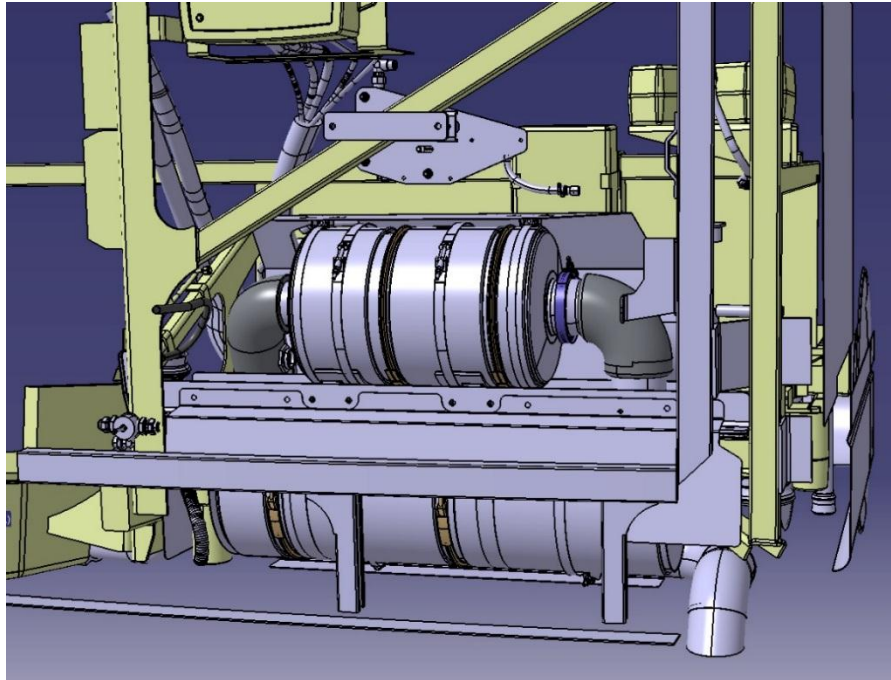
*Baseline CO₂ results taken from tests ML02016040, ML02016041 & ML02016042 run in 2016
 Candidate tests are - ML02016539, ML02016540 & ML02016541, conducted on 5 June 2017
 ** Concession on CO₂ eq result given by Finn Coyle (TFL), 06 June 2017

CO₂ equivalence factors: CO₂ : 1 - N₂O : 298 - CH₄ : 25

Compiling Engineer:  DATE: 05/08/2017 Approving Engineer:  DATE: 07/08/2017

Test No. 6539, 6540, 6541		Tailpipe Summary						
Date	05/06/2017	NO _x	NO ₂	N ₂ O	CH ₄	CO ₂	CO ₂ eq	NH ₃
Units:		g/km	g/km	g/km	g/km	g/km	g/km	ppm (max)
Analysed:		MODAL	FTIR(Tail)	FTIR (Tail)	FTIR (Tail)	BAG	Calculated	FTIR (Tail)
Phase 1	Outer London	0.117	0.012	0.240	0.000	1111.1	71.6	7.34
Phase 2	Inner London	0.217	0.007	0.198	0.000	1488.3	59.2	6.67
Combined result		0.145	0.010	0.229	0.000	1210.9	68.2	8.28
Change vs Baseline		-99.4%	-99.5%			-2.3%		Pass

Volvo B5 Hybrid - Challenging inner city stop / start duty cycles



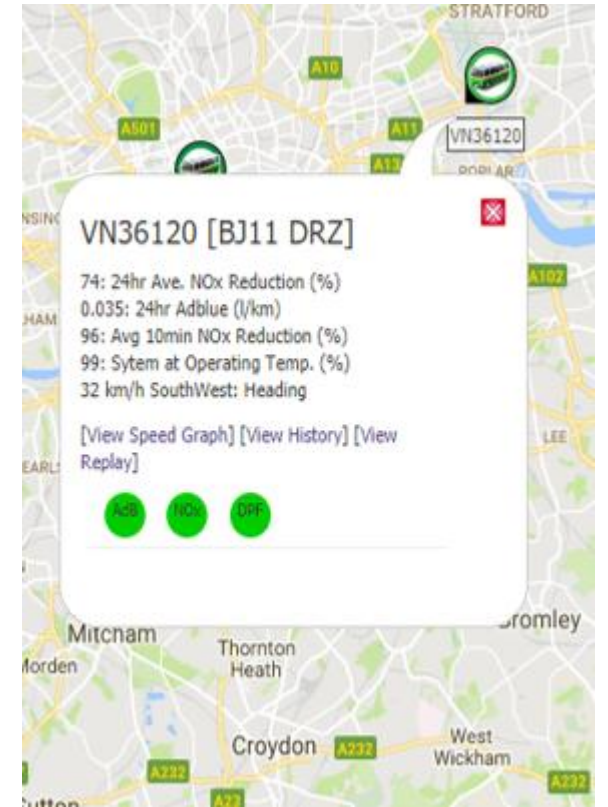
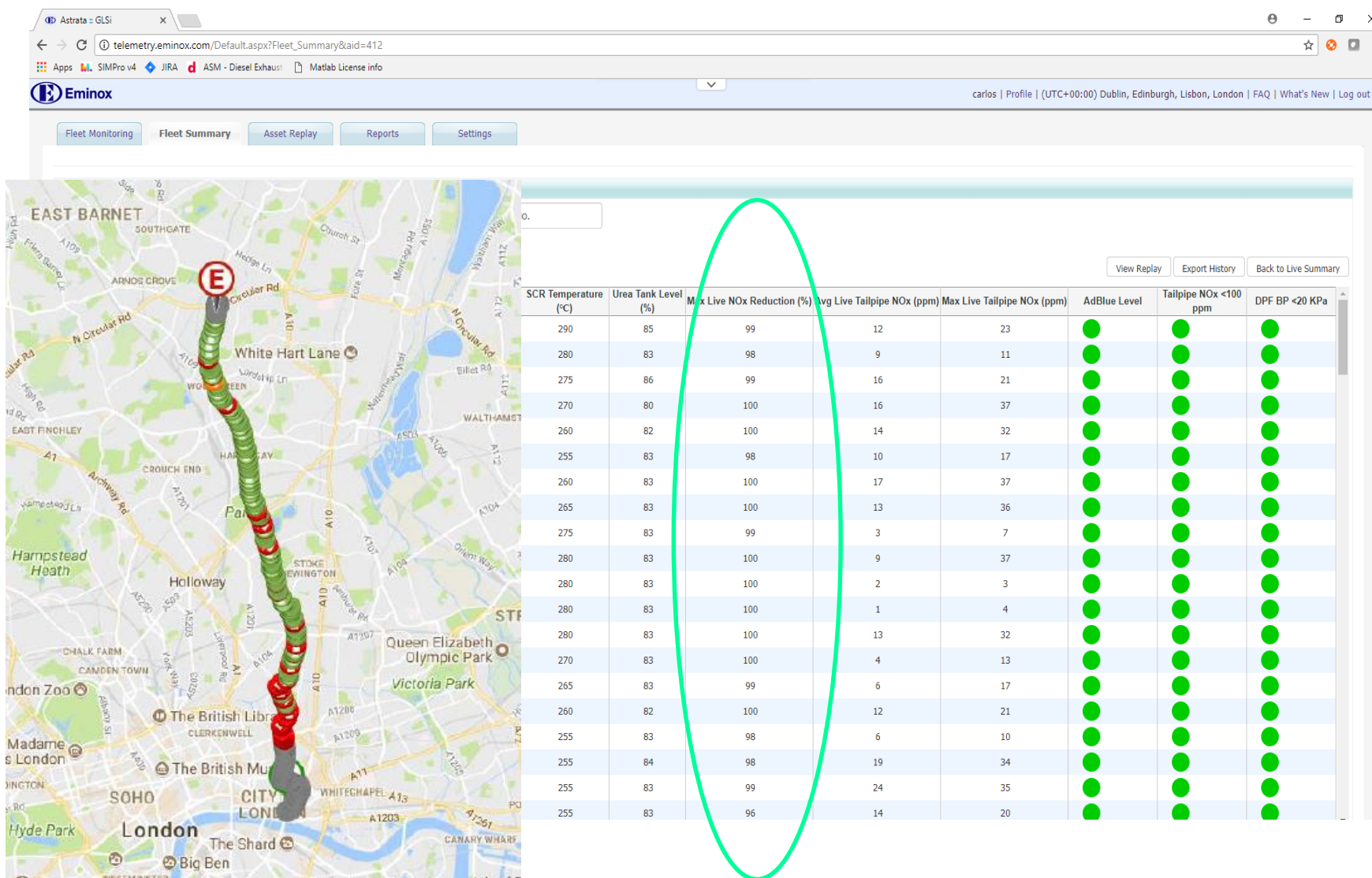
Euro 5 Hybrid bus – Test result over London MLTB Cycle = 97.7% NO_x & NO₂ reduction

In service compliance & real time monitoring

- Control and Diagnostics Interface (CADI) + telemetry systems
- On board diagnostic integration for Euro V (De-rate)
- Real time monitoring of system performance
- Maintenance alerts for operators
- 80% in service performance is a CVRAS requirement



Validated in service via Telemetry....



Technology Partners - Scandinavia & UK



- Unique Ammonia dosing systems that can operate in low climate or exhaust gas temperatures
- Collaboration for the Scandinavia market
- Lowest results ever recorded at Millbrook from Retrofit SCR technology
- UK co-operation was launched at Coach & Bus UK in October to target new market sectors
- Suited for challenging duty cycles such as RCVs and Non Road Equipment



Technology Partners - Germany

- Announcing today at the VERT Forum **New** partnership to help reduce diesel emissions in Germany!
- PURltech of Germany + Eminox Limited Collaboration to supply retrofit Euro VI solutions for the German Market
- 28 air quality regions & more than 60 municipalities across Germany, need to take action to reduce pollution.
- €150m, as part of the €1bn funding programme Clean air 2017-2020, to upgrade city buses using retrofit technology
- Again system will need to comply with Euro VI emission standards and reduce NO2 emissions accordingly.



Eminox **PURltech**
ARGASTECHNIK - EMISSIONSTECHNOLOGIE

**Working Together
for
Cleaner Air**

**Eine starke Allianz
für
Saubere Luft**

www.puritech.de
Follow us  

The graphic features a stylized green leaf shape on the left side, composed of a network of white lines representing a city street grid. The background is white with a blue footer bar.

Eminox Retrofit solutions



- Over 99% reduction of pollutant emissions is possible



- Upgrades Euro III IV & V vehicles to Euro VI emissions levels
- Proven in real world tests, supported by in service telematics
- Upgrade around 15 buses for the cost of one new bus !**



Questions ?

carlos.vicente@eminox.com