9th VERT Forum 2018

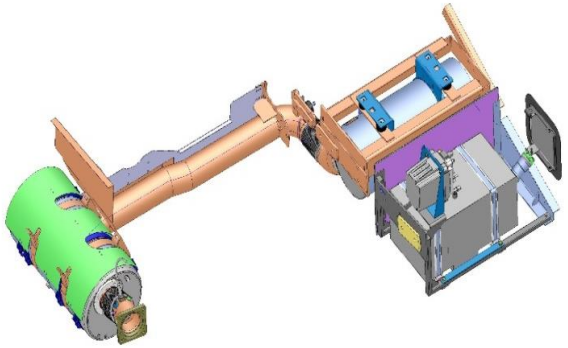
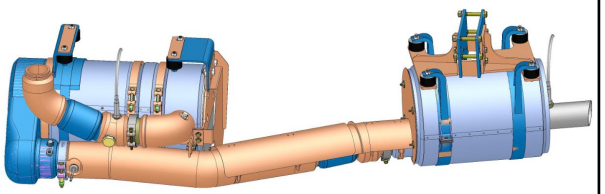
Upgrading EU V City Busses towards EU VI Emissions under Real Driving Conditions

Klaus Schrewe – March, 15th 2018 - Dübendorf, CH

Content – Upgrading EU V City Busses towards EU VI Emissions under Real Driving Conditions

Upgrading EU V City Busses to EU VI Emissions at Real Driving Conditions

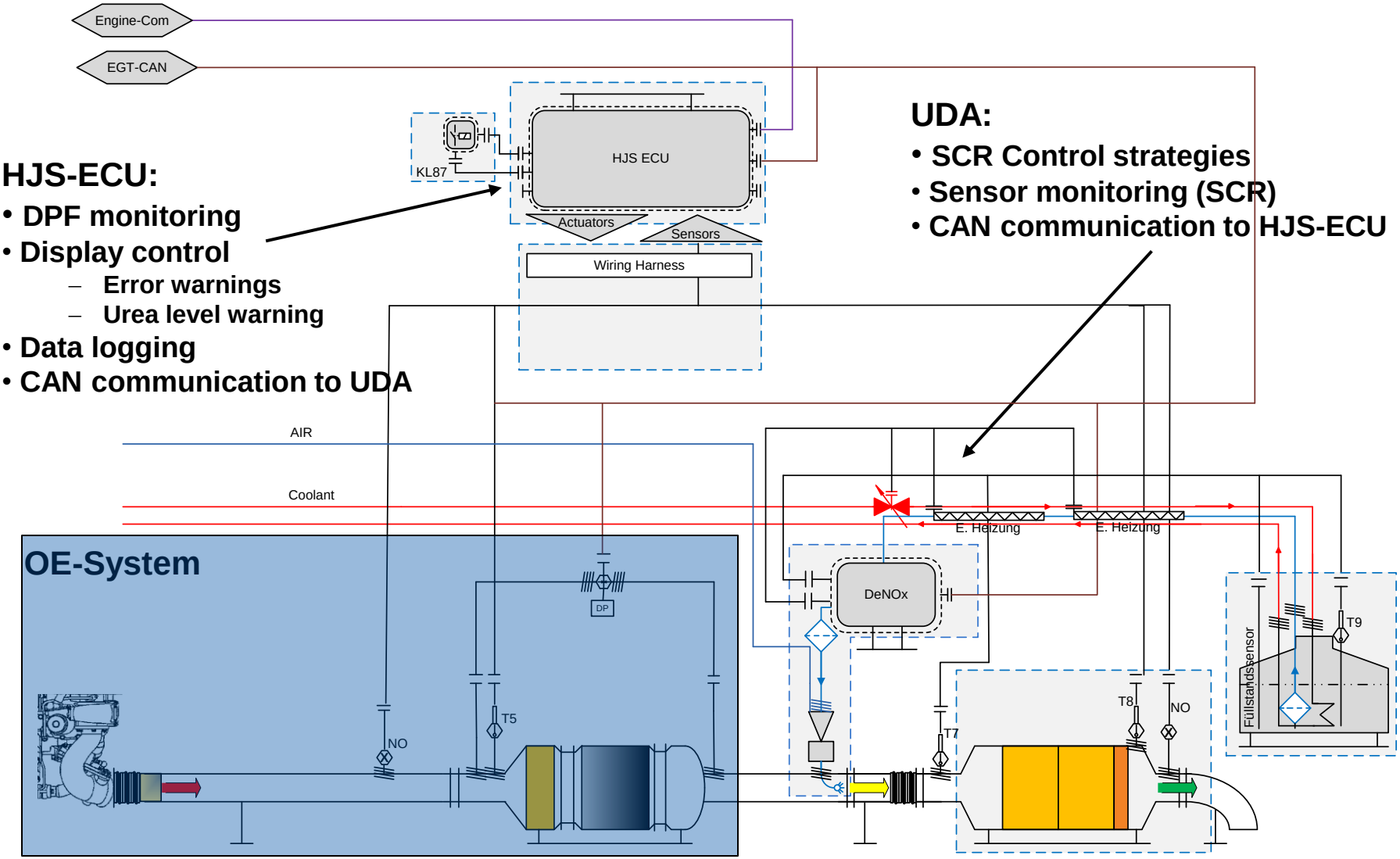
HJS DeNO$_X$ Technologies for City Busses – Bus / Engine Types

Bus Type	Engines / EGT	EGT Upgrade ⇨ EU VI
 e.g. MAN A23 articulated	Engines: Displacement: 6,5 L – 10,5 L Power: 162 kW - 265 kW Emission class: EU V / EEV **Serial EGT:** **EGR + DOC + DPF**	**Autarcic SCR(T)-System** 
 e.g. ADL Trident Enviro 400 H	Engine: Displacement: 4,5 L – 12,0 L Power: 132 kW - 265 kW Emission class: EU V / EEV **Serial EGT:** **SCR(T)**	**Integrated SCR(T)-System** 

Autarcic SCRT® – System Overview

HJS-ECU:
- **DPF monitoring**
- **Display control**
  - **Error warnings**
  - **Urea level warning**
- **Data logging**
- **CAN communication to UDA**

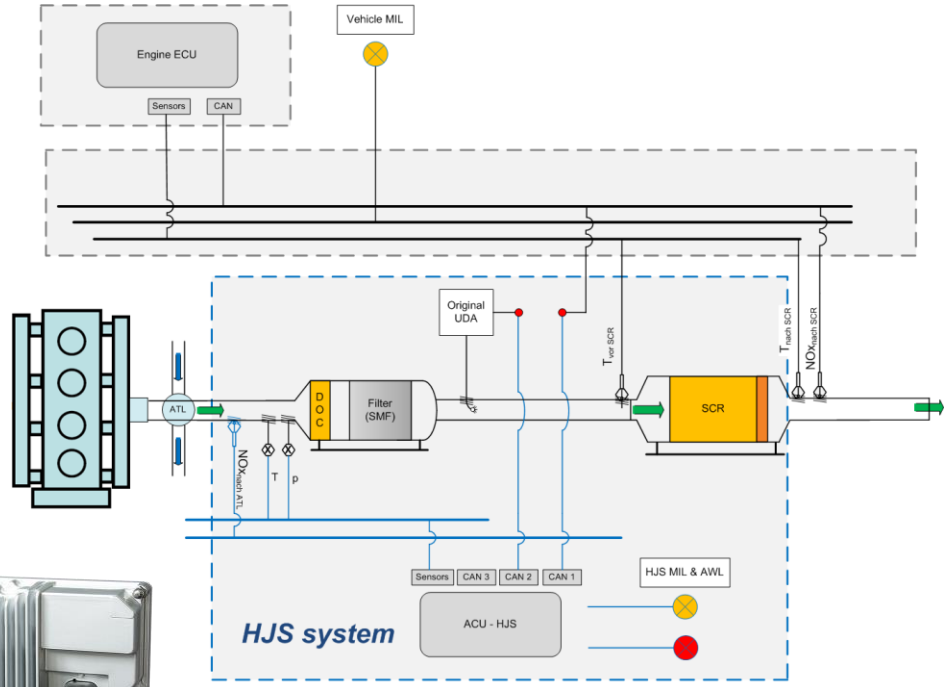
UDA:
- **SCR Control strategies**
- **Sensor monitoring (SCR)**
- **CAN communication to HJS-ECU**



Integrated SCRT® – System Overview

Components of the OE EGT system maintain in the bus

- AdBlue Tank
- AdBlue Dosing System (if applicable)
- NO_X sensor(s)
- Temperture sensor(s)



HJS ACU control unit

- **Increase quantity of urea injection to new target level**
- **(Max quantity of OE-ECM or HJS-ACU will be injected)**

Original Engine Control Unit

Reception of all relevant information via CAN-Bus

Feedback of status of dosing pump via CAN-Bus

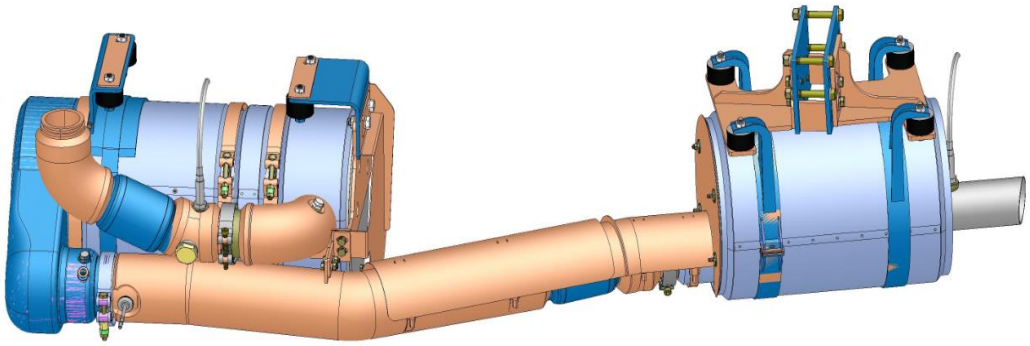
Original Dosing system

Integrated SCRT® – System Description

Applied Technology

Hardware:

- ACU as basis for functional and diagnosis requirements
- Latest generation of VWT-catalysts to achieve very high NO_X-reduction
- DOC; adaption of coating: NO_2 < 50 % (trade off filter regeneration vs. NO_X reduction)
- Latest generation ASC to avoid formation of N_2O
- Wall flow filter (Cordierite; SMF)
- GSM capable data logger



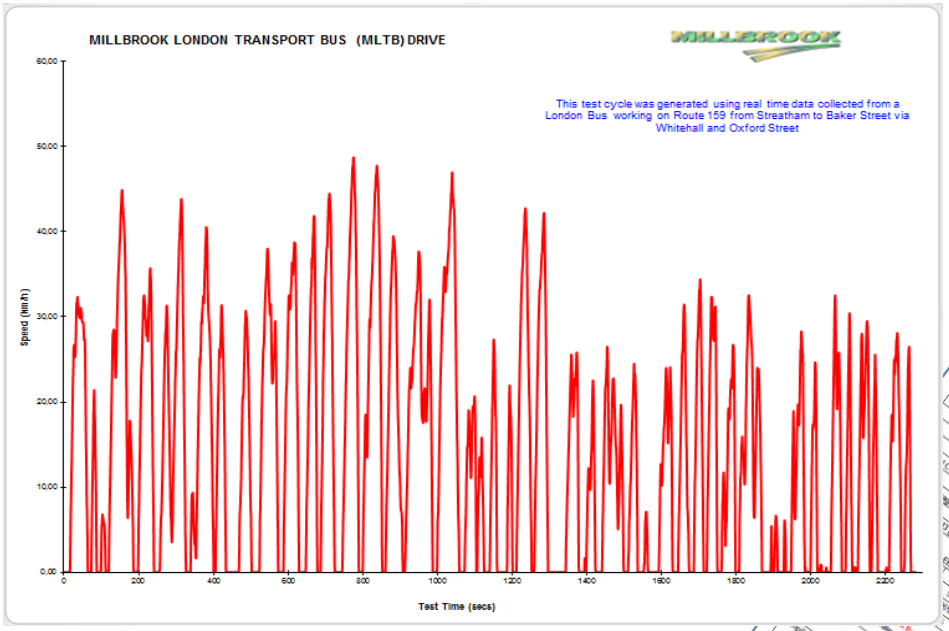
Applied Technology

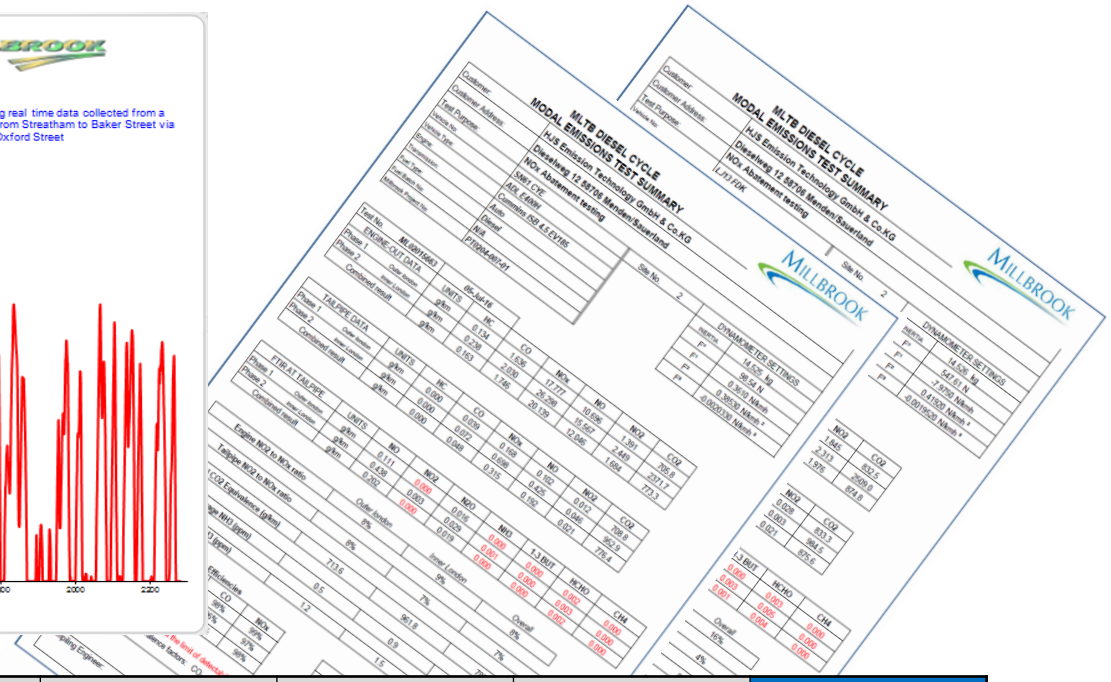
Software:

- ACU as CAN Gateway: Use of vehicle infrastructure possible.
  - Dosing system of vehicle (Cummins only)
  - Temperature- and NO_X-Sensors of vehicle continuously used
  - AdBlue - level display of vehicle continuously used
- ACU as interface to vehicle OBD;
  - Derate-functionality of vehicle remains
  - Function carry over of original OBD
- ACU dosing strategies to fulfill TfL emission demands comparable EU VI
- Connection of Remote Monitoring to ACU
- Integration CRT and SCR in one control unit

Upgrading EU V City Busses to EU VI Emissions at Real Driving Conditions

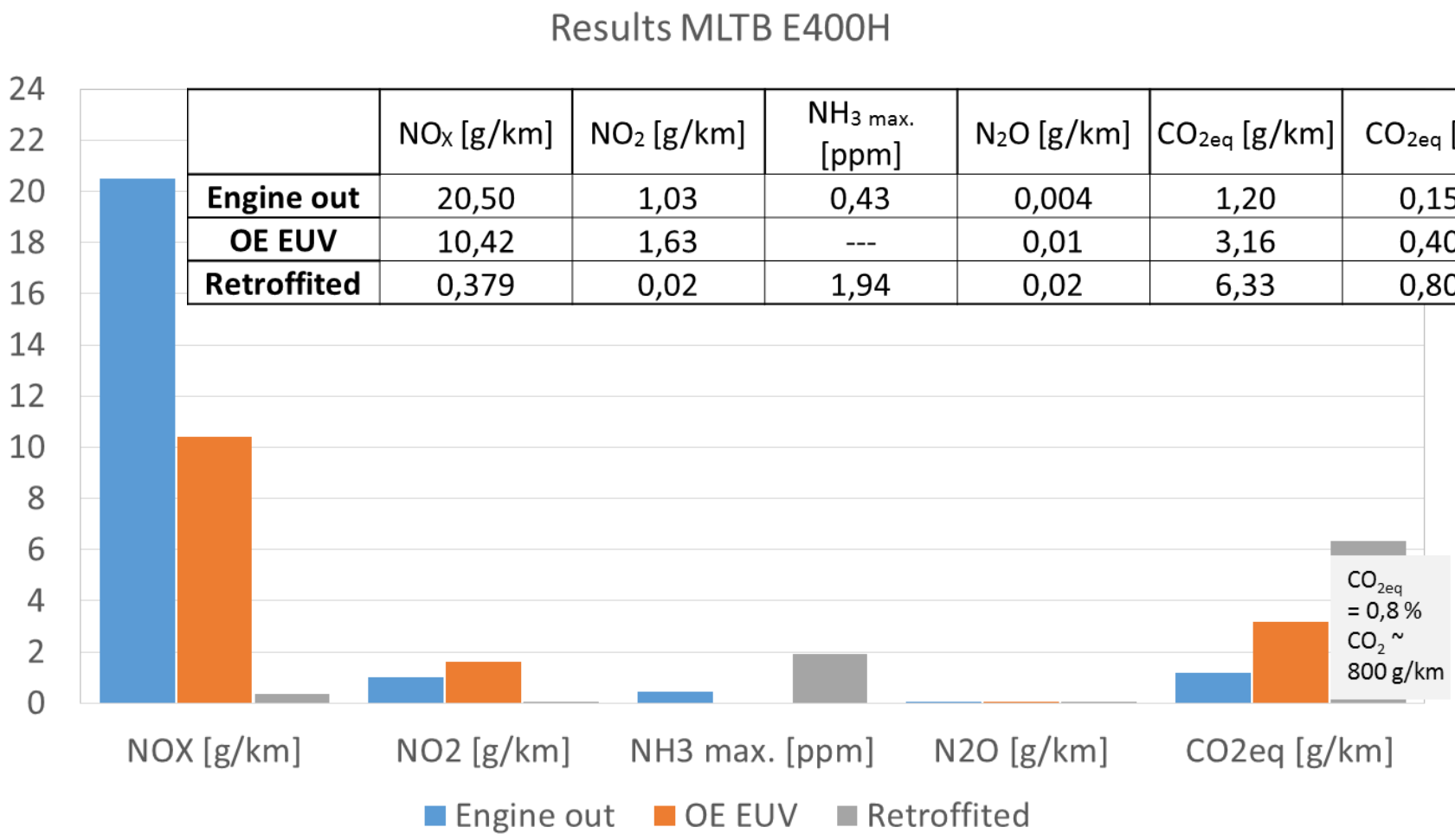
Results MLTB Cycle / TfL – Cycle and HJS Results





Vehicle	Engine	Standard	Cycle	NO_X orginal [g/km]	NO_X Retrofit [g/km]	NO_X Reduction
Enviro 400	ISBe 4,5 H	EURO V	MLTB	10,42	0,379	**96%**
Volvo	B5H	EURO V	MLTB	7,45	0,349	**95%**
Enviro 400	ISBe 6,7	EURO V	MLTB	11,34	0,08	**99%**
Enviro 200	ISBe 4,5	EURO V	MLTB	8,63	0,265	**97%**
Volvo B9	B9	EURO V	MLTB	9,21	0,197	**98%**

Results MLTB Cycle / TfL – E400 H Cummins in Detail



	NO_X [g/km]	NO_2 [g/km]	NH_3 max. [ppm]	N_2O [g/km]	CO_{2eq} [g/km]	CO_{2eq} [%]
Engine out	20,50	1,03	0,43	0,004	1,20	0,15
OE EUV	10,42	1,63	---	0,01	3,16	0,40
Retroffited	0,379	0,02	1,94	0,02	6,33	0,80

Upgrading EU V City Busses to EU VI Emissions at Real Driving Conditions

German City Bus Retrofit Program – Approach IUC Testing EU VI

Test according City Bus Cycle Euro VI (595/2009, 582/2011, 2016/1718)

- 70% inner city, 30 % rural (time based, starting in city)
- Mean velocity city: 15 – 30 km/h, mean velocity rural 45 – 70 km/h
- Payload 50% - 60%
- Cycle duration approx. 2,5 h (acc. 4 – 7 x WHTC (30 min) cycle work)

Targets for NO_X reduction

- Reduction of NO_X in average by approx. 70% in relation to EU V / EEV emission level at IUC testing into area of EU VI IUC results:

10 km/h	15 km/h	20 km/h	25 km/h	30 km/h
7,5 g/km	5,0 g/km	4,0 g/km	3,0 g/km	2,5 g/km

- **After discussion with NGOs and Association of German Transport Companies (VDV) conditions for German City Bus Retrofit Program were significantly tightened!**

German City Bus Retrofit Program – General Conditions

Test Cycle (more severe than EU VI IUC)

- Measuring runs under real driving conditions.
- **3 consecutive test runs**, each individual composed of 125 min [± 5min.] representative for local public transport, including stops. **The engine of the vehicle is switched off for 15 minutes between the measuring runs.**
- **Average speed of each measuring run must be between 10 km/h and 30 km/h. At stops doors to be opened for 15 seconds.**
- **Vehicle payload has to be 30 % of the maximum vehicle payload**
- Evaluation of the data beginning if coolant temperature reaches 343 K (70 °C) for the first time or at the latest 15 minutes after engine starting

Assessment criteria for NO_X reduction systems

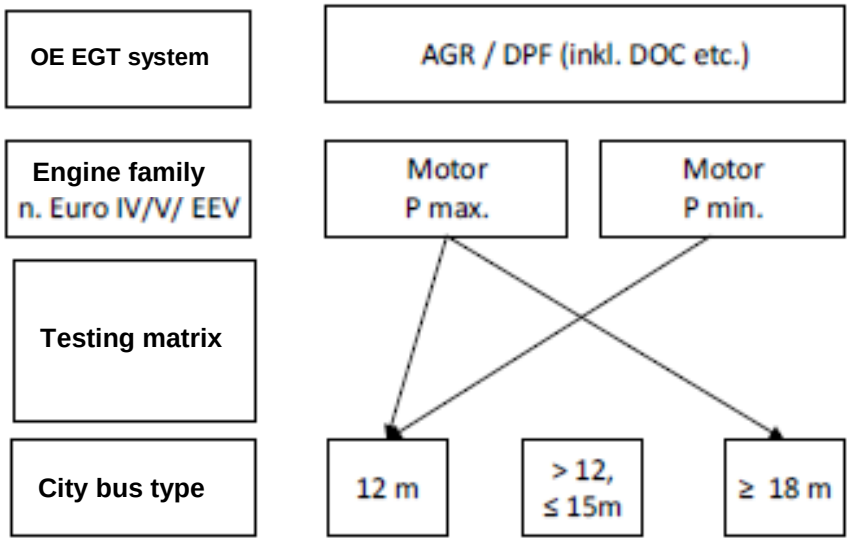
- Full flow DPF mandatory (Annex XXVII, FAD, VERT, R.132)
- The retrofitted NO_X reduction system must have a reduction rate of at least 85% based on the nitrogen oxide emissions (NO_X) raw emissions of the vehicle at ambient temperature ≥ -7°C.
- Route-related NO_X emissions in g/km in relation to the respective speed classes (± 2,5km/h) shall be in the area of EU VI IUC results and less than:

10 km/h	15 km/h	20 km/h	25 km/h	30 km/h
7,5 g/km	5,0 g/km	4,0 g/km	3,0 g/km	2,5 g/km

German City Bus Retrofit Program – Certification Procedure

Test families / groups for certification

- Groups for emission class EU III – EU IV – EU V / EEV
- Groups according OE EGT System
- Min./max. Engine Performance and min./max. city bus size to be covered



- **=> One family can be covered with approx. 3 city bus test runs with two channel PEMS**
- **OBD / NC** / warning and inducement systems existing for the serial system must be maintained without restriction in terms of their functionality and must be displayed in the same way.
- Emission compliance for 200.000 km or 4 years (with a DF of 1,15)

Upgrading EU V City Busses to EU VI Emissions at Real Driving Conditions

German City Bus Retrofit Program – Initial Results

SWO OSNABRÜCK-REALEMISSIONSMESSUNG

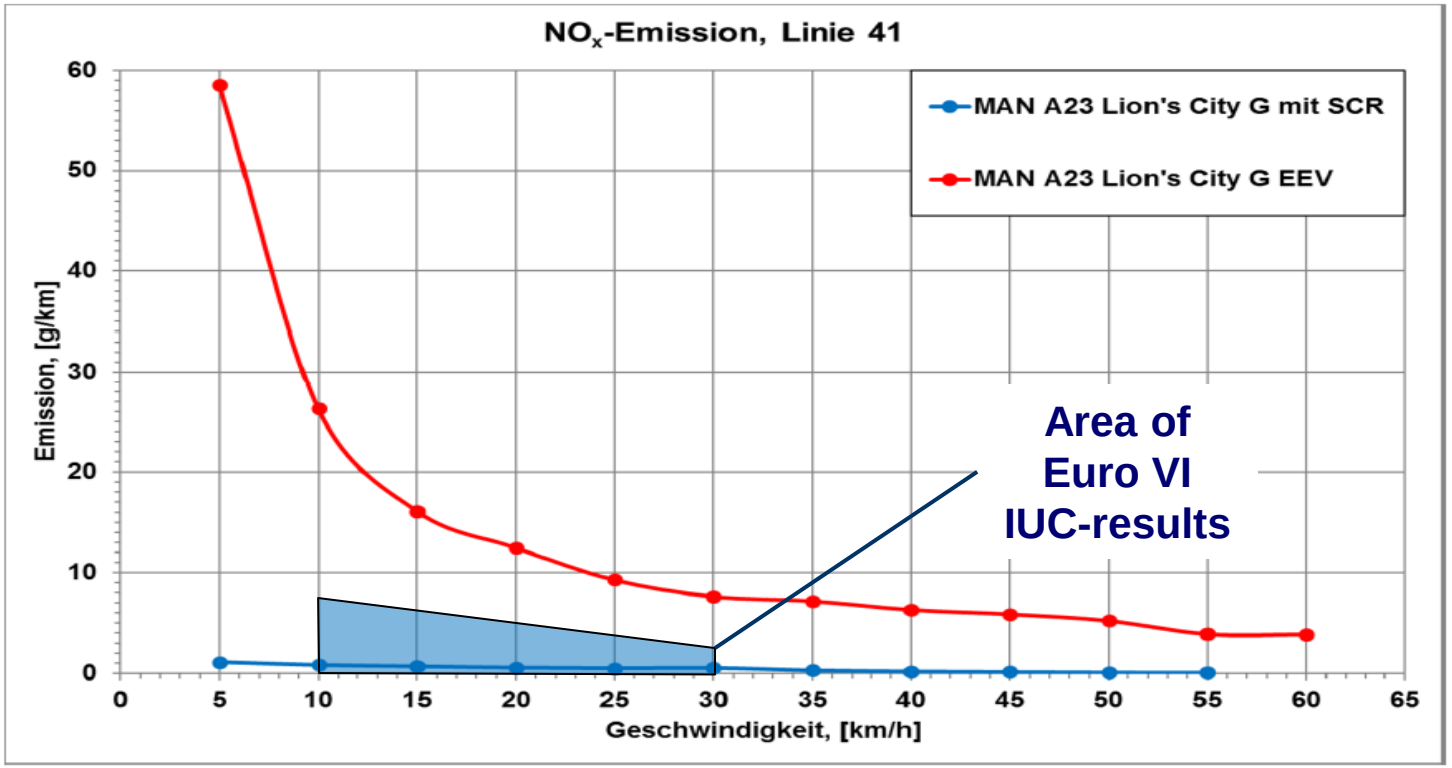
Abgasemissionsmessungen auf der Linienführung der Linie 41 mit einem mit einer SCR-Abgasnachbehandlung nachgerüsteten MAN A23 Gelenkbus.

TÜV NORD

MAN A23 – 10,5 L – 235 kW - EEV

German City Bus Retrofit Program – Initial Results

ABGASEMISSIONSMESSUNGEN
STRECKENBEZOGENE EMISSIONSMASSEN



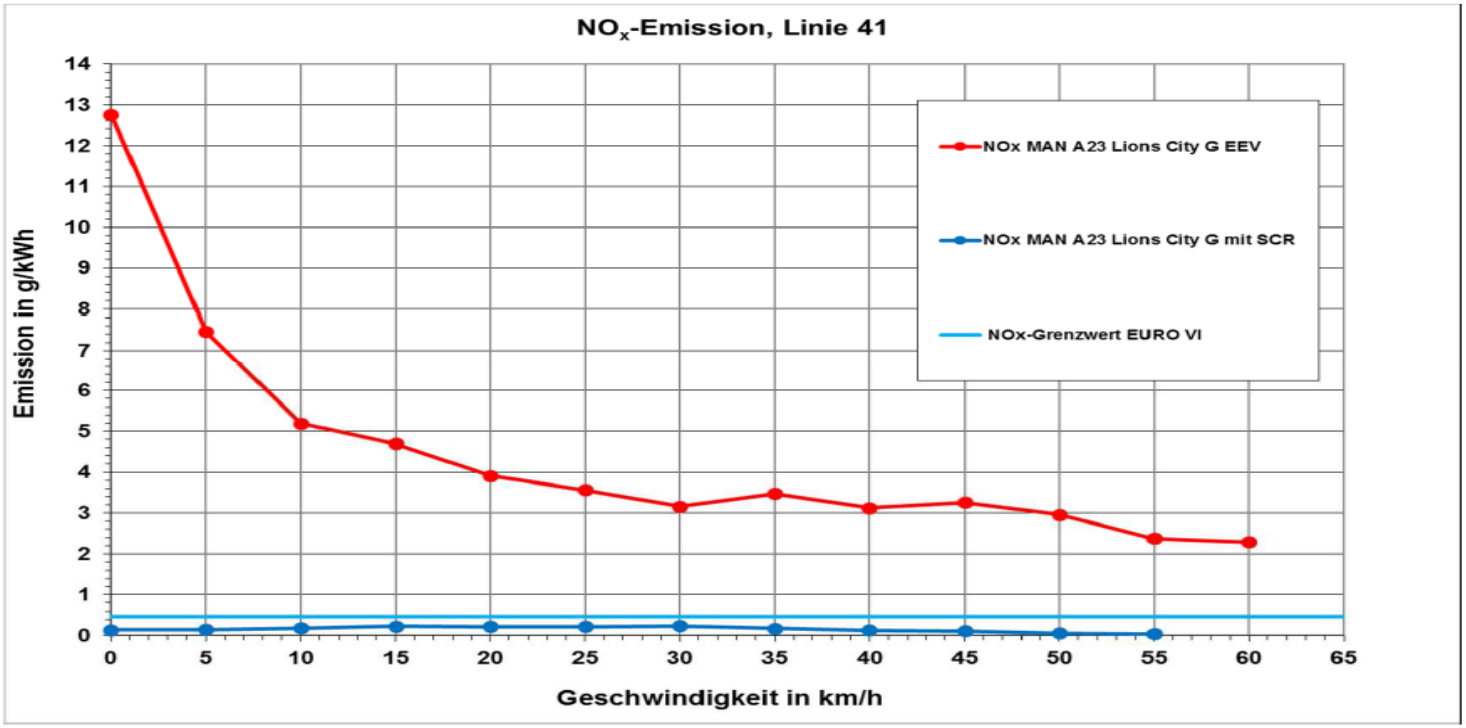
Normal city bus route, not 100% acc. „German test procedure“

TÜV NORD

HJS Emission Technology

German City Bus Retrofit Program – Results compared to EU VI

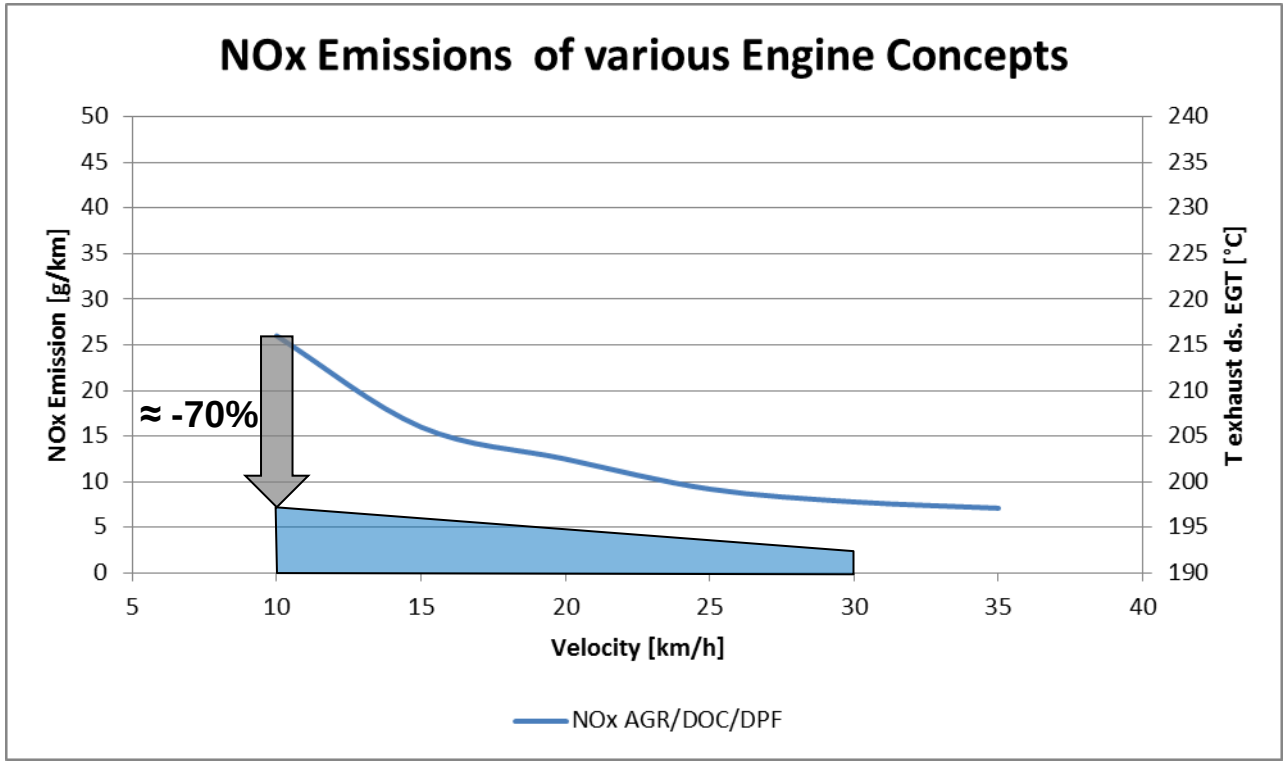
ABGASEMISSIONSMESSUNGEN
LEISTUNGSBEZOGENE EMISSIONSMASSEN



Some applications can achieve emissions at Euro VI level

Upgrading EU V City Busses to EU VI Emissions at Real Driving Conditions

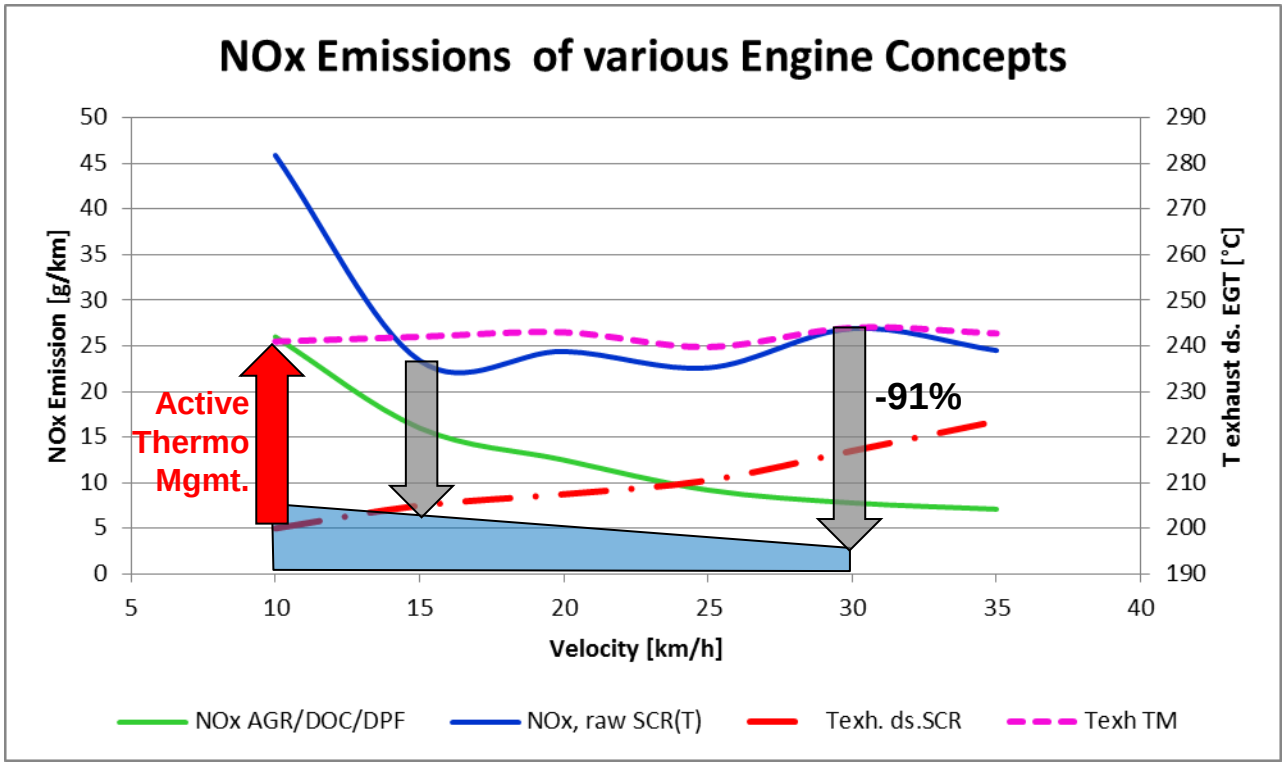
Conclusions



NO_X reduction targets (apporx. 70%) of German City Bus Retrofit Program in a city bus cycle seems to be comforable at the face of it, but:

- Maintaining of the serial OBD / NC warning and inducement systems
- NO_X reduction of 85% over entire cycle even at -7°C ambient temperature

Outlook – extremely challenging!



- Integration of a SCR(T) system with significatnly increased NO_X reduction into the serial OBD / NC warning and inducement system
- NO_X reduction of 79 to 91% at exhaust gas temperature between 200 and 220°C
- NO_X reduction of 85% over entire cycle even at lower exhaust gas temperatures due to -7°C ambient temperature

HJS Technology to fullfil German City Bus Retrofit Requirements

- Application of OE series prooved AdBlue dosing components
- Increase of exhaust gas temperature by smart active thermo management to realize high NO_X reduction and ensure DPF regeneration