DPF/FBC systems to reduce both PM and NO_2

Precious metals have been used for many years in diesel oxidation (DOC). A DOC is designed to reduce the level of carbon monoxide (CO) and hydrocarbon (HC) emissions but will also reduce particulate matter (PM) mass emissions by reducing the mass of adsorbed volatile material. However the DOC makes no significant difference to the number of particles emitted. The DOC also has negligible effect on the total oxides of nitrogen (NO_X) emitted. The effect of the DOC on nitrogen dioxide (NO_2) varies with temperature. At light duties and hence lower temperatures the DOC reduces the NO_2 emissions, however at high duty the DOC significantly increases NO_2 emissions such that overall the NO_2 emissions are increased. Data to support this was presented at the 7th International ETH Conference.

Work on a London Taxi Cab with a SiC wall flow diesel particulate filter (DPF) using an iron based fuel borne catalyst (FBC) not only gave 99% reduction of particulate number emissions but it has the added benefit of reducing emissions of NO_X and in particular NO_2. However it had little effect on the HC emissions. The use of a precious metal coating on such a filter has been proposed as an alternative regeneration method. However the work on the London Taxi Cab showed that this significantly increased NO_2 emissions, but did significantly reduce hydrocarbon and carbon monoxide emissions. Slide 4 shows the NO_2 data from the Taxi Cab with the alternative filter systems. Using the DPF/FBC system the total NO_2 emissions were reduced by 30% with the majority of this reduction occurring during the EUDC part of the test cycle. However when the catalysed DPF was used the total NO_2 emissions increased by 79%, again the majority of the difference occurred during the EUDC phase of the test cycle. The use of the DPF/FBC system produced similar results when applied to a >3.5 t truck. Slide 5 shows that the DPF/FBC system reduced NO_2 emissions by 23%.

However by using a non-precious metal coating on the DPF, to facilitate the reduction of hydrocarbons and carbon monoxide, a system was developed that reduced all the hazardous emissions. The FBC was used to facilitate regeneration of the system. This type of system was been demonstrated on a Euro I specification single deck bus as shown in slide 8, with the installation shown in slide 9. Engine details are given in slide 10. The bus was tested to the FIGE cycle as shown in slide 11. The CO emissions were reduced by 78% whilst the HC and PM emissions were reduced by 94% and 87% respectively. The NO_X emissions were also reduced by 11%, this is shown in slide 12. Besides being measured according to the regulated procedure NO_X emissions were also speciated using FTIR. The total NO_X emissions throughout the cycle are shown in slide 13 with the cumulative NO_X emissions shown in slide 14. The instantaneous NO_2 emissions are shown in slide 15 with the cumulative NO_2 emissions shown in slide 16. This shows that the NO_2 emissions were reduced by 89%. Following on from these promising early results further testing was undertaken with the base metal catalysed DPF with the FBC to ensure regeneration. Steady state testing was performed as part of the VERT Filter Test, Phase 1 using a Liebherr D914T engine. Testing was conducted according to the ISO 8178/4 procedure. Particle number measurements were performed using the SMPS instrument. The results at the 1400 rev/min, full load and 297 Nm test conditions are shown as slides18 and 19 respectively. This shows that the DPF is reducing particle numbers by over two orders of magnitude.

Secondary emissions measurements were also conducted by EMPA. The overall results of the regulated gaseous emissions measurements are shown in slide20. This shows a reduction of total HC and CO emissions of 65%. The total NO_X emissions were also reduced by 7%. The secondary emissions testing investigated the effect of the DPF/FBC system on PAH and nitro-PAH emissions. This is shown in slide 21 and shows that the overall PAH emissions were reduced by 99% with the DPF/FBC system and that the overall N-PAH emissions were reduced by 92%. Previous work with heavy metal FBCs has demonstrated that the DPF can act as a high temperature reactor and promote the production of dioxins and furans. However it has also been previously demonstrated that a base metal FBC and an uncatalysed DPF do not generate dioxins or furans even when the fuel is doped with additional chlorine. The base metal catalysed DPF in conjunction with the FBC was also tested to ensure that it did not produce dioxins or furans. The results of this testing showed clear reductions in the level of PCCD/F when using the DPF/FBC system with conventional diesel fuel. This is shown in slide 22. When the fuel was doped with additional chlorine there was again a small reduction of measured PCCD/F with the DPF/FBC system as shown in slide 23. The conclusion was thus drawn that the base metal catalysed DPF in conjunction with the base metal FBC gave “PCCD/F emissions factors comparable to those of the reference”.

Further vehicle testing was performed using a double deck bus that was to be used for city sightseeing tours. The bus is shown in slide 24 along with details of the DPF. Engine details are given in slide 25. This bus was tested according to the Millbrook London Bus Test (MLBT) cycle which is shown in slide 26. Again NO_X was speciated using the FTIR analyser. The instantaneous NO_2 emissions are shown in slide 27 with the cumulative NO_2 shown in slide 28. This shows that the overall NO2 emissions were reduced by 92%.

The conclusions drawn are;

- A DPF/FBC system will reduce the number of emitted particles by over two orders of magnitude, including the ultra-fine particles and will slightly reduce NO_X emissions but has little effect on HC or CO.
- A catalysed DPF with high Pt loading will reduce HC, CO and PM emissions but can significantly increase NO_2 emissions.
- A base metal catalysed DPF/FBC system not only reduced CO, HC and PM emissions it also reduced NO_X emissions and produced a significant reduction in NO_2 emissions
- The base metal catalysed DPF/FBC system will also reduce the number of emitted particles by over two orders of magnitude, including the ultra-fine particles
- A base metal catalysed DPF/FBC system has also been shown to significantly reduce PAH and N-PAH emissions
- The base metal catalysed DPF/FBC system does not increase PCCD/F emissions even when the fuel is doped with chlorine

DPF/FBC Systems to reduce both PM and NO_2

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OCTEL

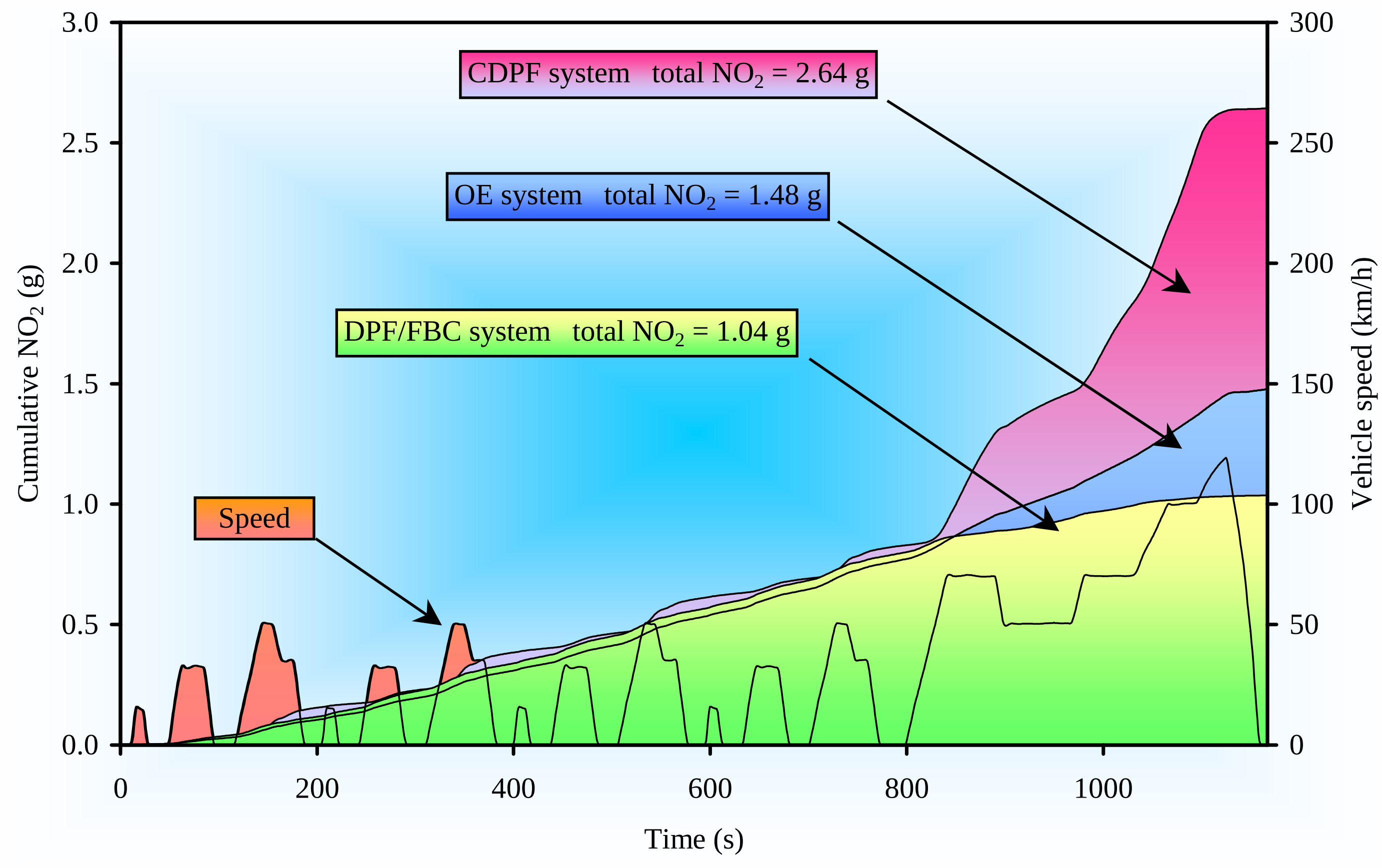
Presentation outline

- Introduction
- Preliminary field application
- Additional bench testing
- Further field application
- Conclusions

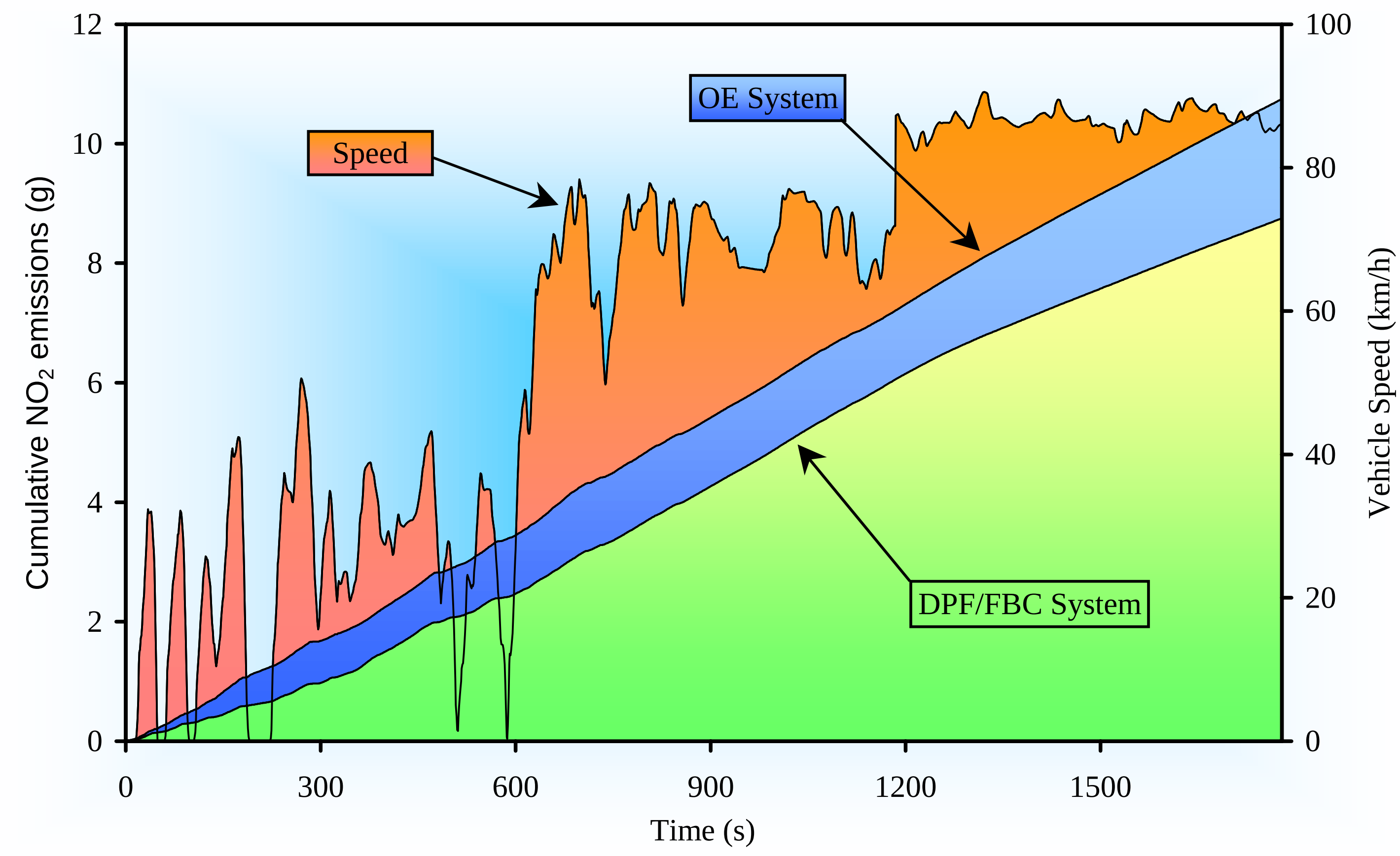
Introduction

- A DOC will reduce PM emissions
  - this is as a result of removal of the VOF
  - a DOC will not significantly effect the number of particles emitted
- A DPF will significantly reduce the number of particles emitted
  - this includes a significant reduction in ultrafine particulate emissions
- A high Pt loading on the DPF (CDPF) will reduce HC, CO and PM emissions along with reducing the number of particles emitted
  - However this may increase NO_2 and sulphate emissions
- A DPF/FBC system does not exhibit these problems

Introduction - Cumulative NO_2 data from taxi cab



Introduction - Cumulative NO_2 on truck > 3.5 t



Introduction

- A low precious metal loading on a DOC will effectively reduce HC and PM mass emissions but has little effect on particulate numbers and can promote NO_2 formation at high engine duty

- The high precious metal loading required to produce a CDPF will also reduce HC emissions but has been shown to promote high levels of NO_2 formation

- A base metal FBC in conjunction with a DPF has been shown to significantly reduce PM mass, particulate numbers and also to reduce NO_2 emissions but has little effect on HC emissions

Introduction - Effect of Base Metal Catalysed DPF

However -

by combining a Base Metal Catalyst coating on the DPF with a base metal FBC to create a BMCDPF/FBC system all of the regulated emissions can be reduced with a significant reduction in NO_2 emissions

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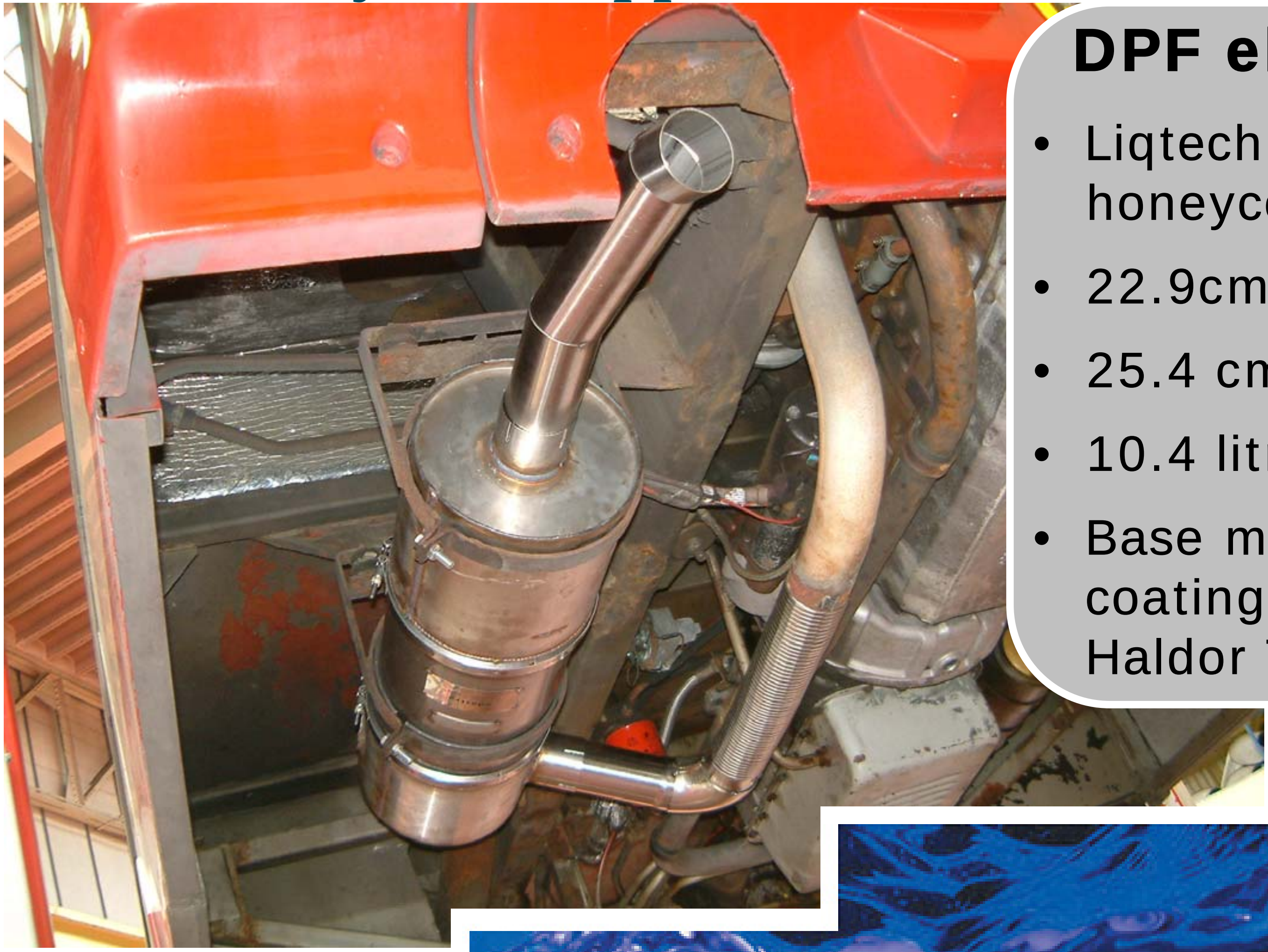
Preliminary field application - Single deck bus

Preliminary field application - DPF installation



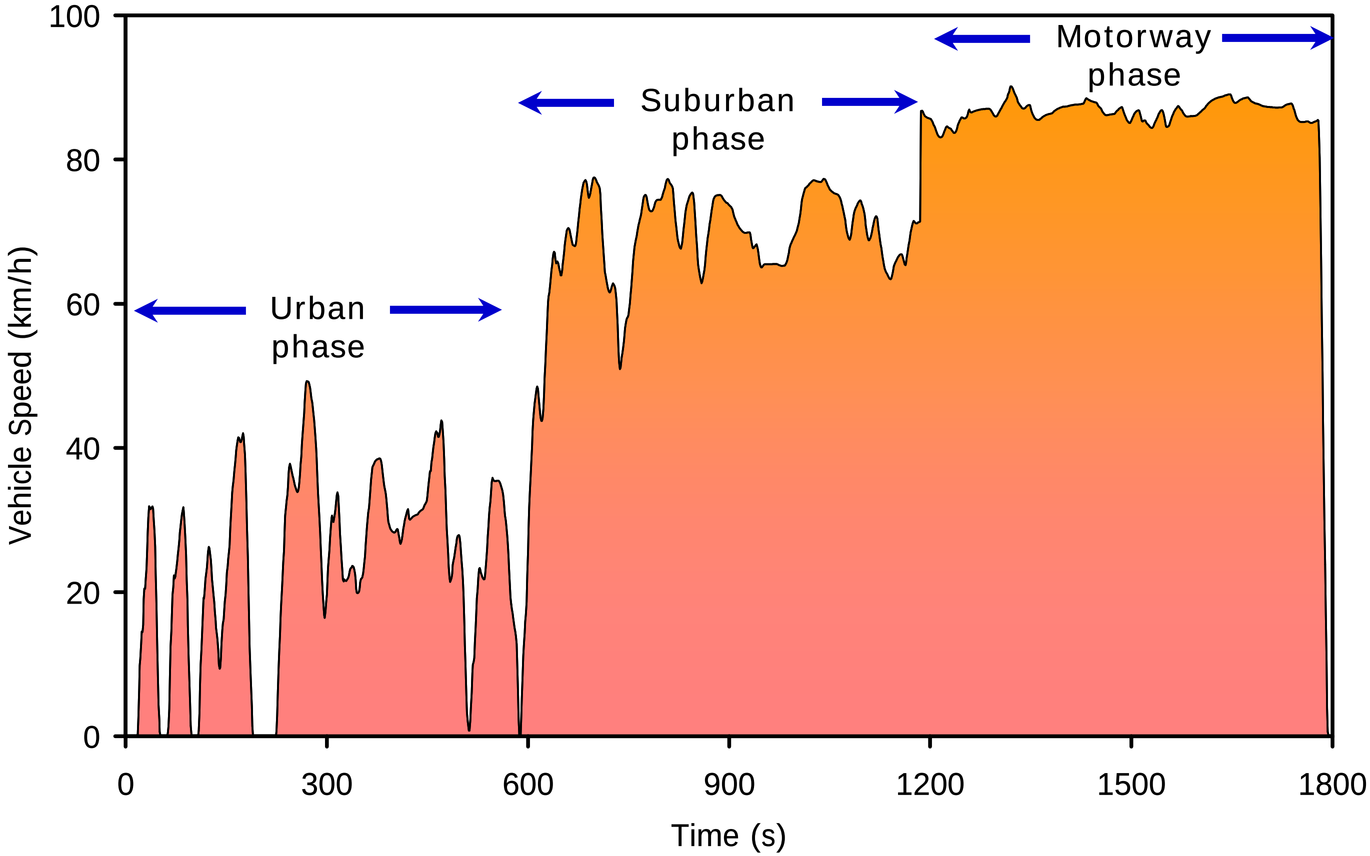
DPF element

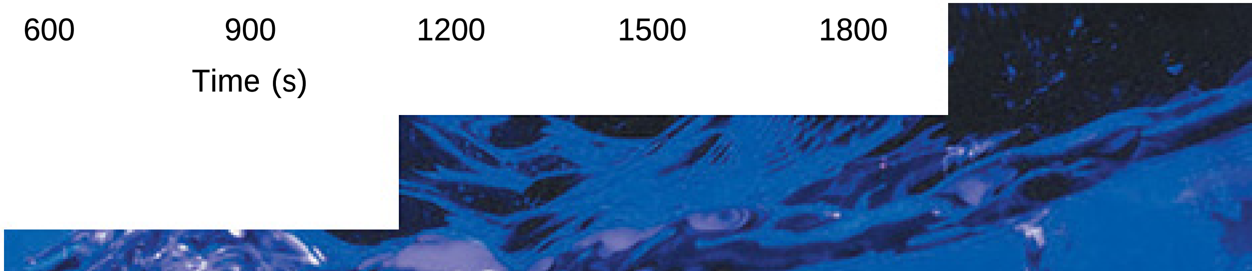
- Liqtech SiC honeycomb
- 22.9cm diameter
- 25.4 cm length
- 10.4 litre volume
- Base metal catalytic coating from Haldor Topsøe A/S

Preliminary field application - Dennis Dart bus engine

Type	Cummins 6BTA-130
No cylinders	6 in-line
Swept Volume	5883 cm3
Bore / Stroke	102 mm / 120 mm
Compression ratio	17.6 : 1
Power	97 kW @ 2500 rev/min
Torque	470 Nm @ 1500 rev/min

Preliminary field application - FIGE Test cycle

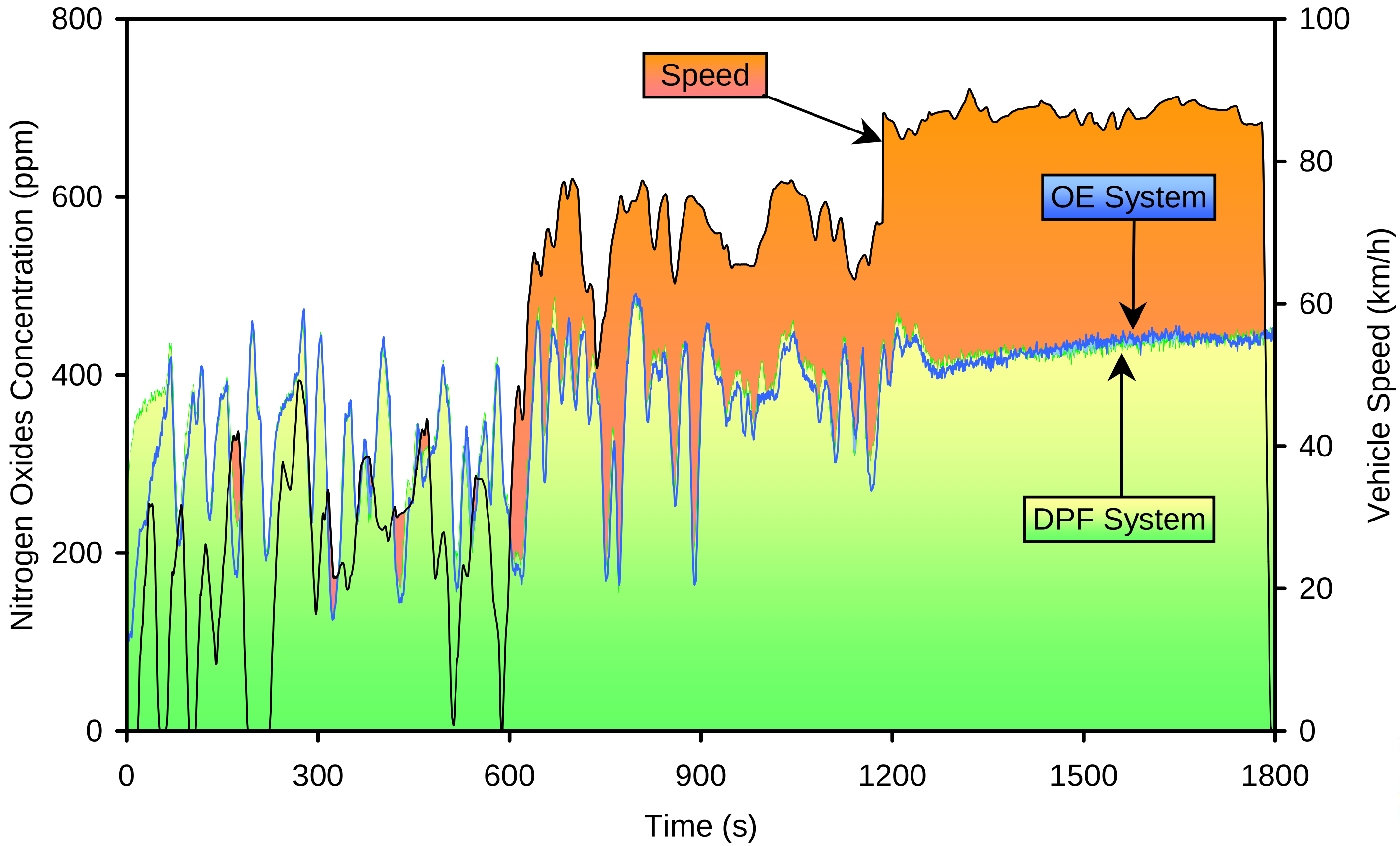




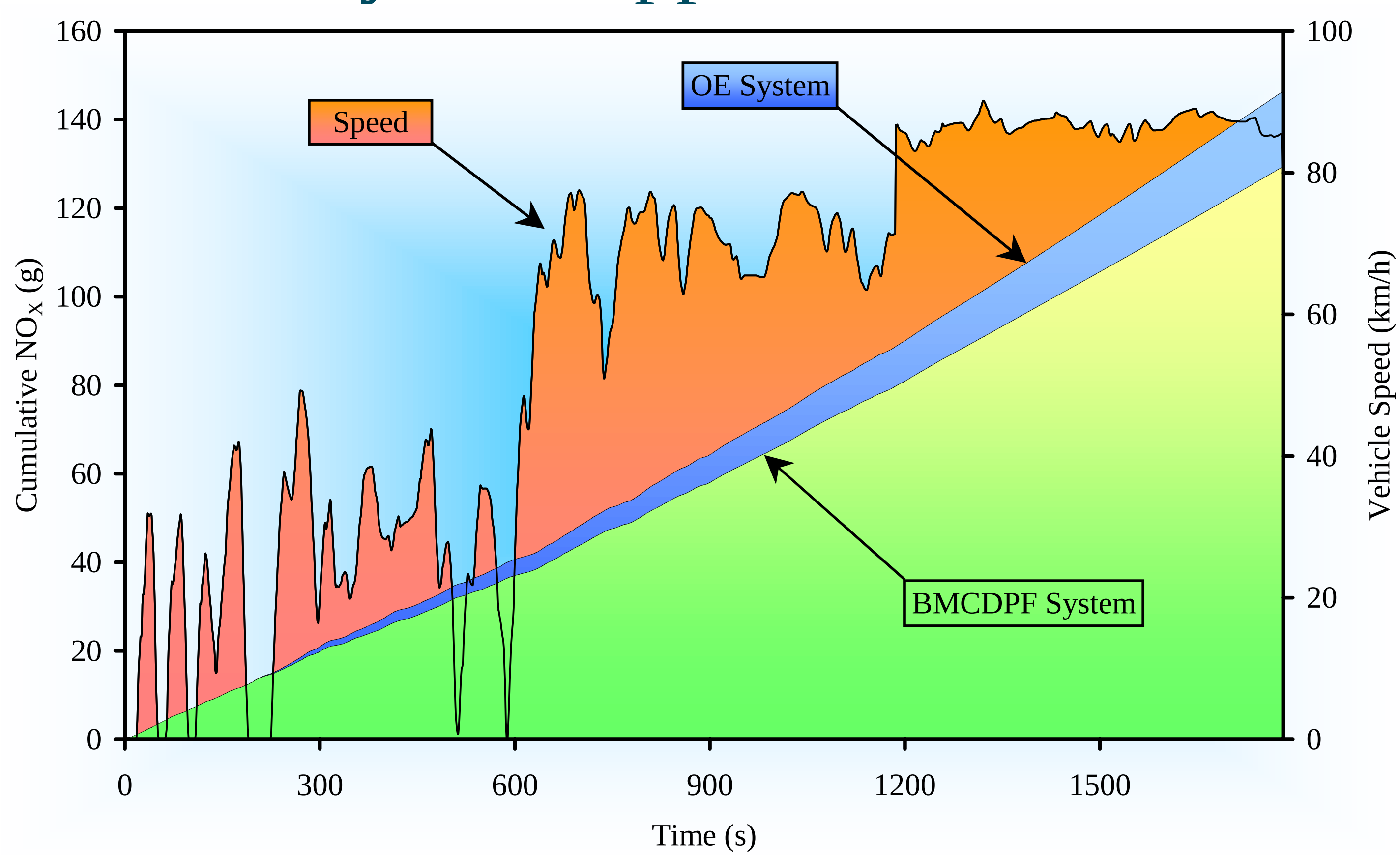
Preliminary field application - Regulated emissions

Emission	Reduction
HC	94 %
CO	78 %
NO_X	11 %
PM	87 %

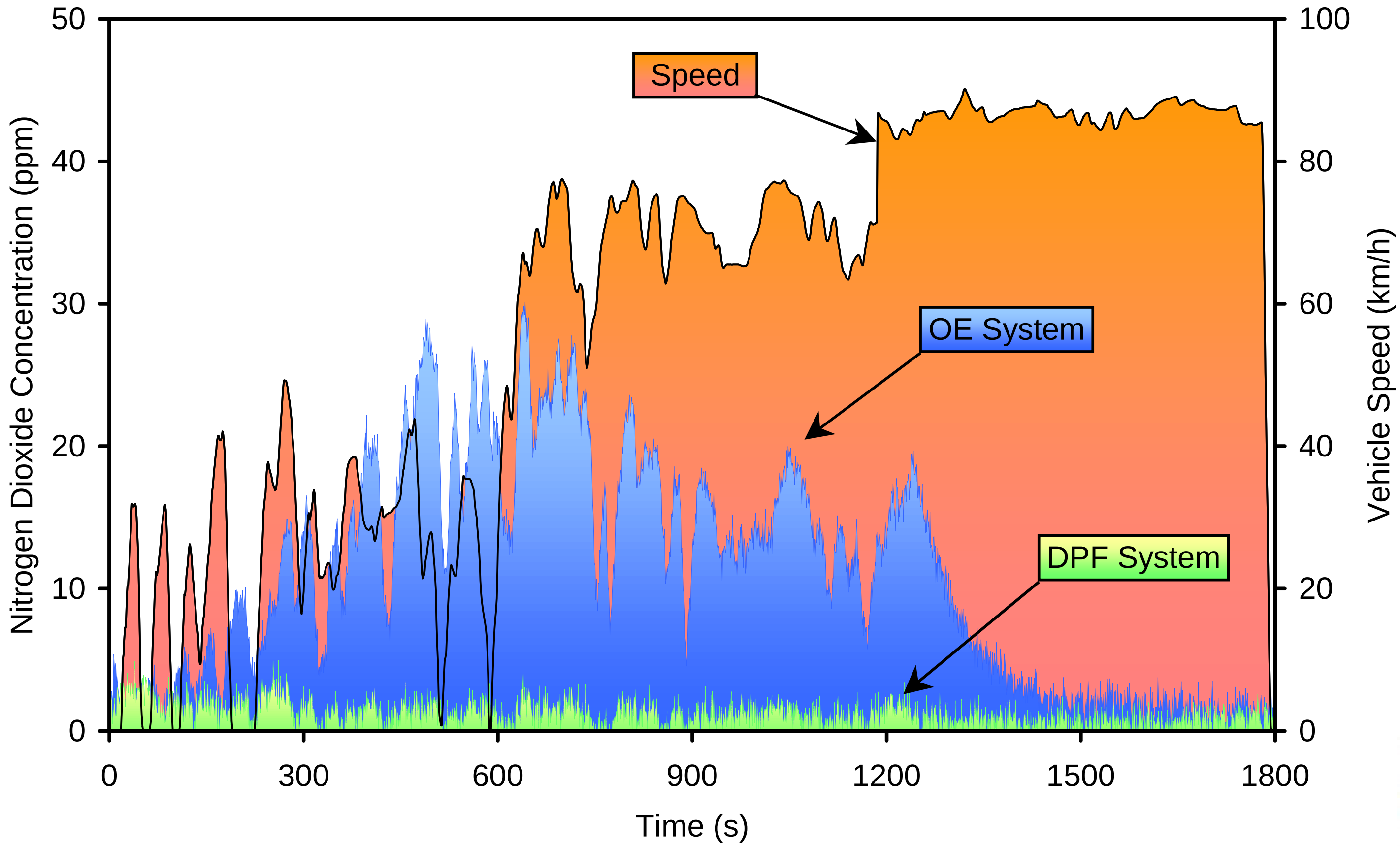
Preliminary field application - NO_X emissions



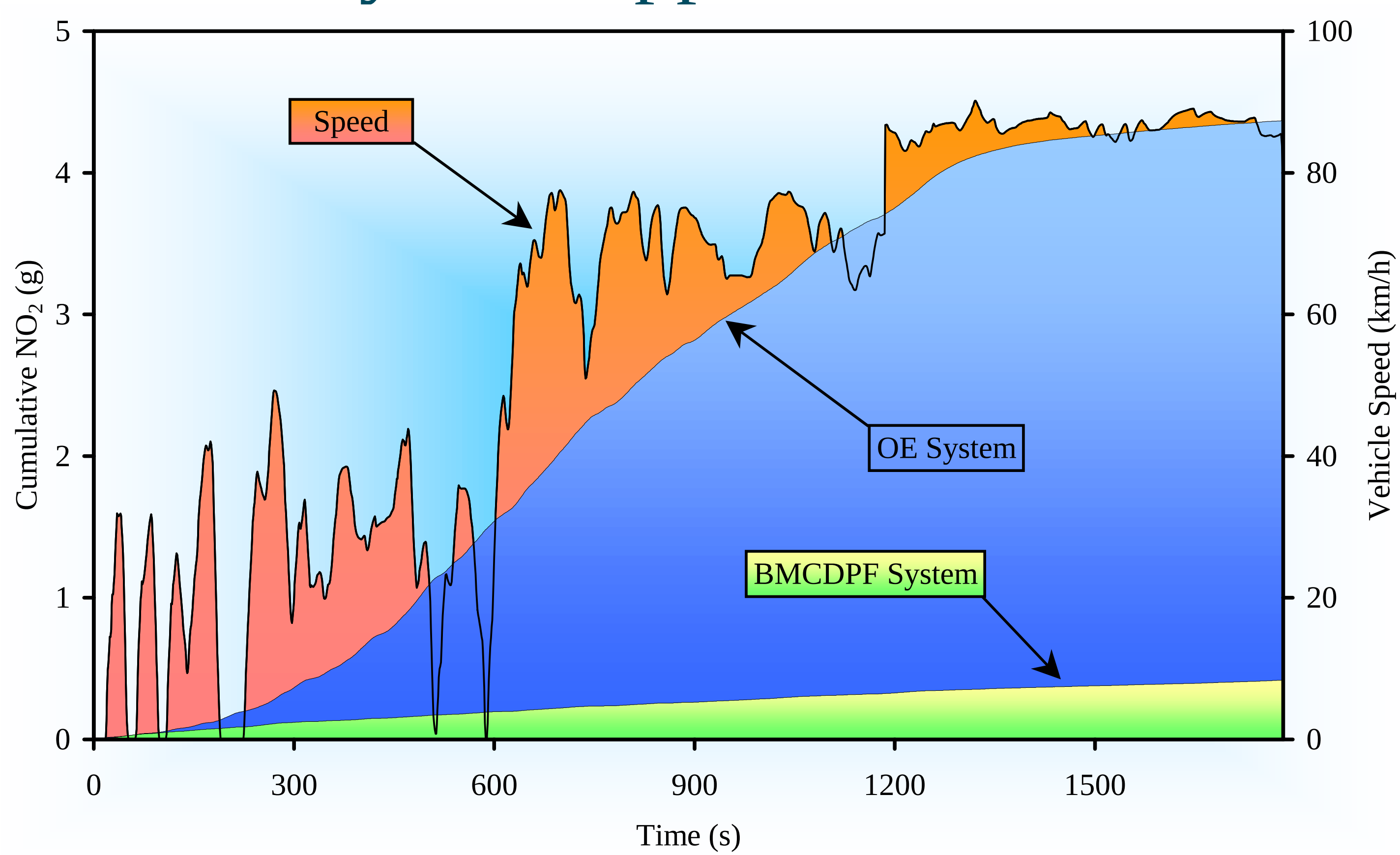
Preliminary field application - Cumulative NO_X



Preliminary field application - NO_2 emissions



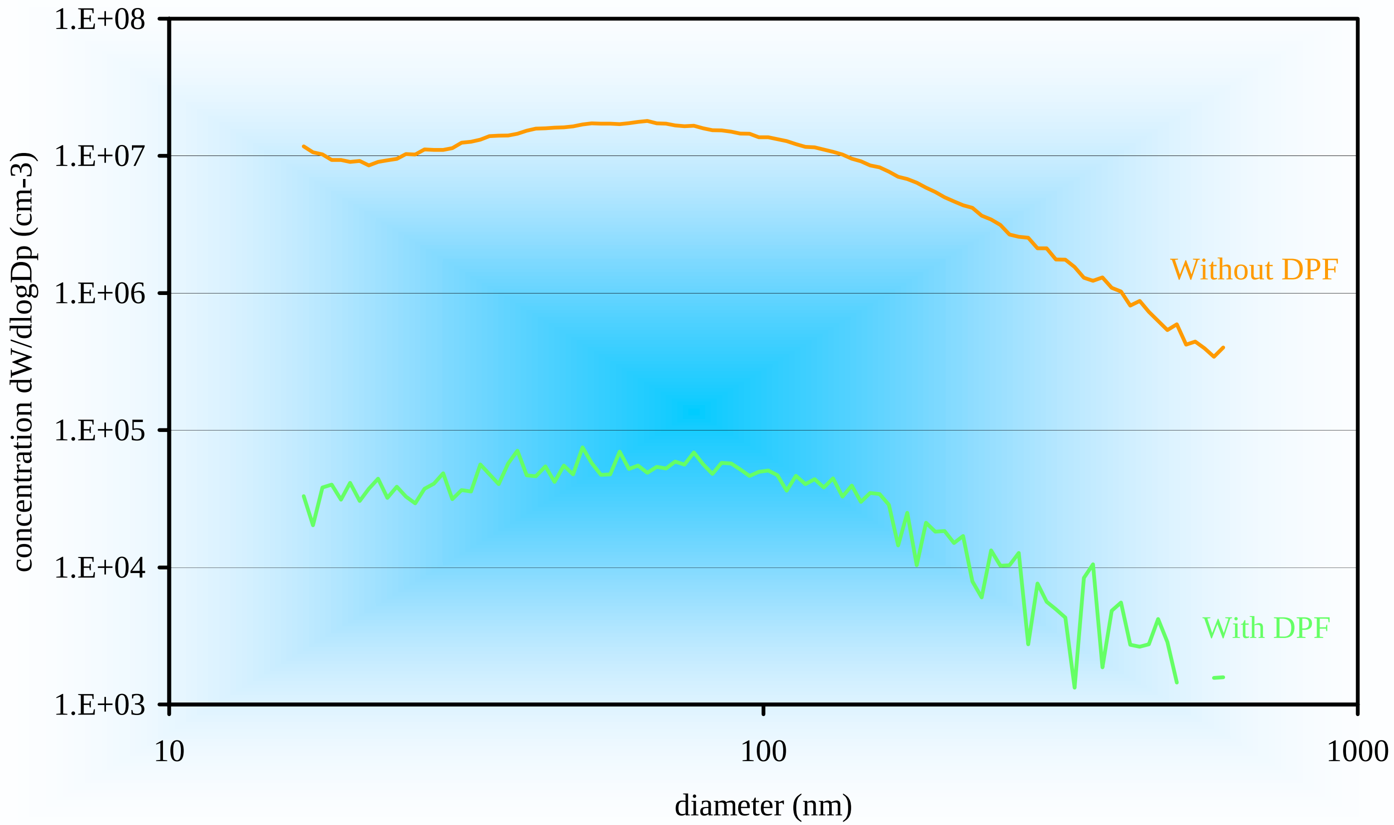
Preliminary field application - Cumulative NO_2



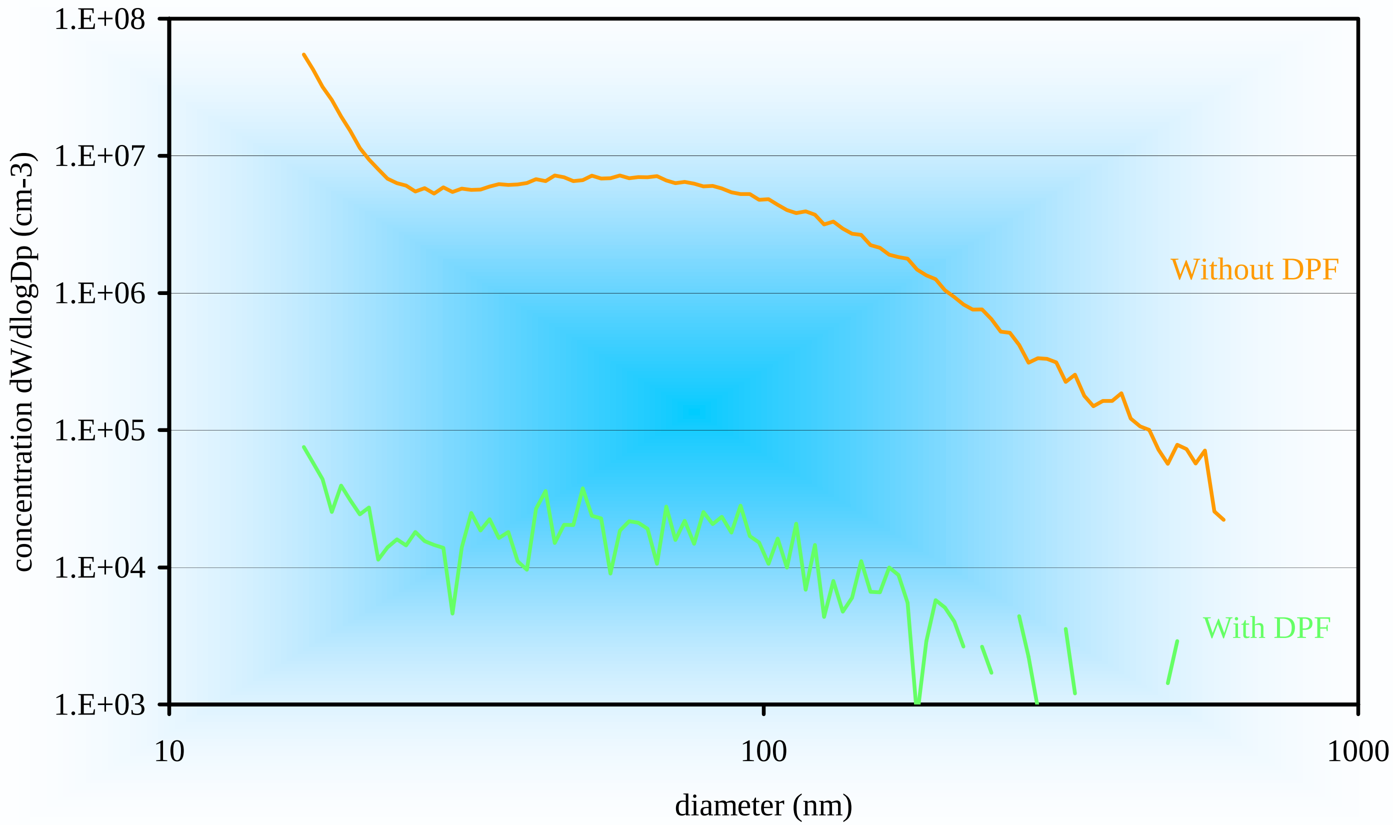
Additional bench testing

- Testing was conducted for VERT Filter Test, Phase 1
- Secondary emissions testing at EMPA
- Testing conducted to ISO 8178/4
- Liebherr D914T engine
  - 6.11ltr
  - rated at 110 kW @ 2000 rev/min

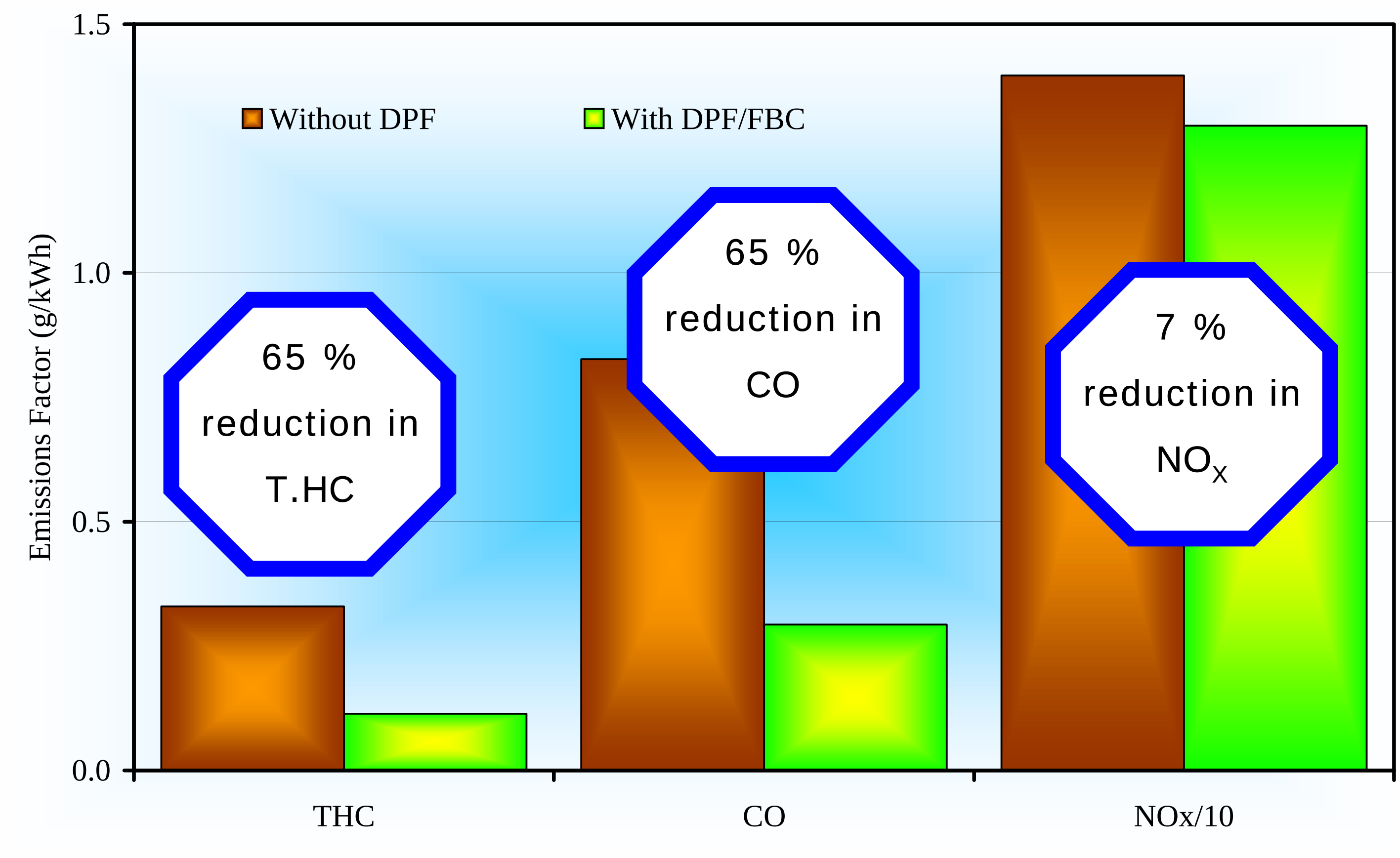
Additional bench testing - 1400 rev/min, full load



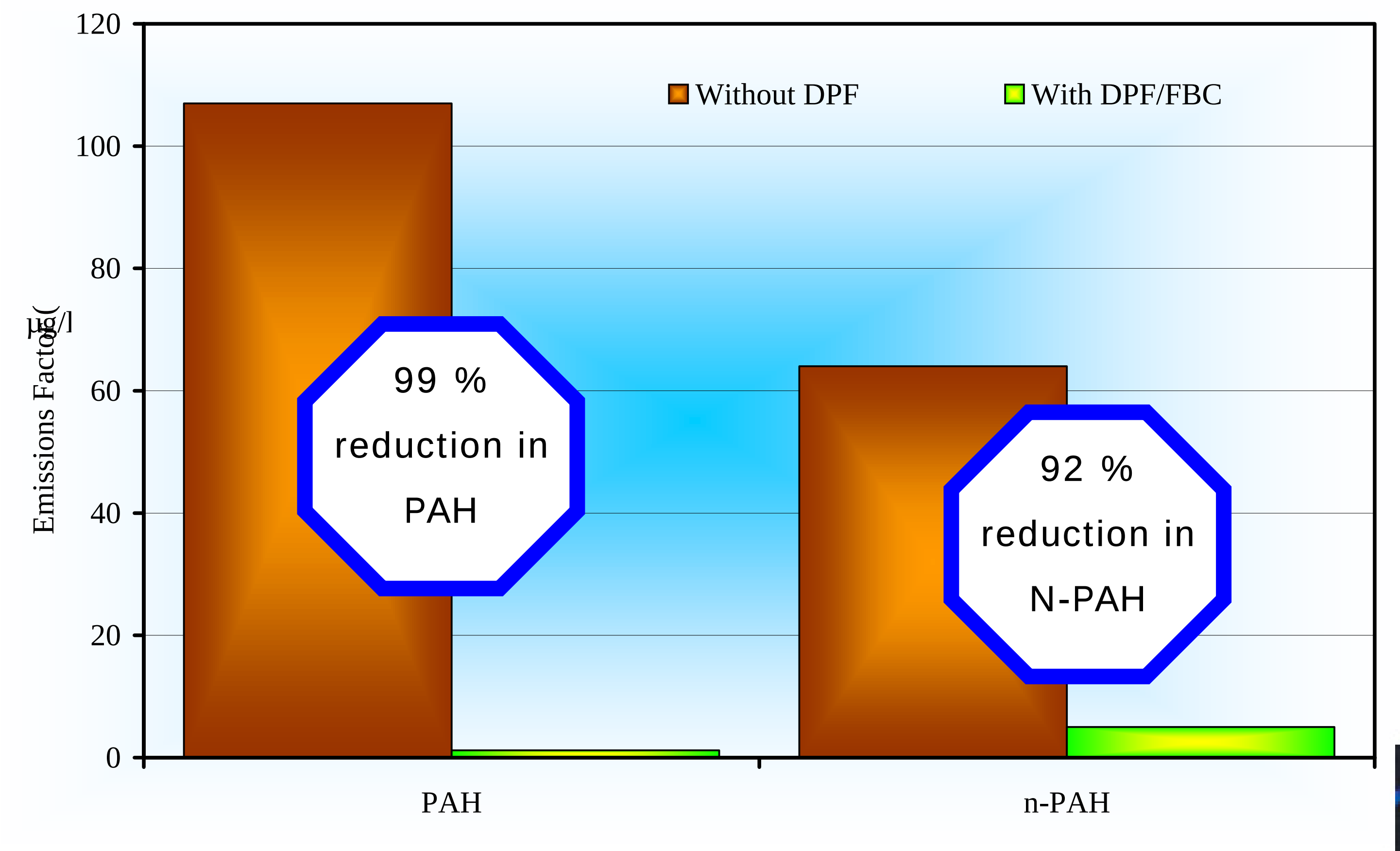
Additional bench testing - 1400 rev/min, 297 Nm



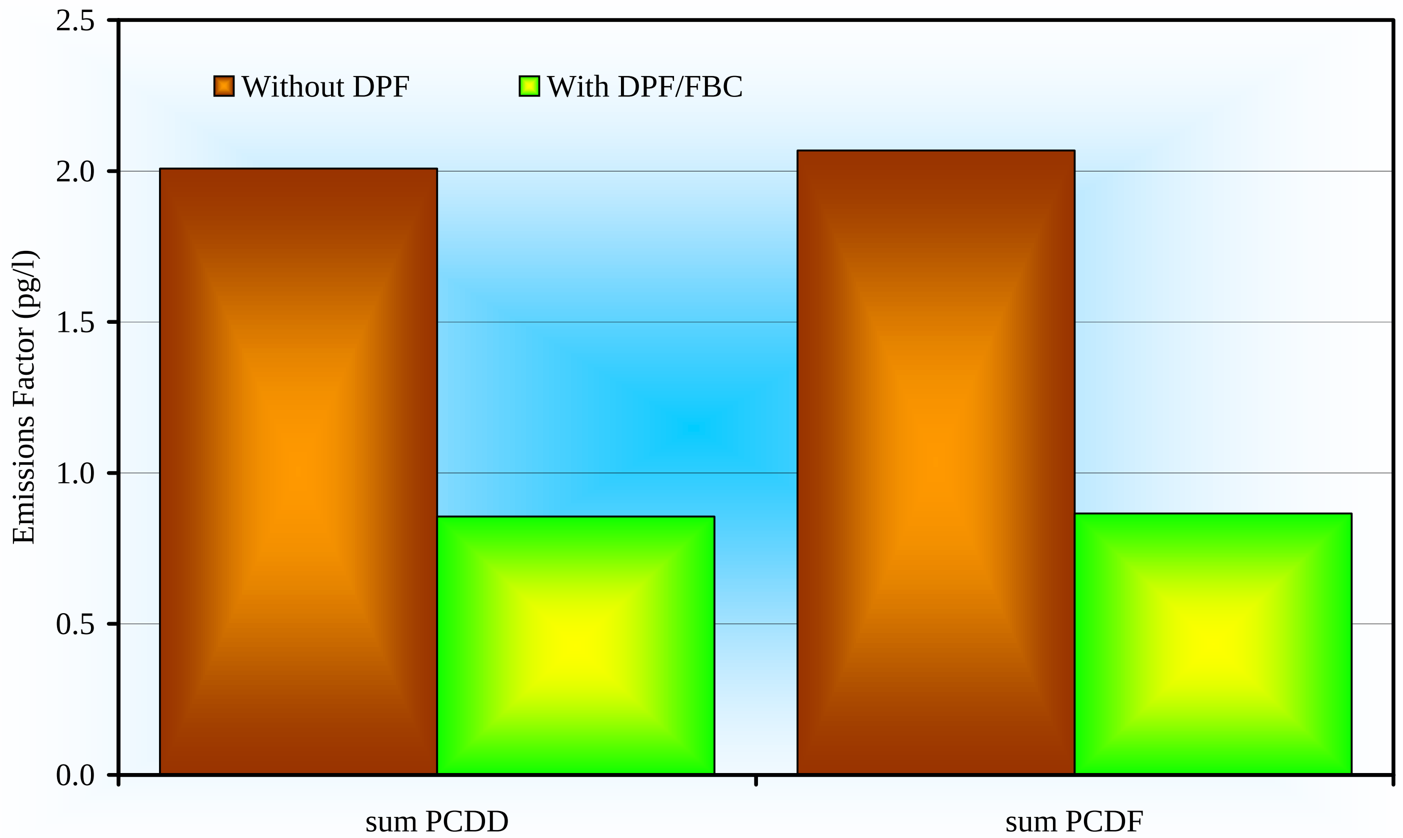
Additional bench testing - Regulated emissions



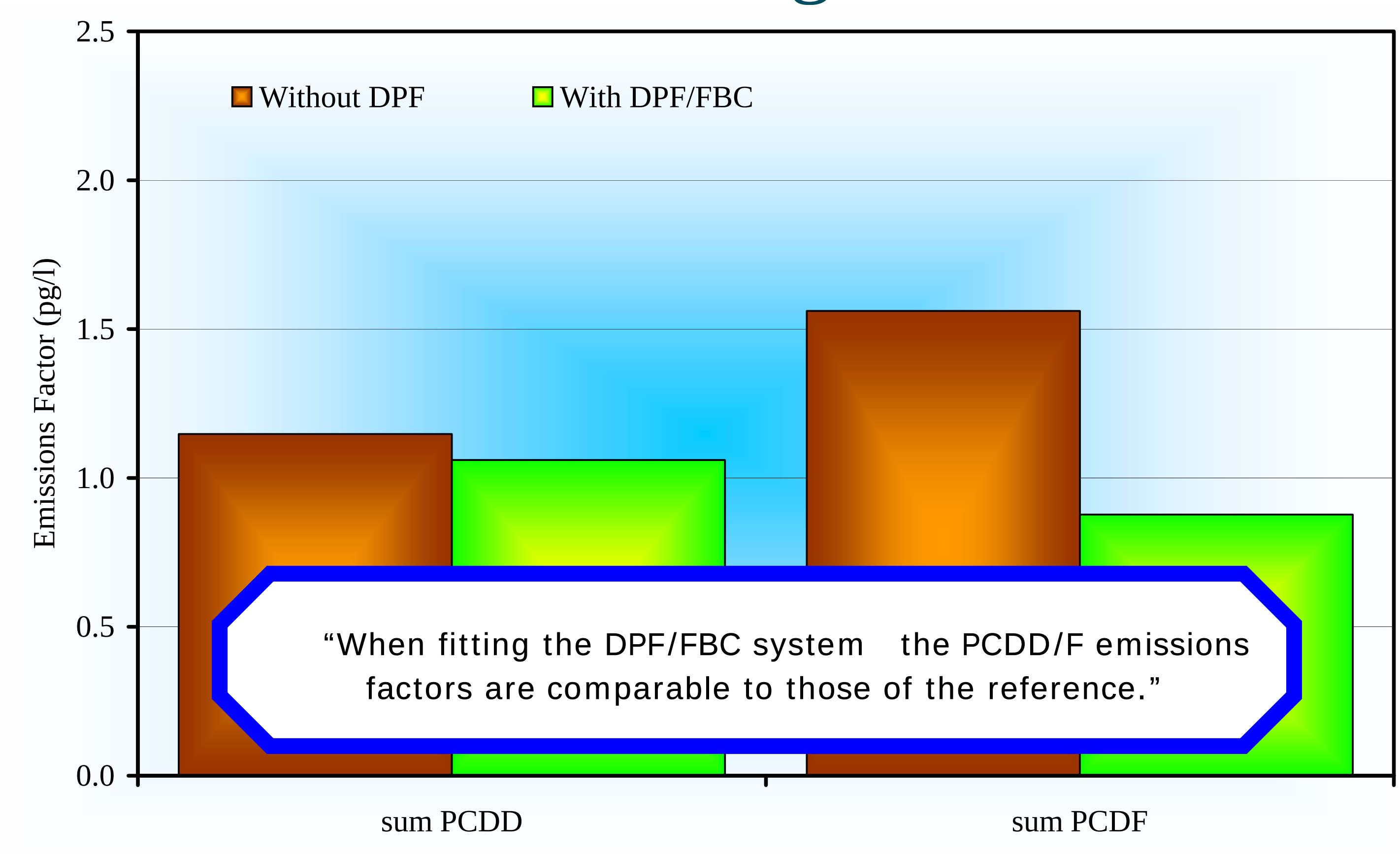
Additional bench testing - PAH, N-PAH emissions



Additional bench testing - PCDD/F emissions



Additional bench testing - PCDD/F emissions



"When fitting the DPF/FBC system the PCDD/F emissions factors are comparable to those of the reference."

with Cl doped fuel

Further field application - City Sightseeing bus

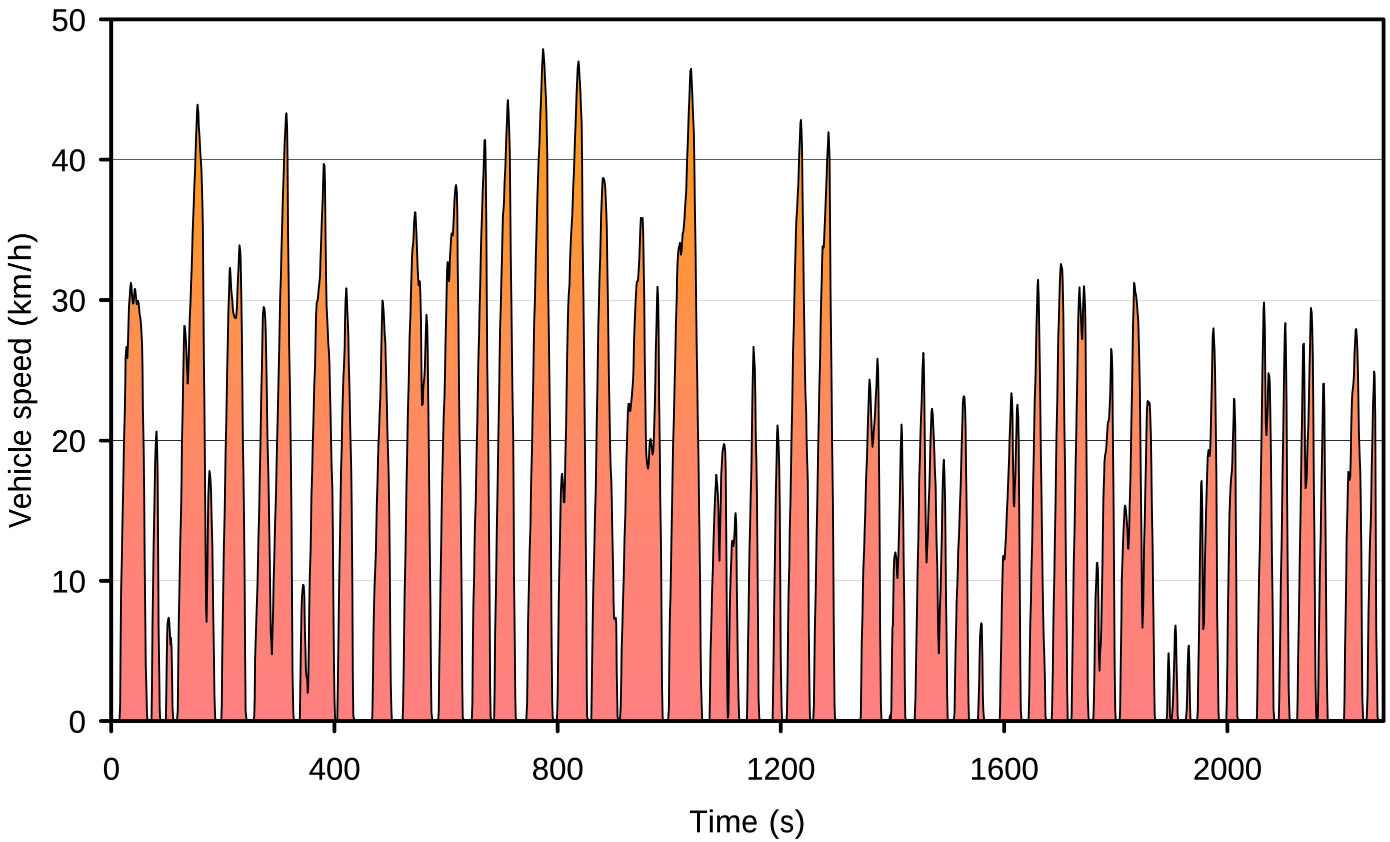
DPF element

- Liqtech SiC honeycomb
- 25.4cm diameter
- 25.4 cm length
- 12.9 litre volume
- Base metal catalytic coating from Haldor Topsøe A/S

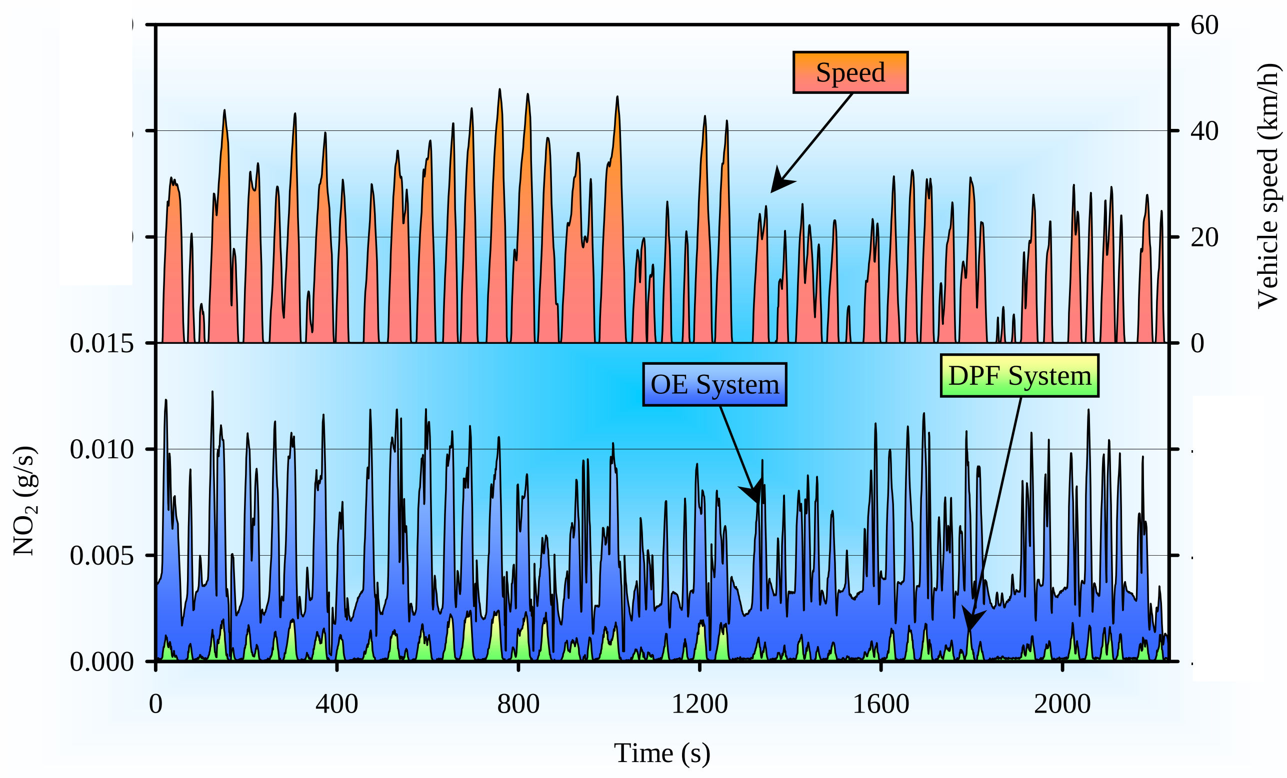
Further field application - MCW Metrobus engine

Type	Gardner 6LXB
No cylinders	6 in-line
Swept Volume	10450 cm3
Bore / Stroke	121 mm / 152 mm
Compression ratio	15:1
Power	134 kW @ 1850 rev/min
Torque	727 Nm @ 1000 - 1100 rev/min

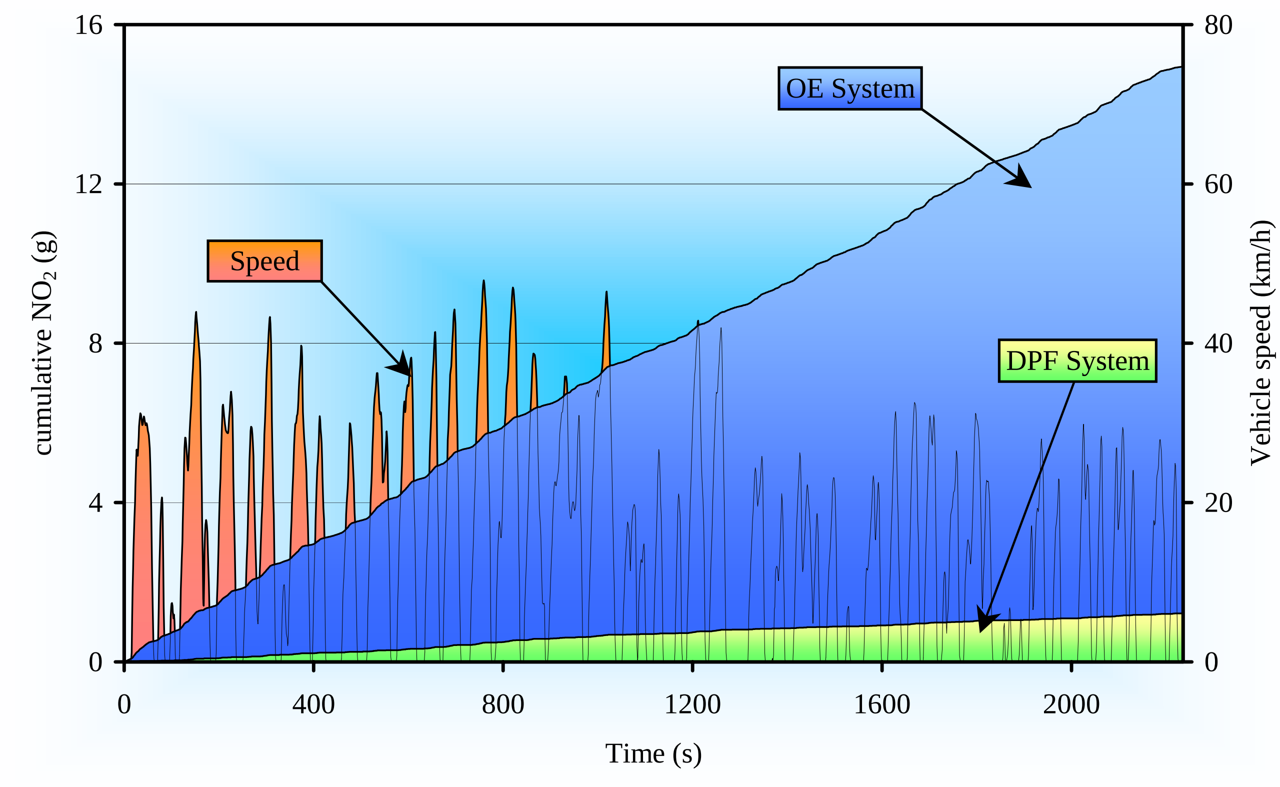
Further field application - MLBT cycle



Further field application - NO_2 emissions



Further field application - Cumulative NO_2 emissions



Conclusions

- A DPF/FBC system will reduce the number of emitted particles by over two orders of magnitude, including the ultra-fine particles, will slightly reduce NO_X emissions but has little effect on HC or CO.
- A CDPF with high Pt loading will reduce HC, CO and PM emissions but can significantly increase NO_2 emissions.
- A BMCDPF/FBC system not only reduced CO, HC and PM emissions it also reduced NO_X emissions and produced a significant reduction in NO_2 emissions

Conclusions

- The BMCDPF/FBC system will also reduce the number of emitted particles by over two orders of magnitude, including the ultra-fine particles
- A BMCDPF/FBC system has also been shown to significantly reduce PAH and N-PAH emissions
- The BMCDPF/FBC system does not increase PCCD/F emissions even when the fuel is doped with Cl


This Bus is Green
RM 1101 Built in 1962 for London Transport
Birkenhead Priory, Birkenhead Tramway, Wirral Museum, Williamson Art Gallery, Shore Road Pumping Station.
RM 1101
WIRRAL MUSEUMS