Additional NOx benefits as a result of using FBC to aid DPF regeneration

When the Diesel engine was originally developed at the end of the nineteenth century, dense plumes of black smoke from the burning of solid fuel were a common sight. Black smoke and particulate emissions were ignored in the quest for more power and efficiency. However as the general level of pollution has been dramatically reduced over the last century the diesel engine has had to follow the trend. Engine designers have made significant advances in reducing the emissions from diesel engines. Reductions in carbon dioxide emissions, i.e. an increase in fuel efficiency, have resulted in the widespread adoption of the diesel engine. However reductions in particulate emissions have largely been achieved by the reduction of the larger particles. Current emissions legislation only measures particulate emissions by mass, therefore eliminating a few of the larger heavier particles enables the engine designer to satisfy the legislation. But this does not remove the health effects that are associated with the smaller particles.

Precious metals have been used for many years now in oxidation catalysts for diesel engines. Diesel oxidation catalysts (DOC) which are designed to reduce the level of carbon monoxide (CO) and hydrocarbon (HC) emissions are also known to reduce particulate matter (PM) mass emissions by reducing the mass of adsorbed volatile material. However as the amount of volatile material adsorbed onto the PM is reduced by engine design so is the reduction in PM emissions that is achieved using a DOC. This is demonstrated by fitting the same DOC to both a Euro II and a Euro III specification >7.5 t truck. Due to the lower level of engine out HC emissions on the Euro III specification truck, the HC conversion efficiency is increased to 81% compared with 61% for the Euro II truck. Thgis is shown in slide 5. However the PM reduction in the Euro III truck is only 14% compared with 64% in the Euro II truck. This is shown in slide 6. However the DOC makes no significant difference to the number of particles emitted, this was demonstrated by ELPI data for the same Euro III truck both with and without DOC, this is shown in slide 8. The DOC also has negligible effect on the total oxides of nitrogen (NO_X) emitted. This is shown in slide 10. The effect of the DOC on nitrogen dioxide (NO2) varies with temperature. At light duties and hence lower temperatures the DOC reduced the NO_2 emissions, however at high duty the DOC significantly increased NO_2 emissions such the for the overall test cycle the NO_2 emissions were increased by 12.8%. This is shown in slide 11.

For decades scientists have been working on aftertreatment devices that will also reduce the number of particles emitted from diesel engined vehicles. Diesel particulate filters (DPFs) have been developed that very effectively trap particulate matter of all sizes. The problem then was how to dispose of this trapped material. The favoured solution was obviously to burn it to carbon dioxide. This was no mean feat and many solutions have been developed. However hand in hand with these developments our understanding has grown of potential to replace one problem with another. A classic example of this was the investigation of the use of fuel borne catalysts (FBC) to aid the regeneration of diesel particulate filters, which showed that the use of copper could promote the production of dioxins. Strict testing criteria have therefore been enacted to ensure that FBCs do not cause such problems. As a result only a limited number of FBCs have been approved for use in Europe. However systems employing a FBC are now the most widely used means of regenerating DPFs.

Whilst FBC system are now well proven, manufacturers continue to look for alternative solutions to the regeneration problem. Some of these alternative strategies rely on a precious metal catalyst within the filter system. However as demonstrated in the work with DOCs, precious metal catalysts will very effectively oxidise nitric oxide to the more harmful nitrogen dioxide. Whilst this nitrogen dioxide can very effectively be used as an oxidising agent to oxidise trapped soot, care must be taken to ensure that the emissions of nitrogen dioxide are not increased.
Work on a London Taxi Cab with a SiC wall flow filter using an iron based FBC not only gives 99% reduction of particulate number emissions but it has the added benefit of reducing emissions of oxides of nitrogen and in particular nitrogen dioxide. 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 increases nitrogen dioxide emissions, but did significantly reduce hydrocarbon and carbon monoxide emissions. Slide 13 shows the HC and PM emissions from the Taxi Cab when fitted with either the DPF/FBC system or the catalysed DPF (CDPF) system when compared to the original equipment (OE) exhaust. The effect of fitting the DPF/FBC system on particle number emissions is shown in slide 15 for the Taxi Cab and in slide 16 for a >7.5 t truck. Slide 18 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 CDPF was used the total NO_2 emissions increased by 79%, again the majority of the difference occured during the EUDC phase of the test cycle. Slide 19 shows that the DPF/FBC system had little effect on the N_2O emissions but that the CDPF system appeared to also increase N_2O emissions. The use of the DPF/FBC system produced similar results when applied to a >3.5 t truck. The results are shown in slides 20 to 22. Slide 20 shows the DPF/FBC system reduced total NO_X by 8%. Slide 21 shows that the DPF/FBC system reduced NO_2 emissions by 23% while slide 22 shows a N_2O reduction of 20%.

However by using a non-precious metal coating on the DPF, to facilitate the reduction of hydrocarbons and carbon monoxide, a system can be developed that reduces all the hazardous emissions. The FBC is relied upon to facilitate regeneration in such a system. This type of system has been demonstrated on a Euro I specification single deck bus as shown in slide 25. The CO emissions were reduced by 78% and as shown in slide 26 the HC and PM emissions were reduced by 94% and 87% respectively. The NO_X emissions were reduced by 11% as shown in slide 27. But most importantly the NO_2 emissions were reduced by 89%. The NO_2 emissions reduction occurred throughout the test cycle. The conclusions are shown in slide 29.

All the test work reported here was conducted at an independent test facility in the UK.

Additional NO_X benefits as a result of using FBC to aid DPF regeneration

P Richards Associated Octel Company
M W Vincent Adastra
W Kalischewski Octel Deutschland GmbH

OCTEL

Presentation outline

- Introduction
- Effect of a DOC
  - Regulated emissions
  - Particulate numbers
  - Speciated NO_X
- Effect of DPF technologies
  - Regulated emissions
  - Particulate numbers
  - Speciated NO_X
- Conclusions

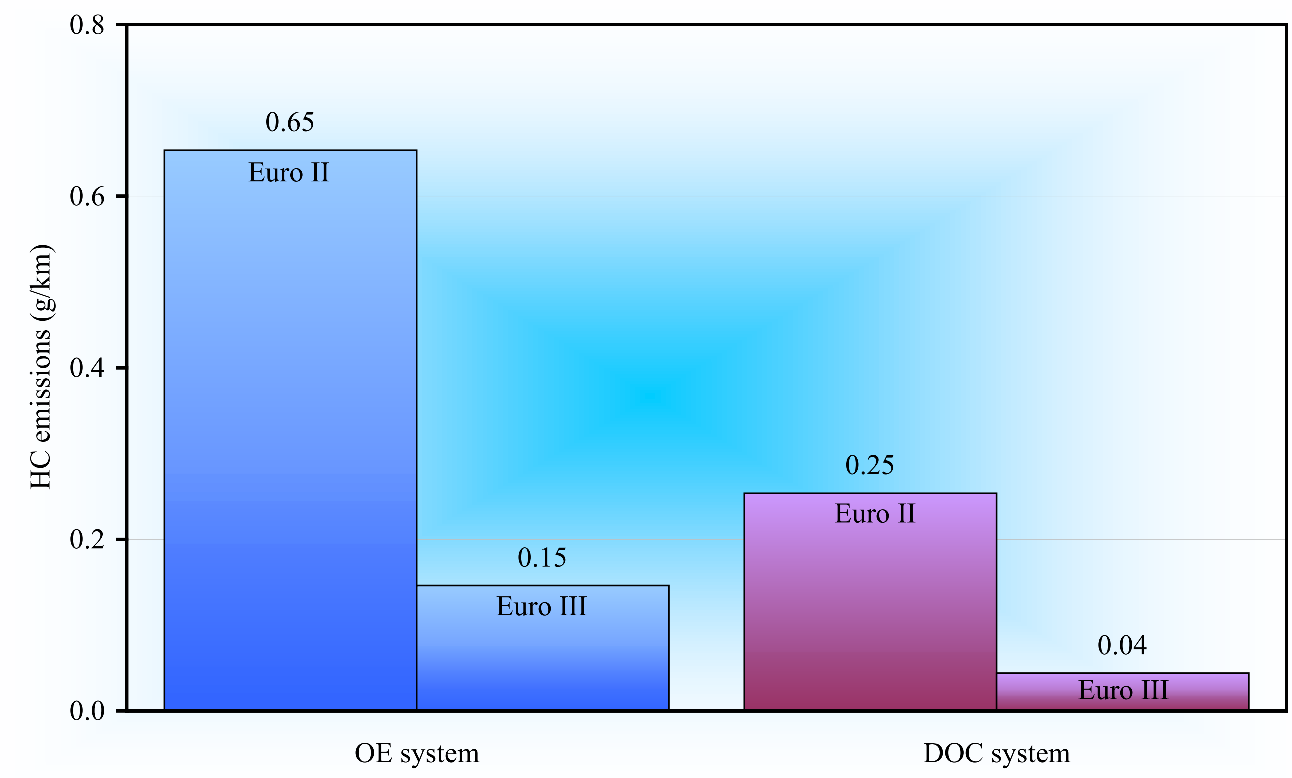
Introduction

- 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

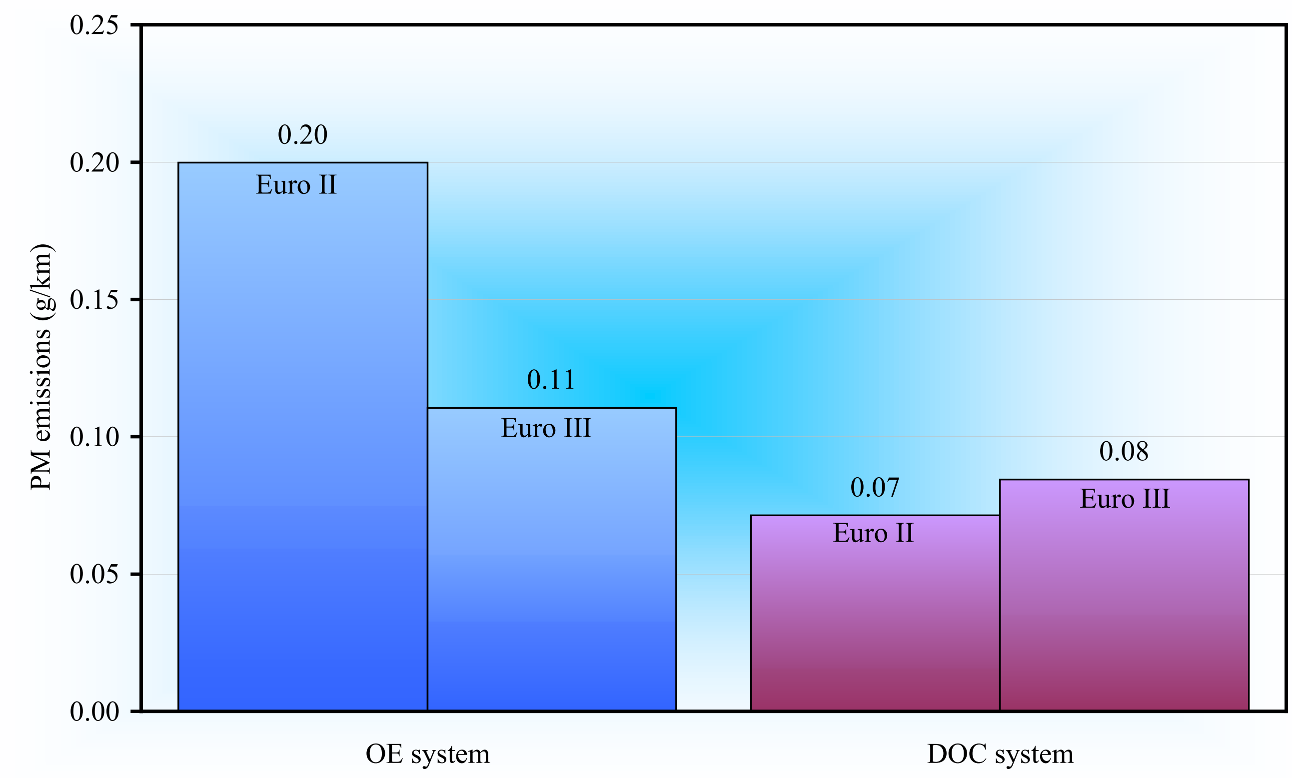
Effect of a DOC

- Regulated emissions
- Particulate numbers
- Speciated NO_X

HC emissions data for truck > 7.5 t



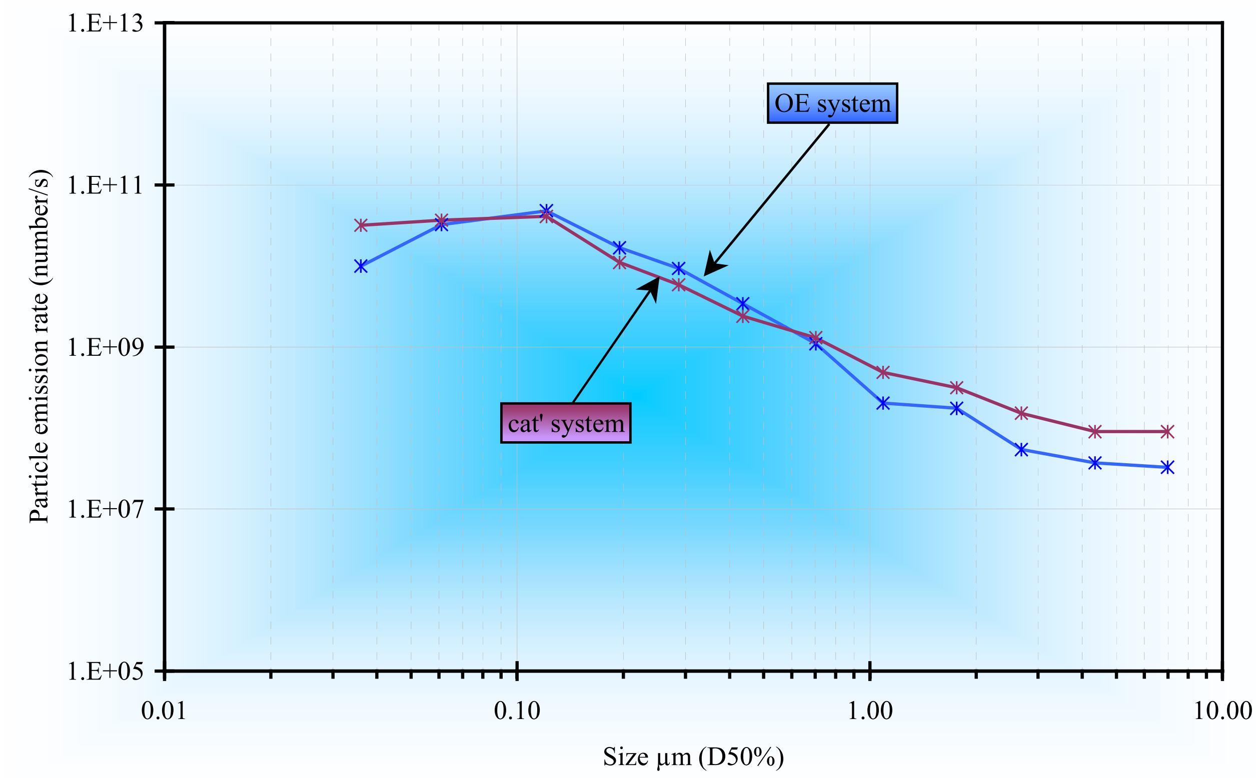
PM emissions data for truck > 7.5 t



Effect of a DOC

- Regulated emissions
- Particulate numbers
- Speciated NO_X

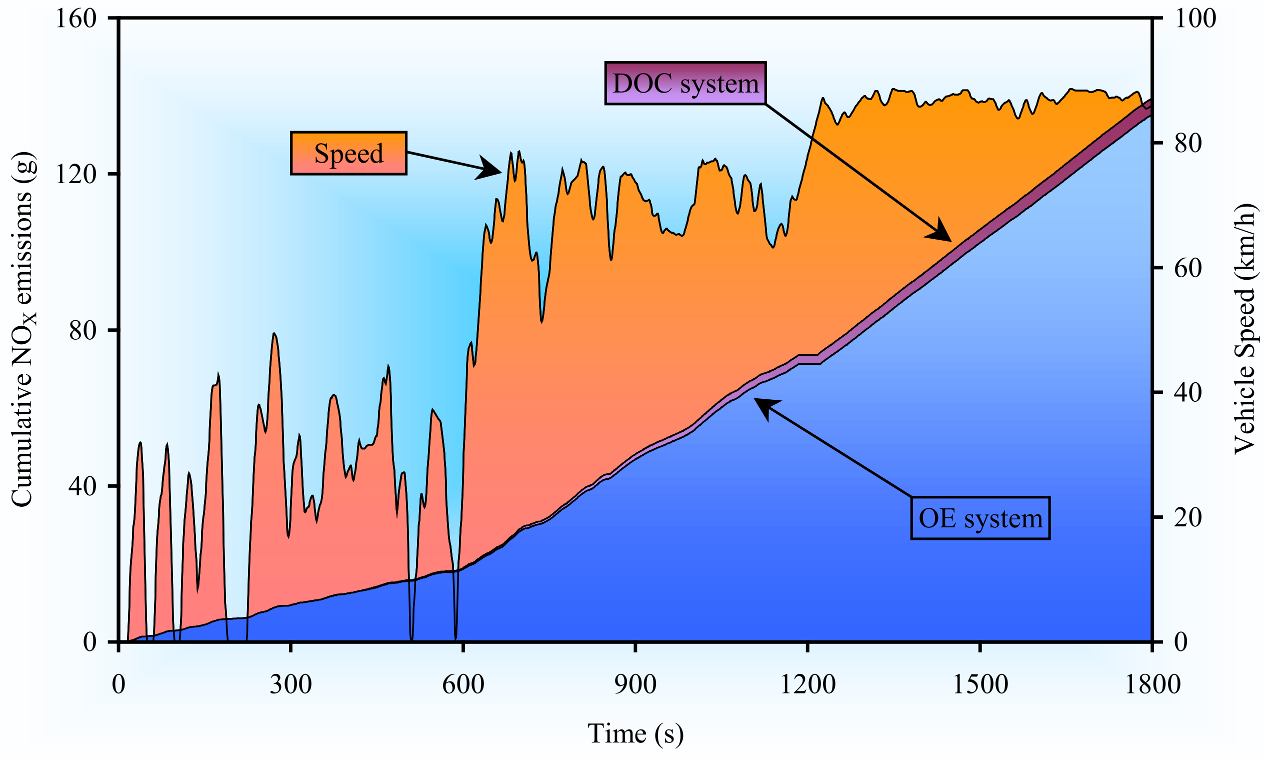
ELPI data for truck > 7.5 t



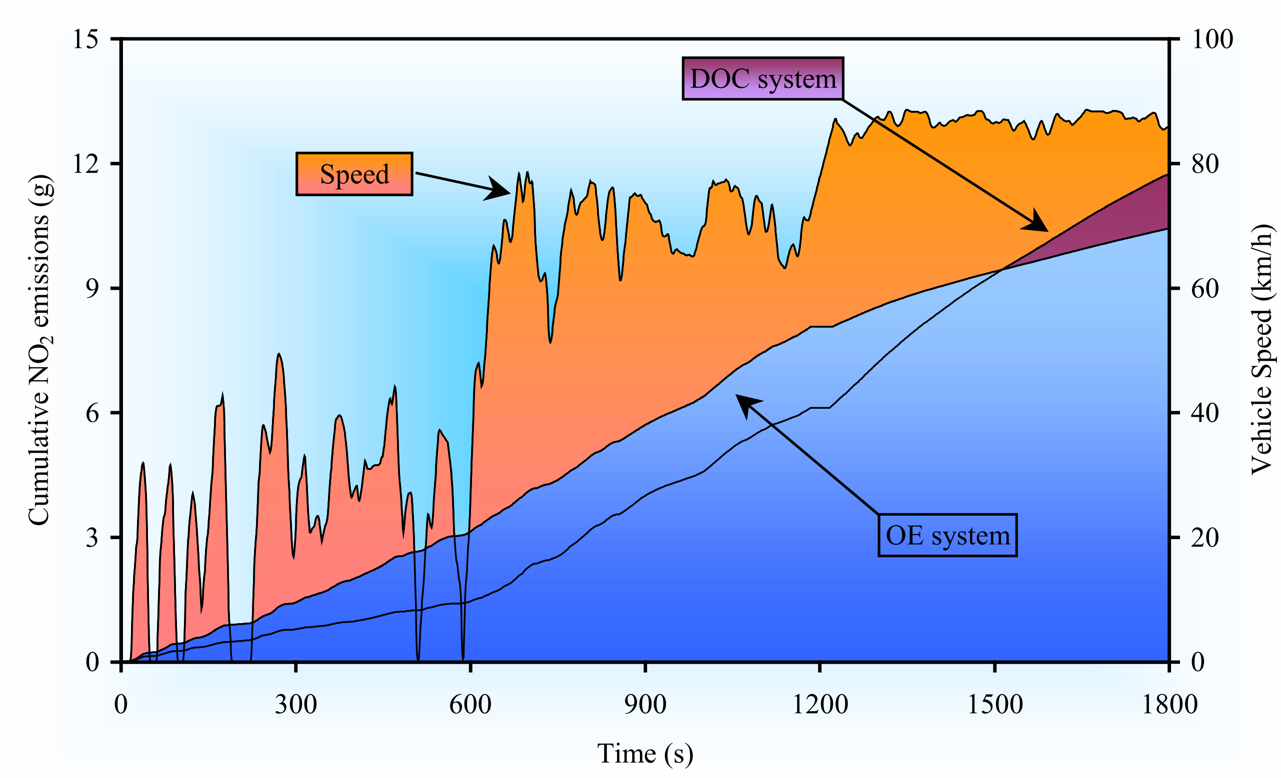
Effect of a DOC

- Regulated emissions
- Particulate numbers
- Speciated NO_X

Cumulative NO_X on > 7.5 t truck



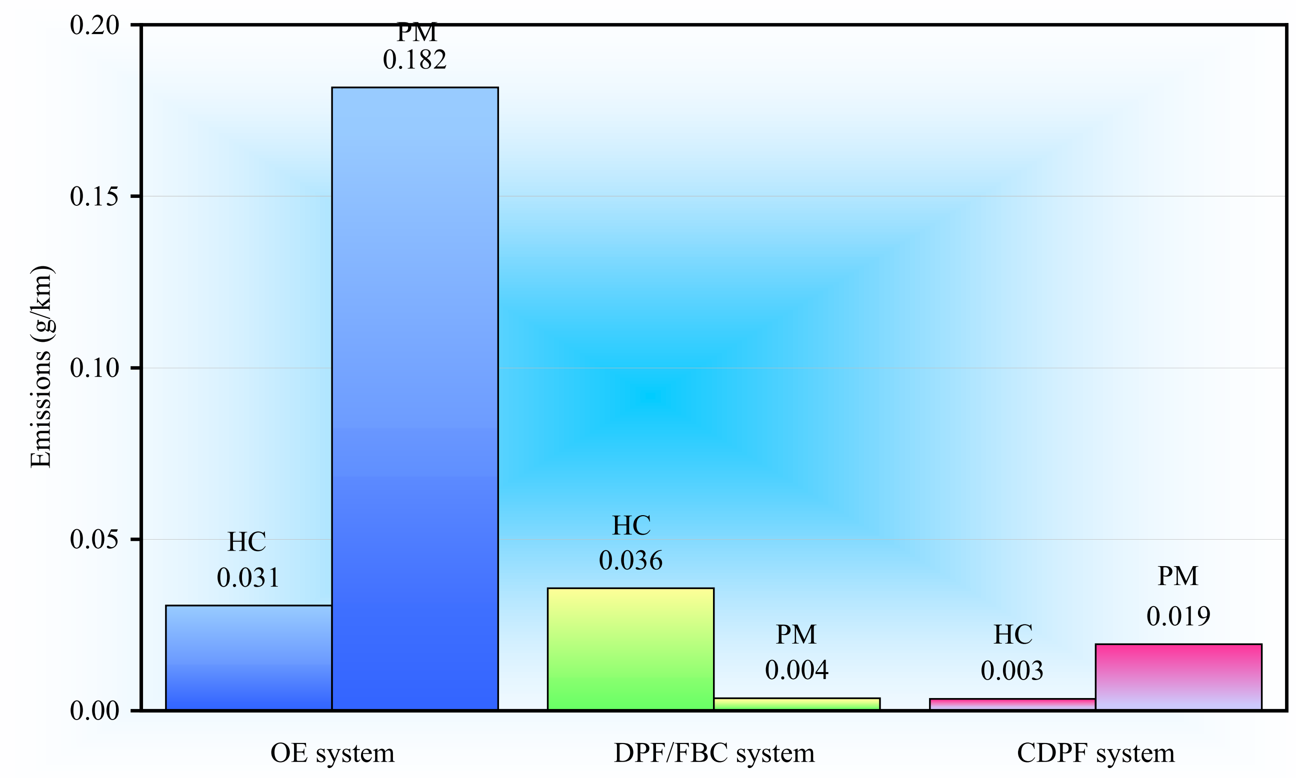
Cumulative NO_2 on > 7.5 t truck



Effect of DPF Technologies

- Regulated emissions
- Particulate numbers
- Speciated NO_X

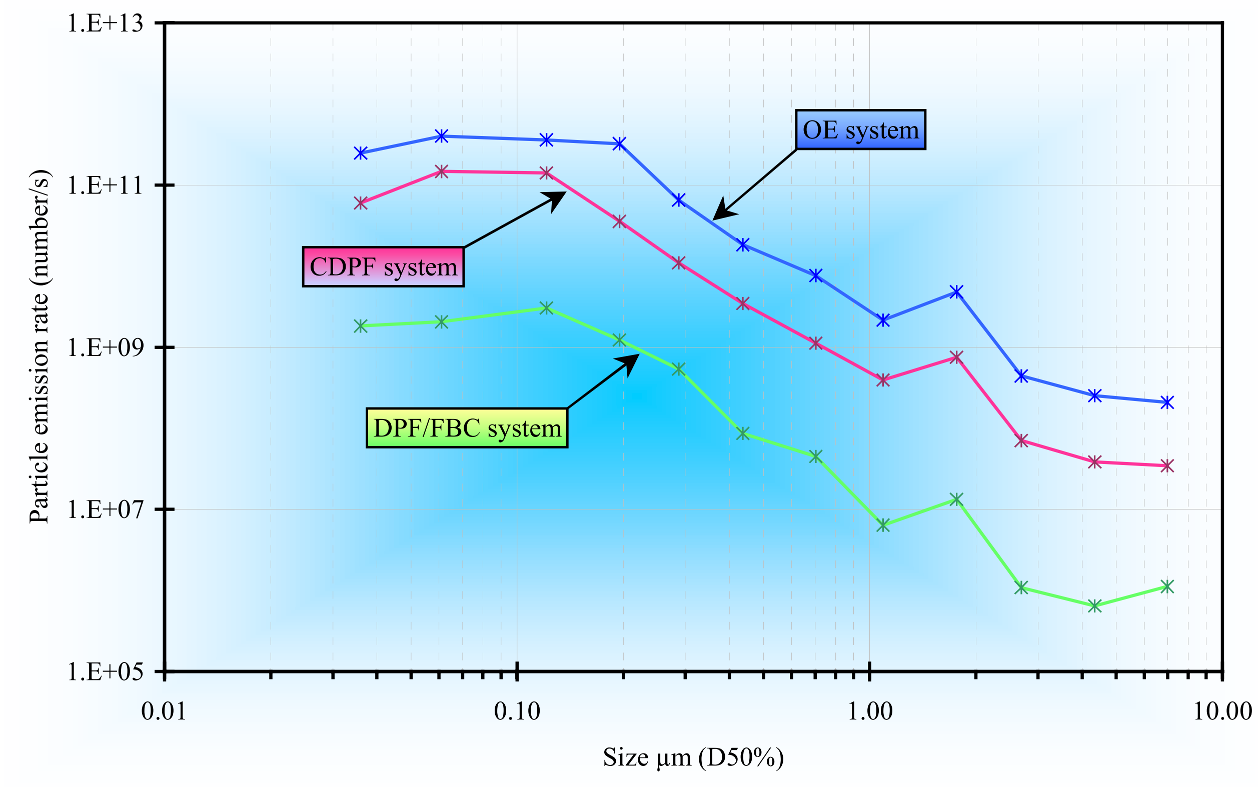
HC & PM data from Taxi Cab



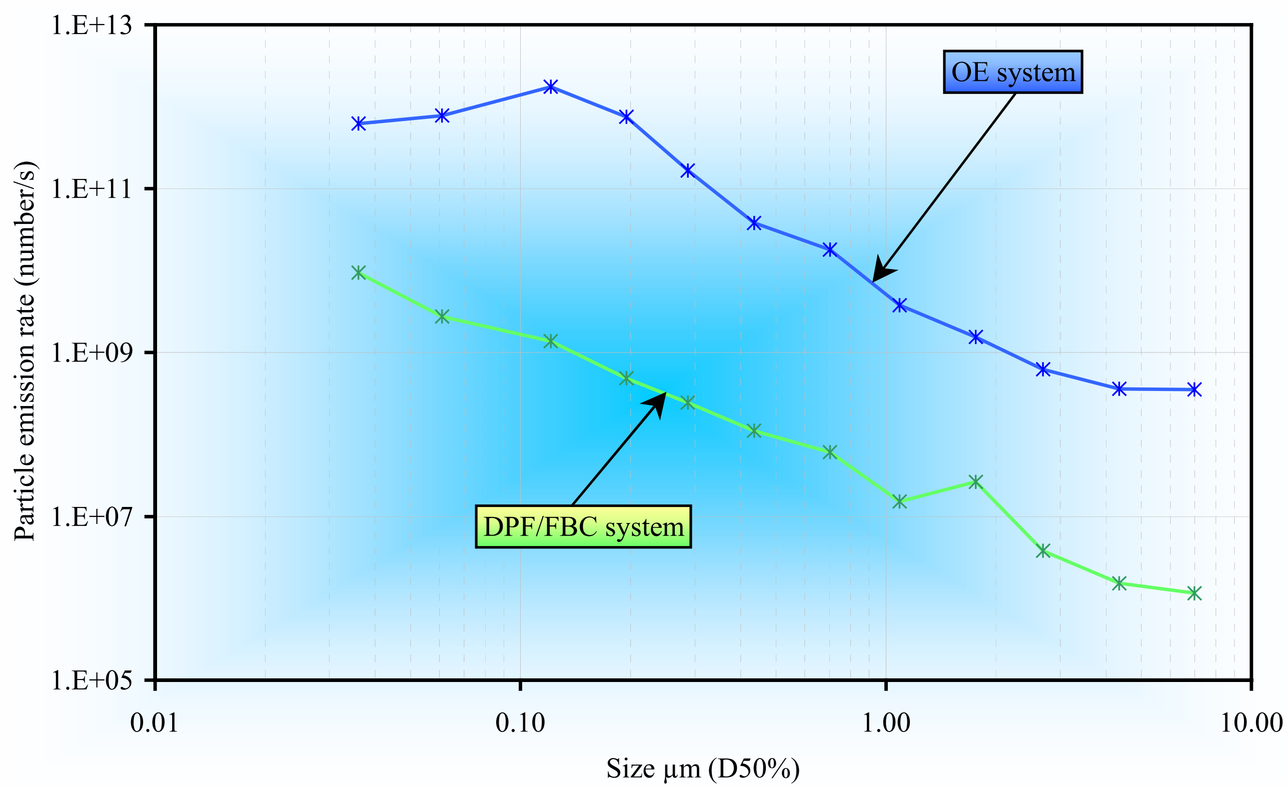
Effect of DPF Technologies

- Regulated emissions
- Particulate numbers
- Speciated NO_X

ELPI data from Taxi Cab



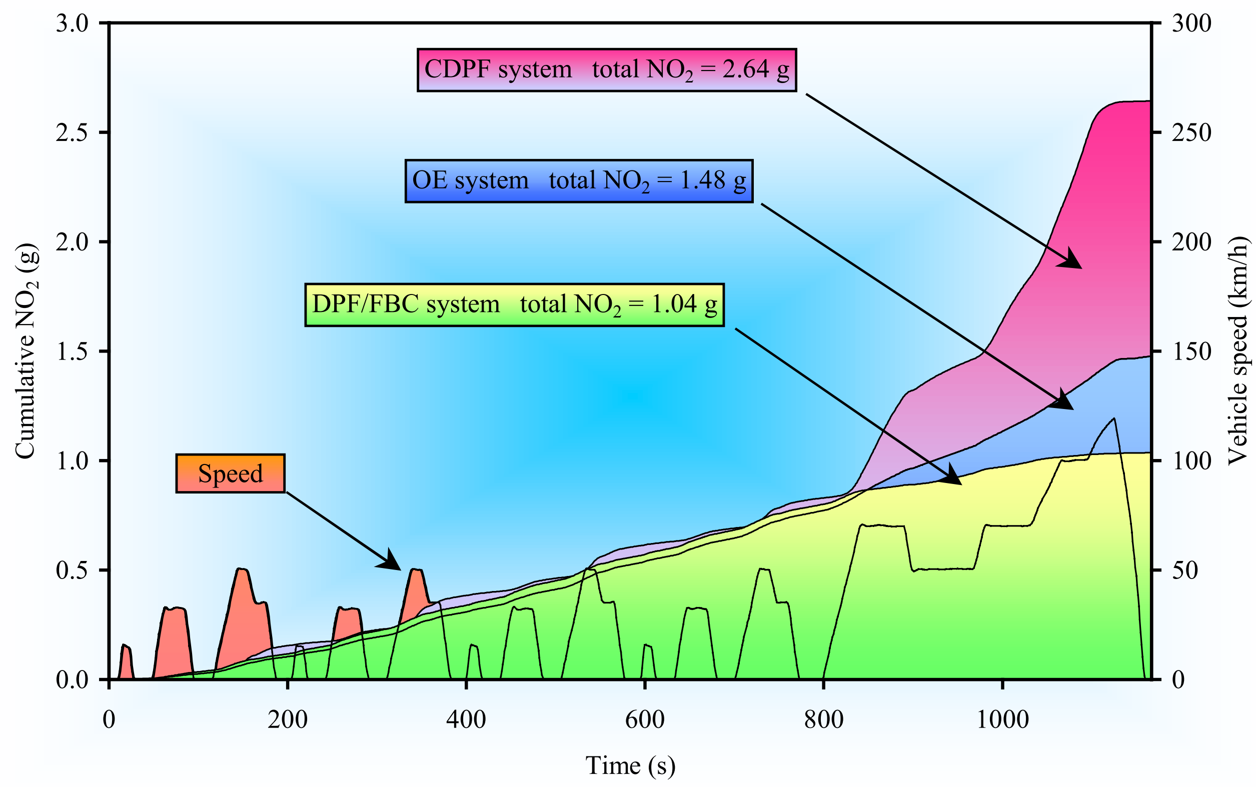
ELPI data for truck > 7.5 t



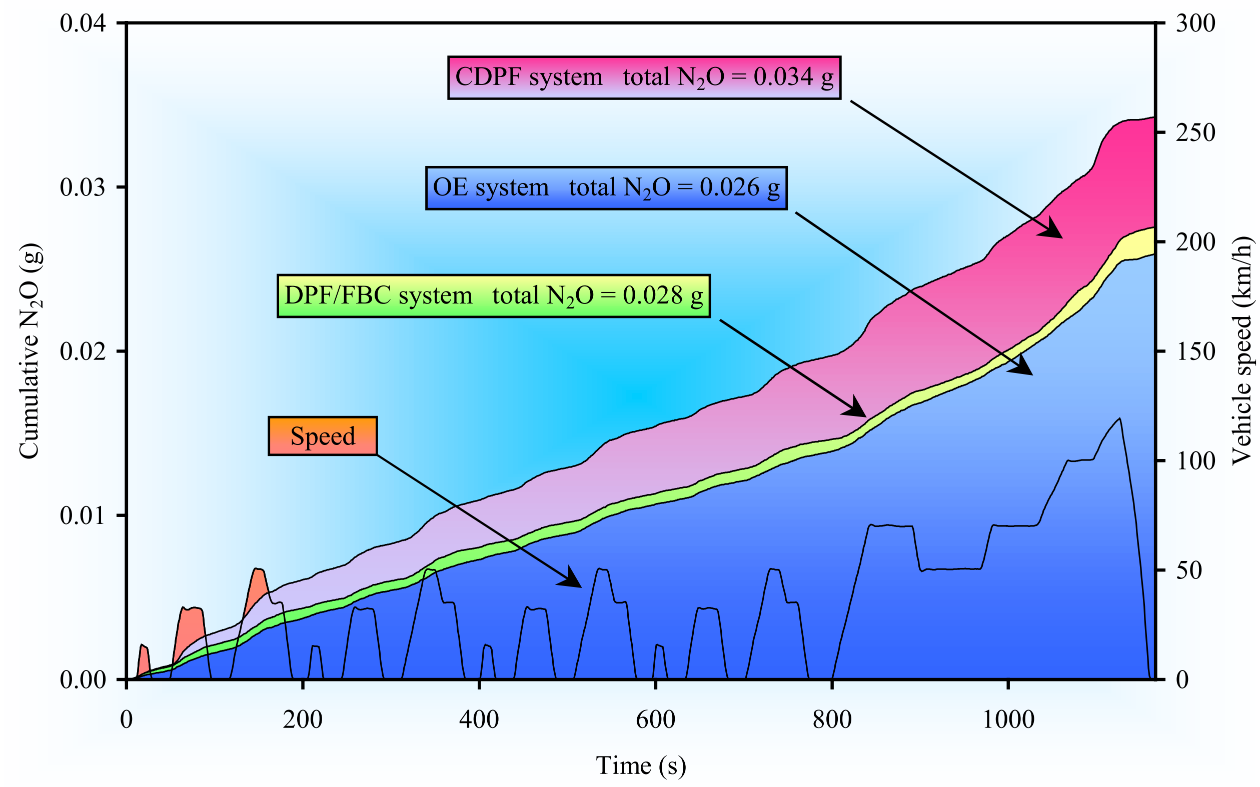
Effect of DPF Technologies

- Regulated emissions
- Particulate numbers
- Speciated NO_X

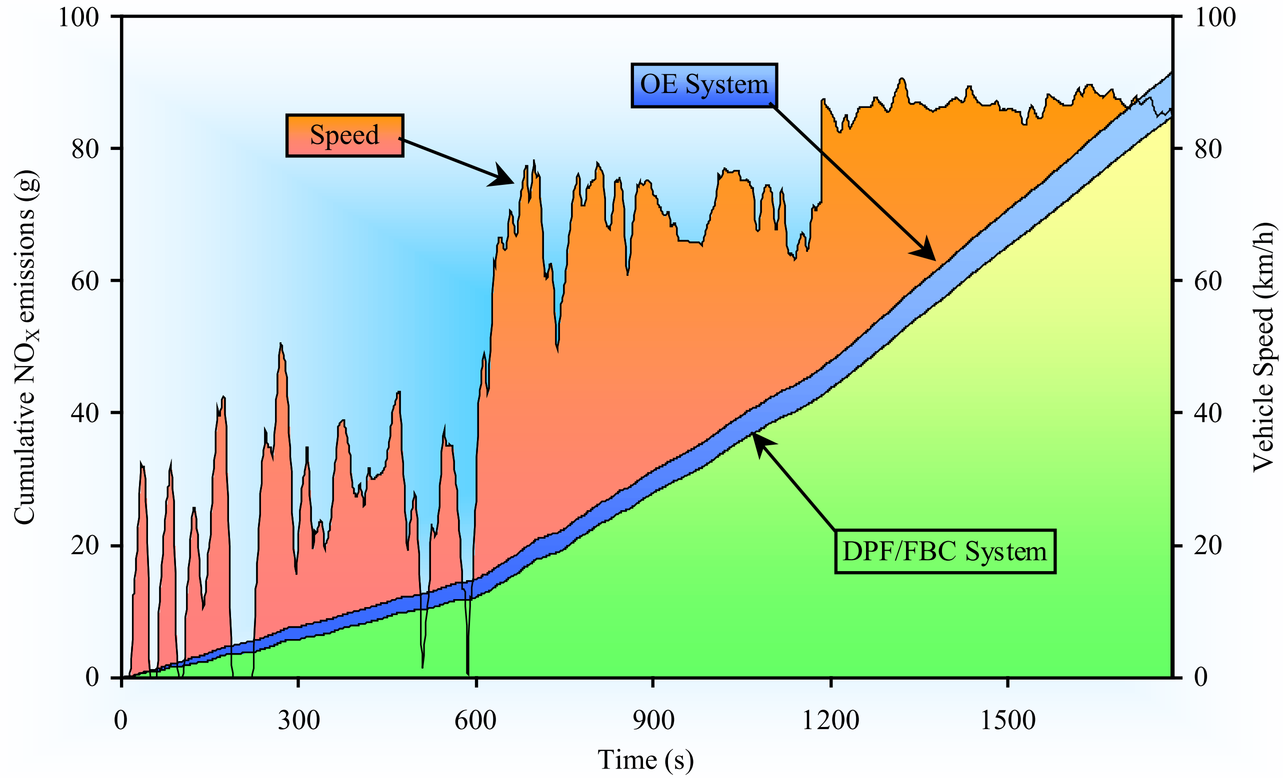
Cumulative NO_2 data from taxi cab



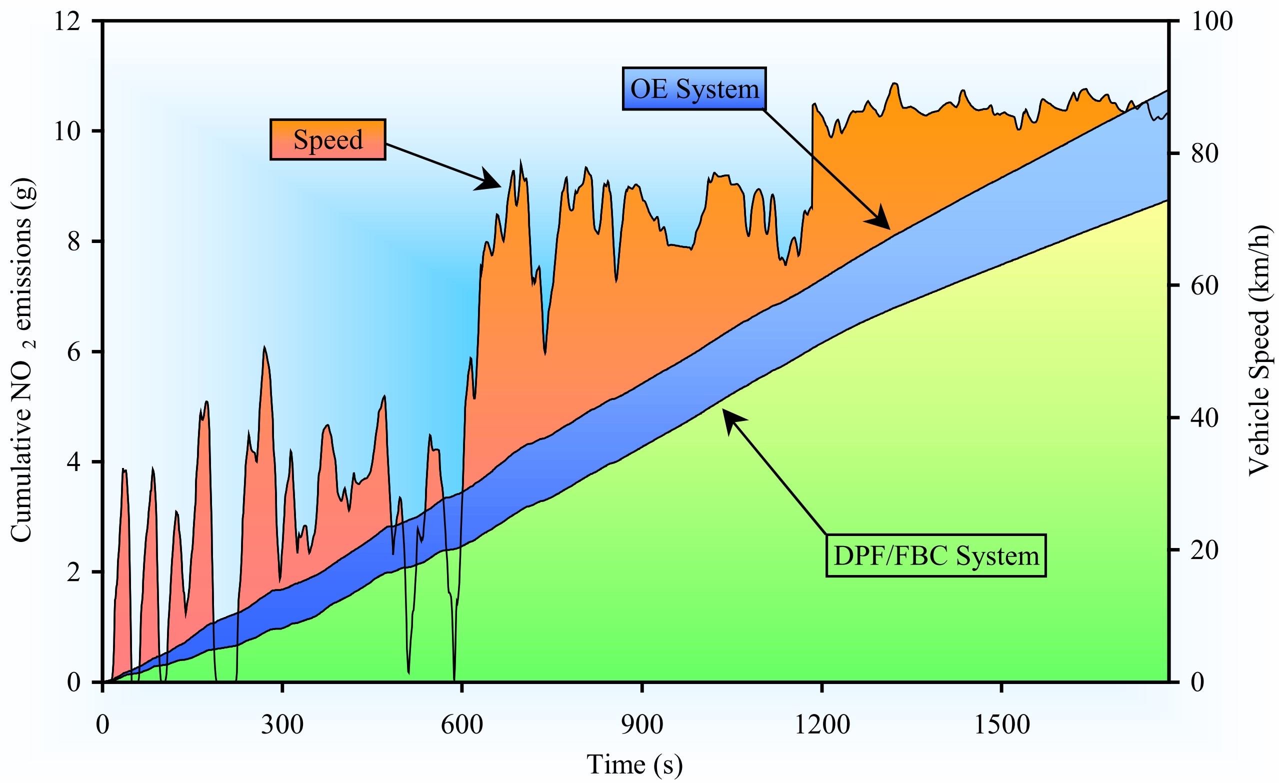
Cumulative N_2O data from taxi cab



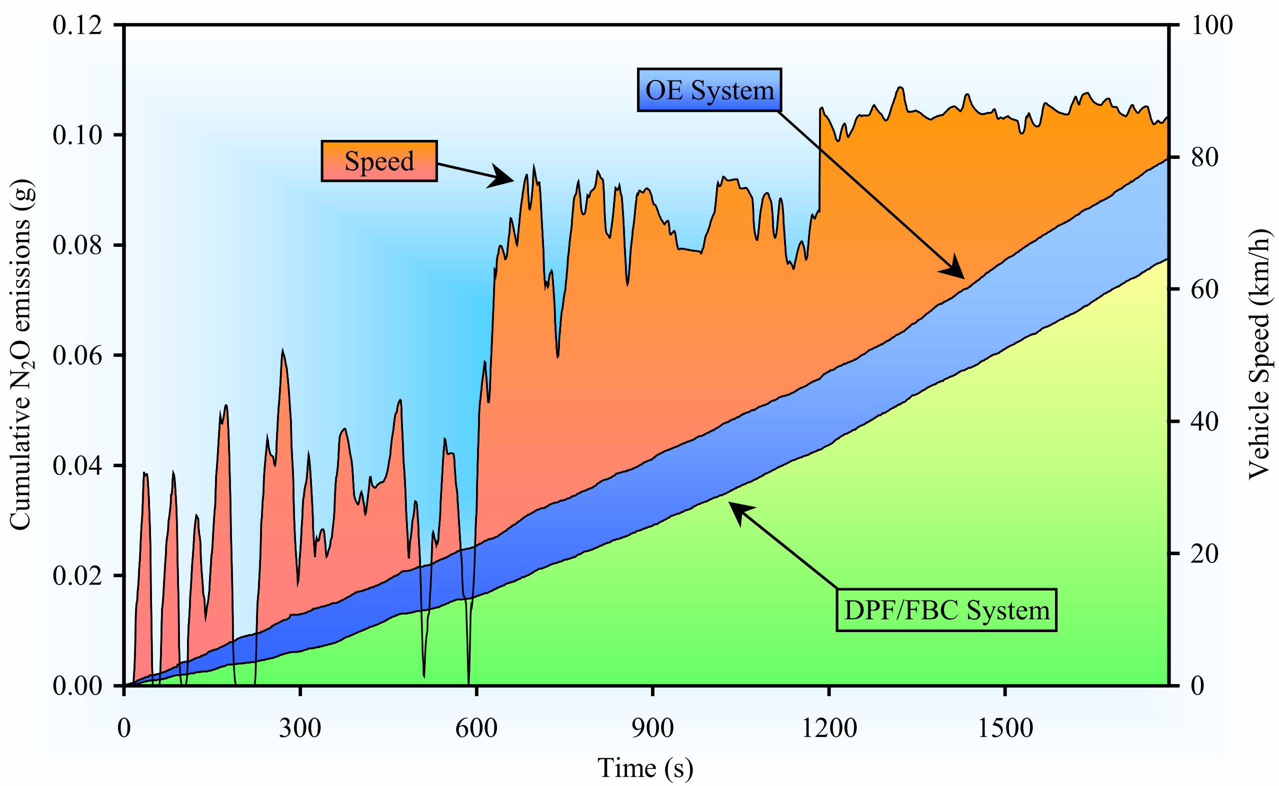
Cumulative NO_X on truck > 3.5 t



Cumulative NO_2 on truck > 3.5 t



Cumulative N_2O on truck > 3.5 t



Summary

- A low precious metal loading on a DOC has been shown to effectively reduce HC and PM mass emissions but to have 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

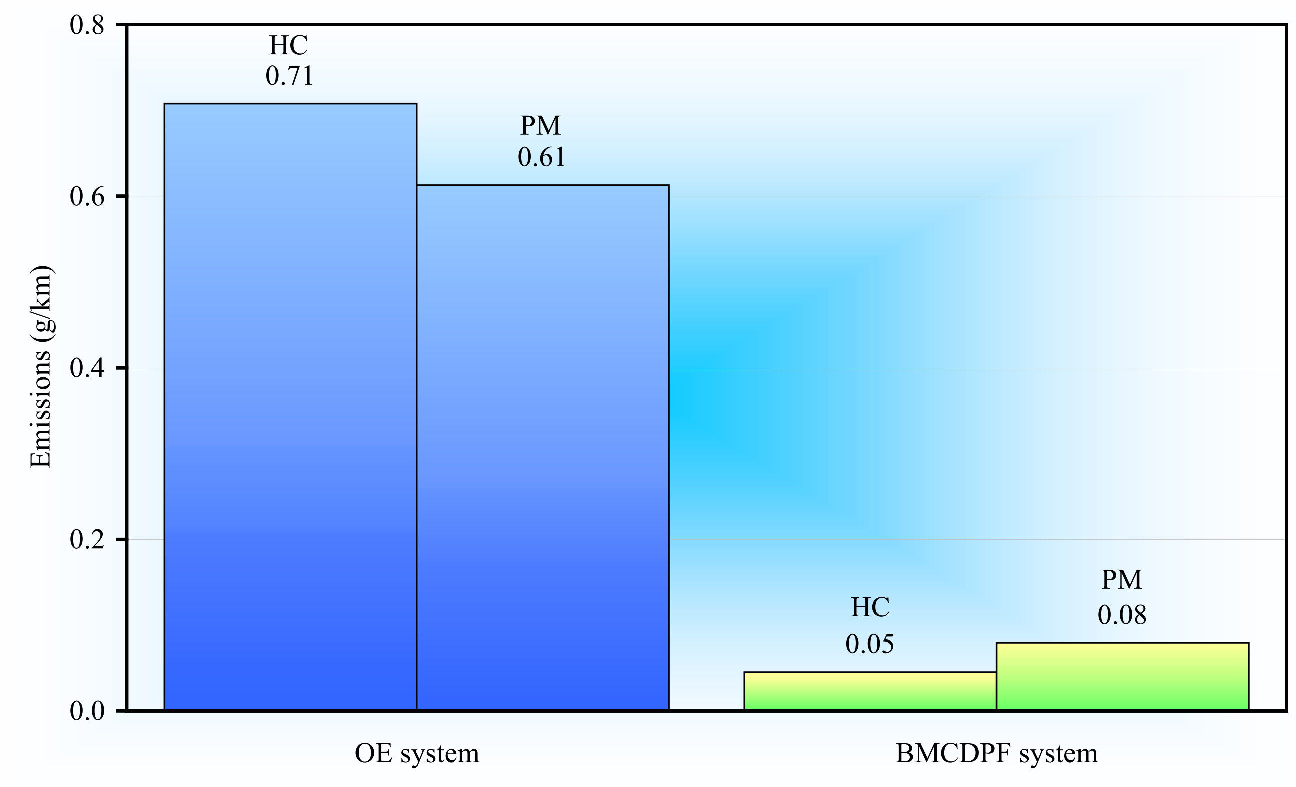
Effect of Base Metal Catalysed DPF

However -

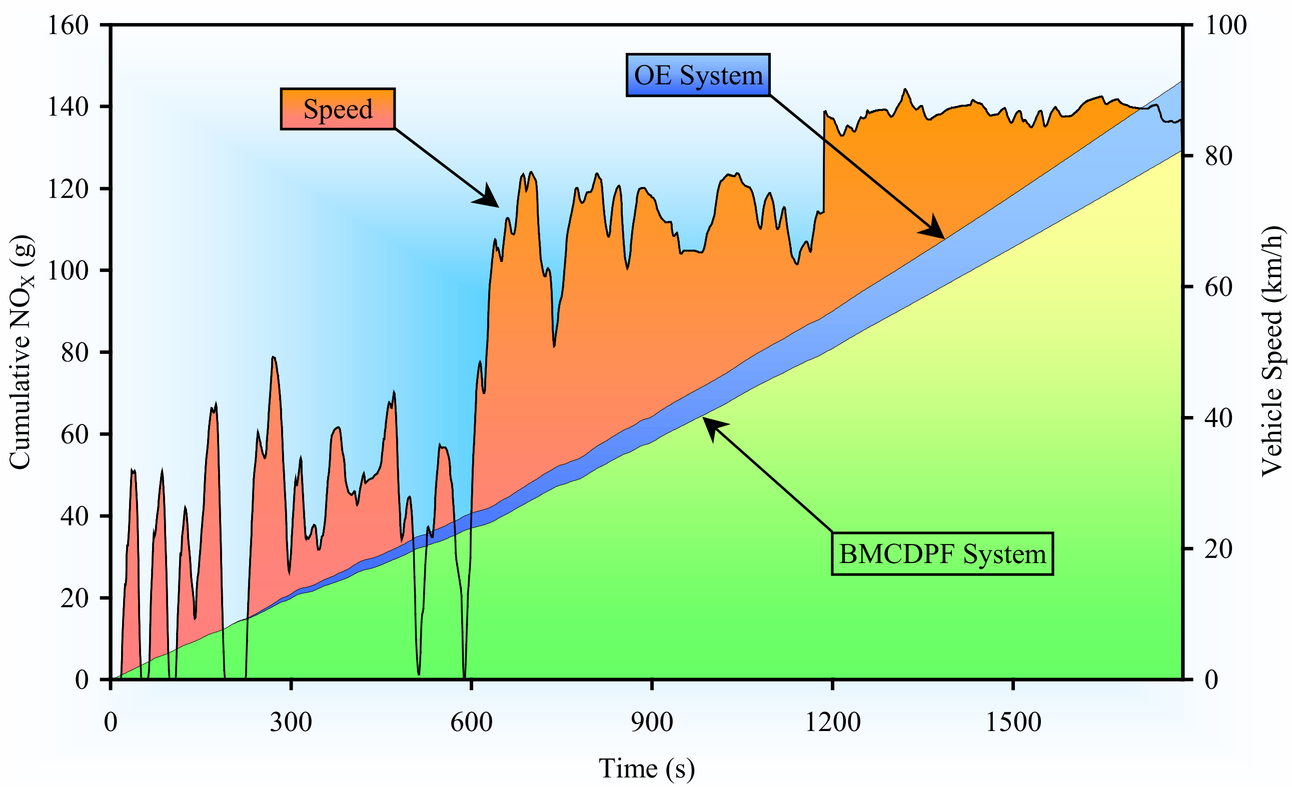
by combining a Base Metal Catalyst coating on the DPF with a base metal FBC to create a BMCDPF/FBC system all of the regulated emissions can be reduced with a significant reduction in NO_2 emissions

Test Vehicle

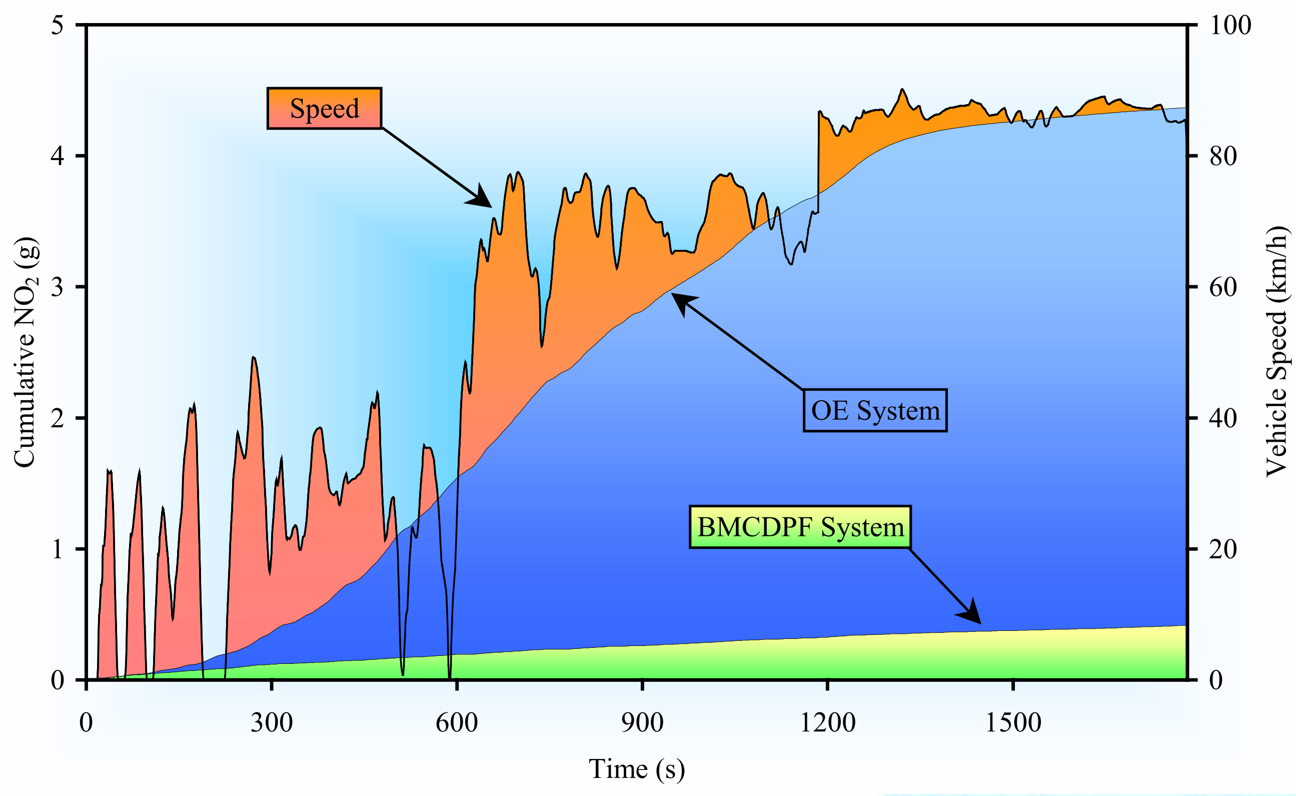
HC & PM data from single deck bus



Cumulative NO_X on single deck bus



Cumulative NO_2 on single deck bus



Conclusions

- A low Pt loading on a DOC reduced will reduce CO, HC and PM emissions, and will reduce NO_2 emissions at light duties but increases NO_2 emissions at high duties.
- 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 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