

Cummins Technology

Euro 4 & 5 Emissions Solutions

Dec 12th 2008
Hong Kong

Jonathon White
Chief Engineer – Engine Business
Cummins, East Asia





Agenda

- Cummins Inc. – Overview
- HD Diesel Engine Emissions
- Clean Diesel Technologies
- Cummins Euro 4 and 5 Products



Agenda

- Cummins Inc. – Overview
- HD Diesel Engine Emissions
- Clean Diesel Technologies
- Cummins Euro 4 and 5 Products

Who We Are



- Largest independent diesel engine maker
- Diesel and alt fuel engines, gensets and related components
- Over 1,200 OEMs, powering more types of equipment in more markets than any other engine company





Diversified Global Power Leader

Four Complementary Businesses



Engines



Power
Generation



Components

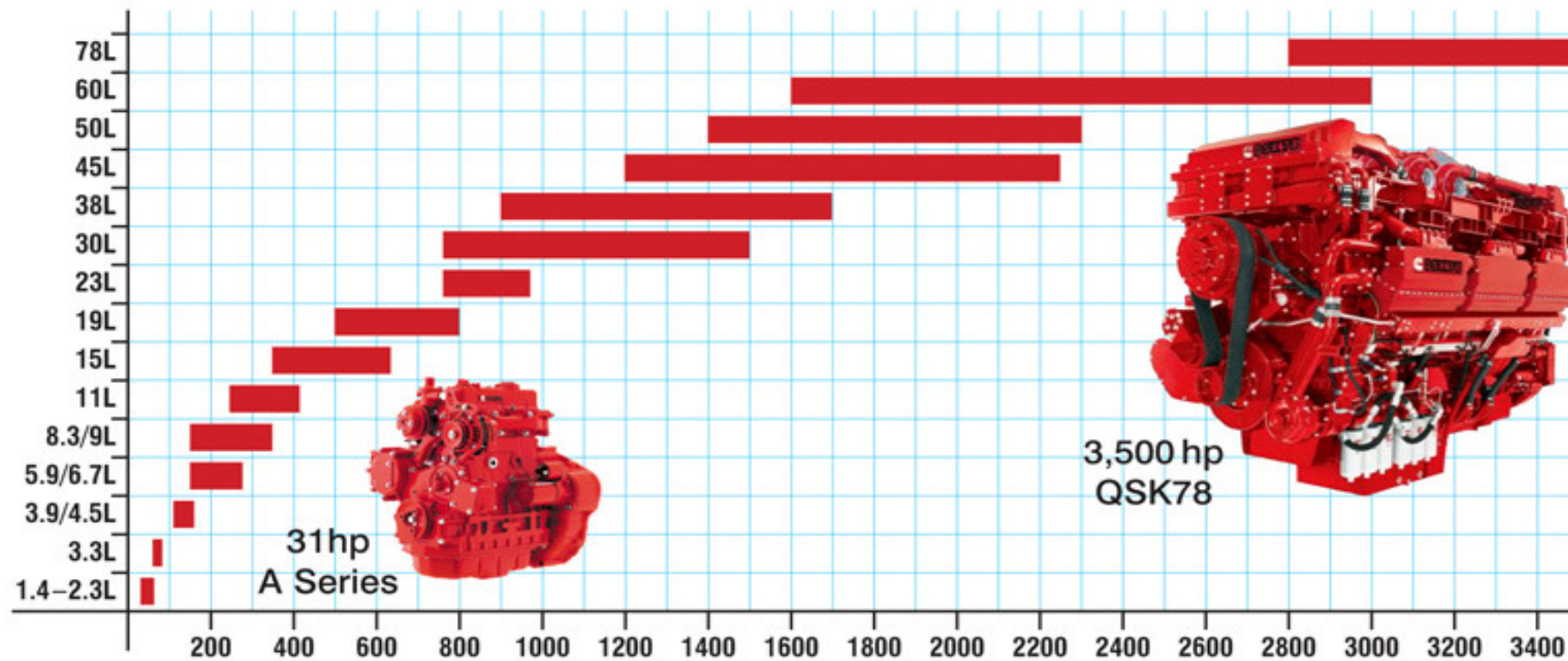


Distribution

Broad Engine Product Range



- A major expansion of the range since the late 1990s with twice the number of engine platforms.
- Diesel engine range from 1.4 to 78 litres
- 15 platforms listed on chart – 8 of these added since late 90s: A Series, B3.3, QSX15, QSK23, QST30, QSK45, QSK60 & QSK78
- A further 3 new automotive platforms under development for release in 2009.





Diversified Global Power Leader Engine Applications



Leading Technology Technical Capability

- Unrivalled global resources with 19 Technical Centers in 8 countries
- 340 test cells in 35 locations, with 88 cells at the main technical facility Columbus, Indiana
- \$329 million R&D investment during 2007
- Expertise with Analysis-Led Design

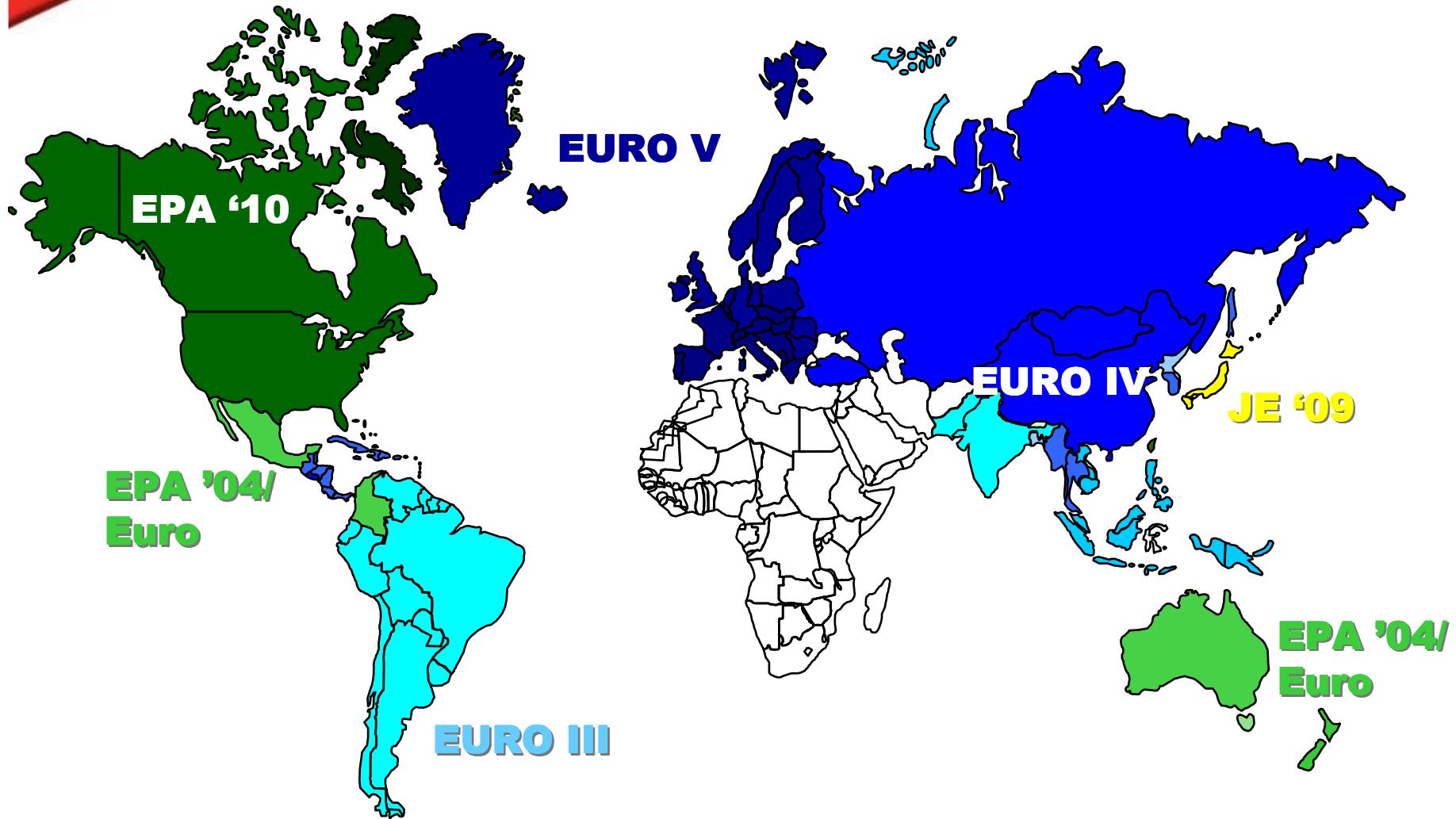




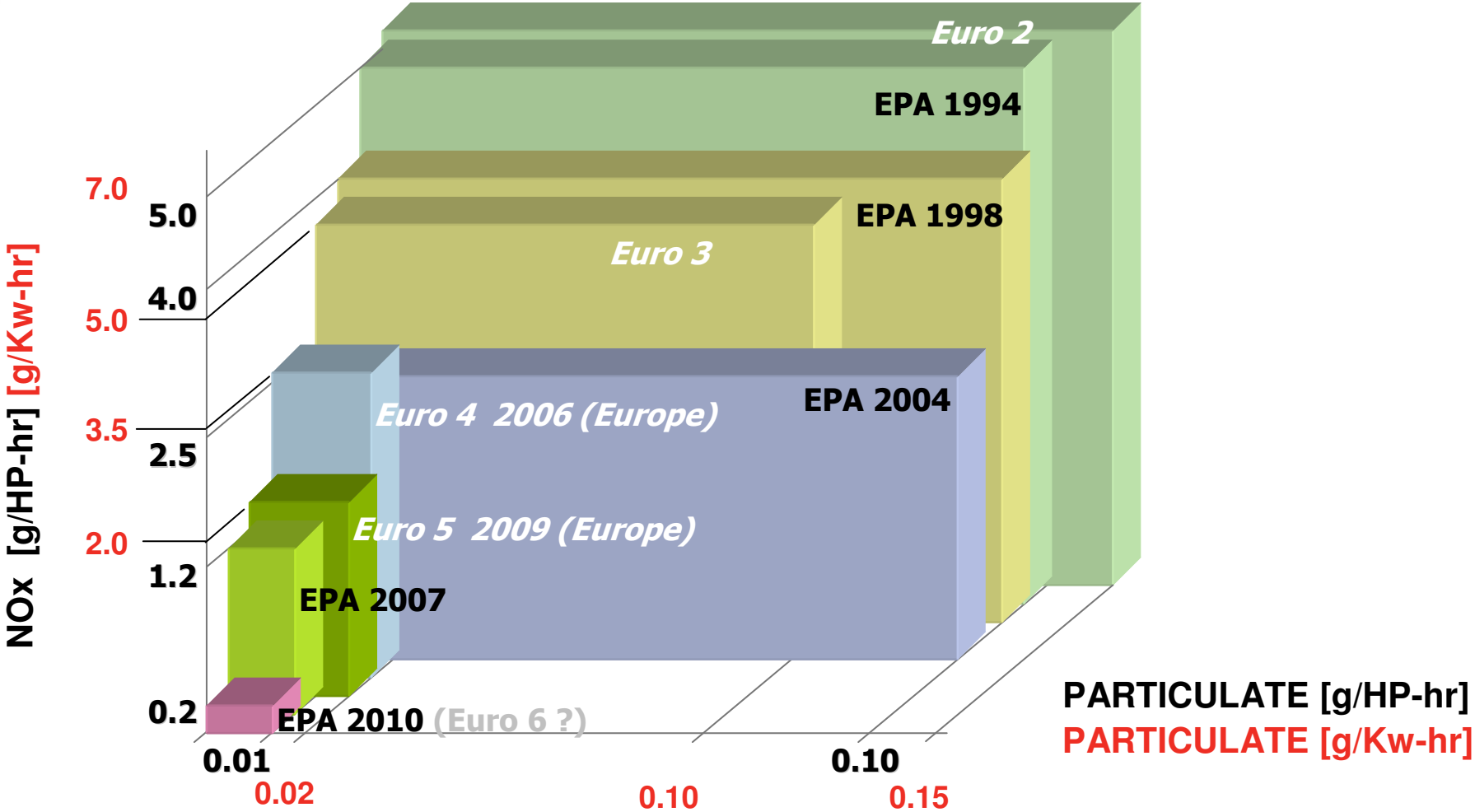
Agenda

- Cummins Inc. – Overview
- HD Diesel Engine Emissions
- Clean Diesel Technologies
- Cummins Euro 4 and 5 Products

On-Highway Emissions - 2011



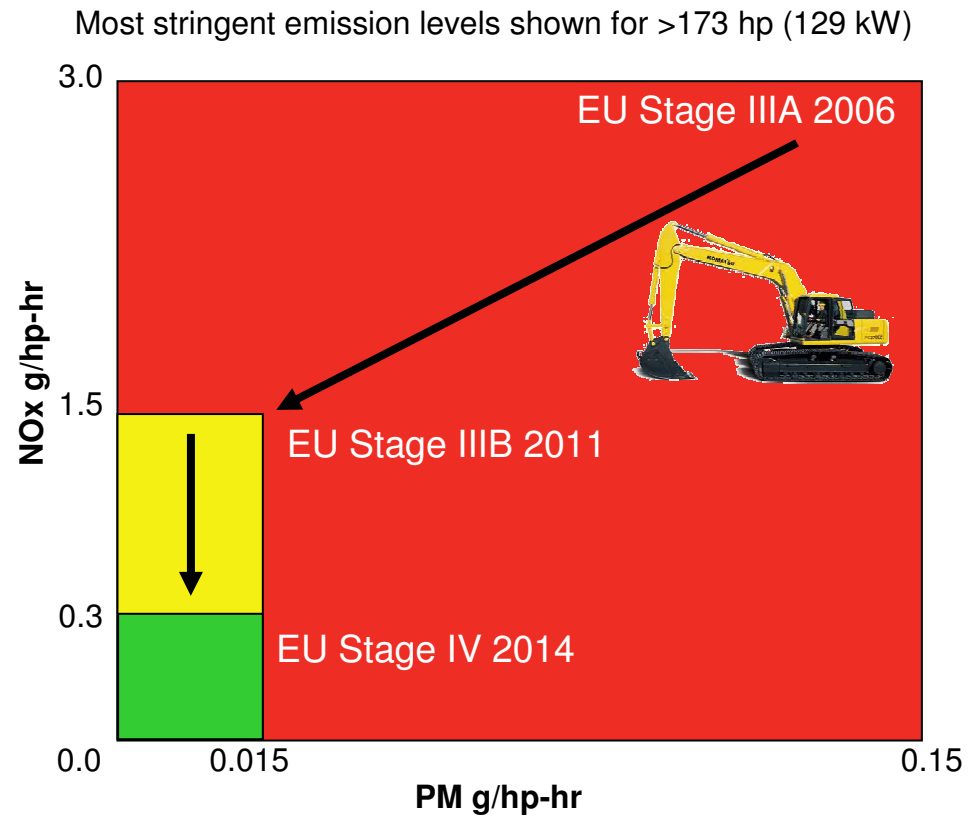
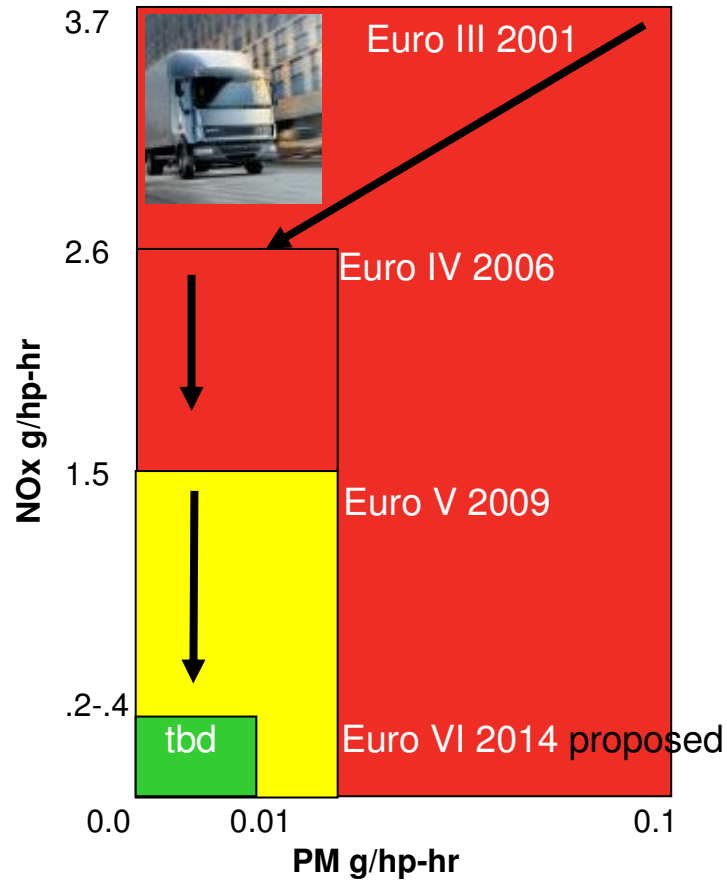
Evolution of On-Highway Standards EPA & Euro



Emissions Alignment

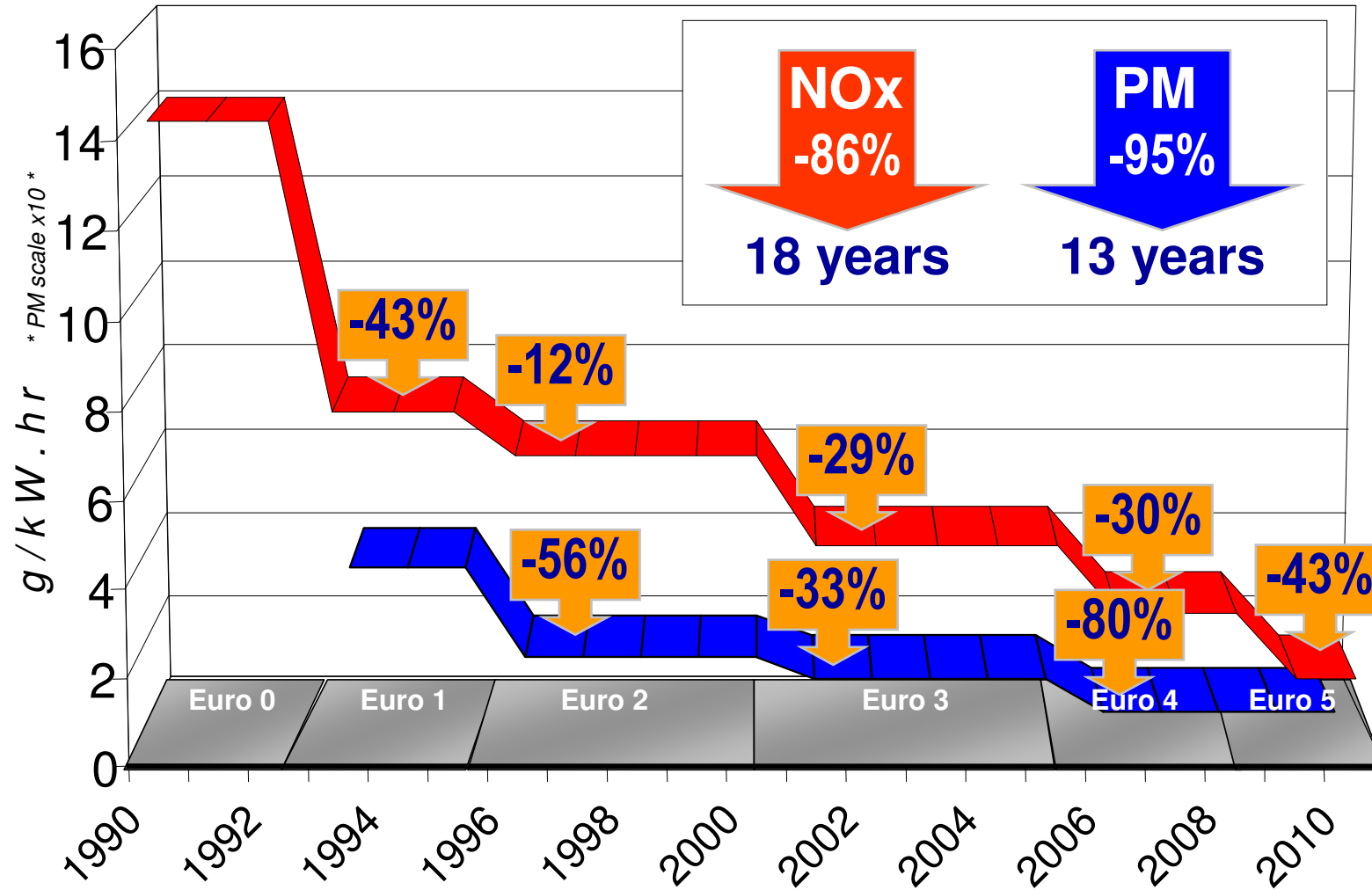


- Convergence of EU emissions



Emission levels in grams per horsepower hour for comparison for EPA

Emissions Reductions - Europe



Equivalent Bus emissions

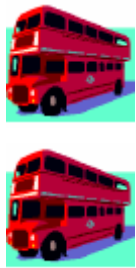
Euro 1

Euro 2

Euro 3

Euro 4

Euro 5



OBD - On Board Diagnostics



- A detection system intended to alert the driver of component or system failures for the life of the vehicle or engine which can adversely affect emissions
- A continuous “emissions” test being conducted by the engine controller while the vehicle is being driven under normal in-use driving conditions.

On-Board Diagnostics



Vehicle System Monitors

- Cooling system
- Vehicle sensors, actuators, switches, malfunction-indicator lamp

Engine Monitors – Emission Thresholds

- Fuel system
- EGR/air handling systems
- Sensors & actuators, lamps, switches ...

Aftertreatment Monitors – Emission Thresholds

- SCR / Urea
- DPF, DOC

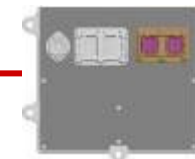


MIL Lamp



Service Information Requirements

- Service tools
 - 3rd party
- Ease of repair



ECM

- Monitors/algorithms
- Fault recording



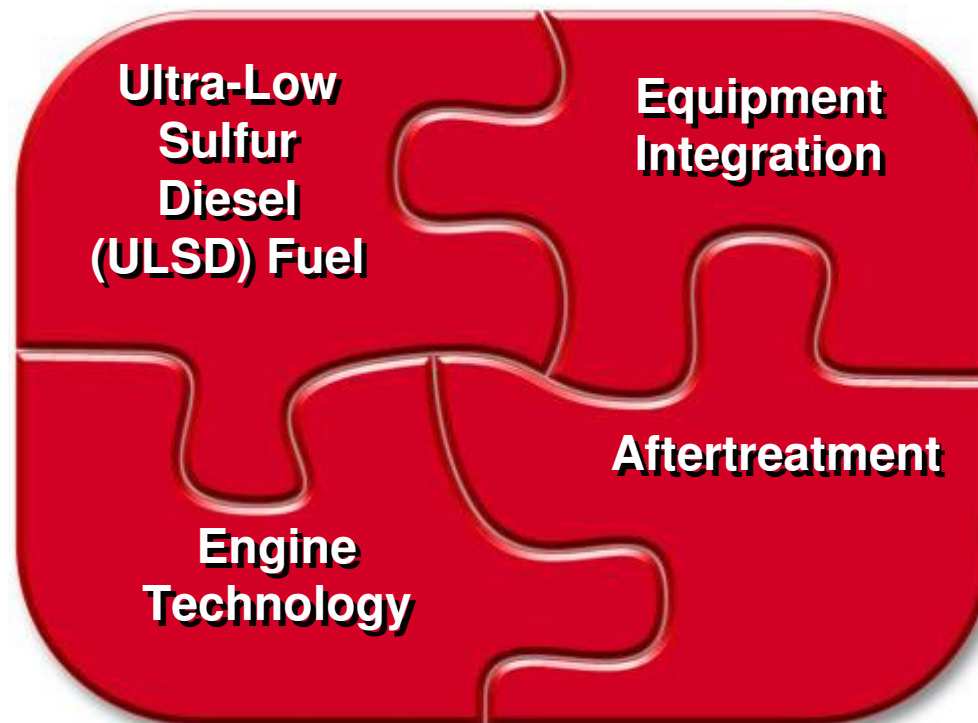
Agenda

- Cummins Inc. – Overview
- HD Diesel Engine Emissions
- Clean Diesel Technologies
- Cummins Euro 4 and 5 Products

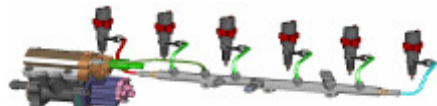
The Emissions Challenge



- All four key elements needed to achieve Future Emissions are interdependent
- Drives the need for an integrated systems solution



Integrating Technologies for Clean Air

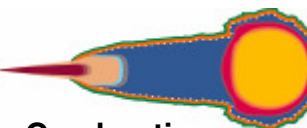
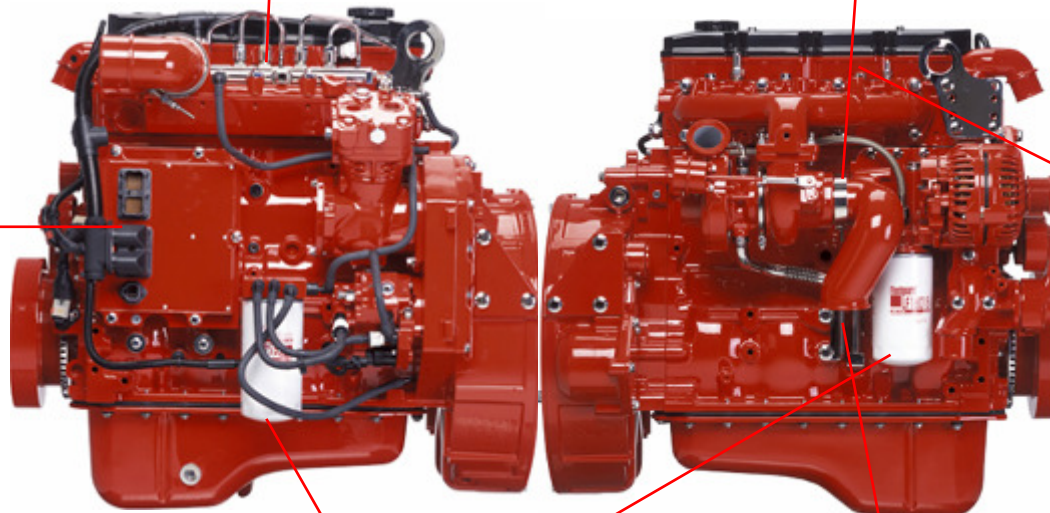


Fuel Systems



Air Handling

Electronic Control and Monitoring



Combustion Technology



Air, Oil, Fuel, Urea and Water Filtration



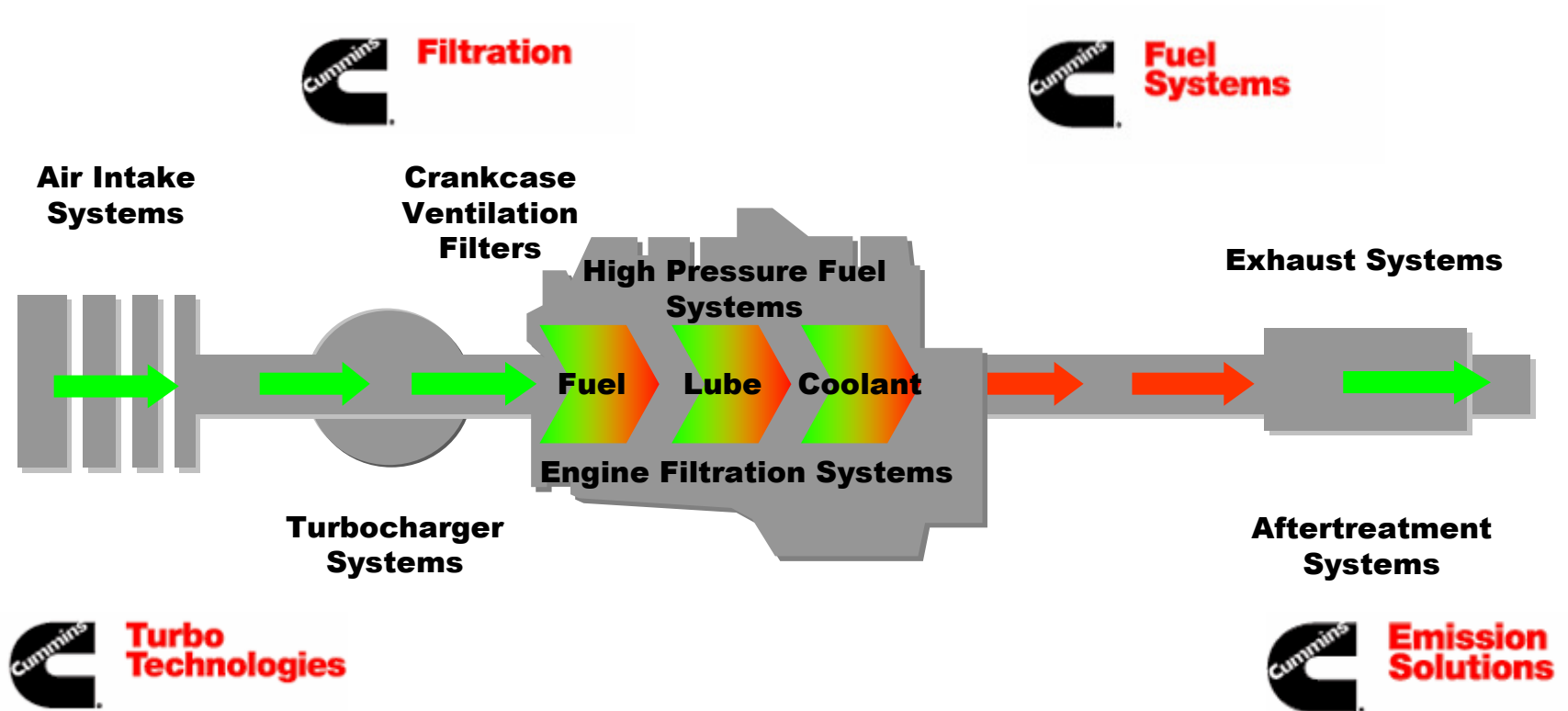
Exhaust Aftertreatment



Integrated Sub-Systems



- Cummins in-house technology from air intake to exhaust
- Ensures a fully integrated, more effective emissions solution



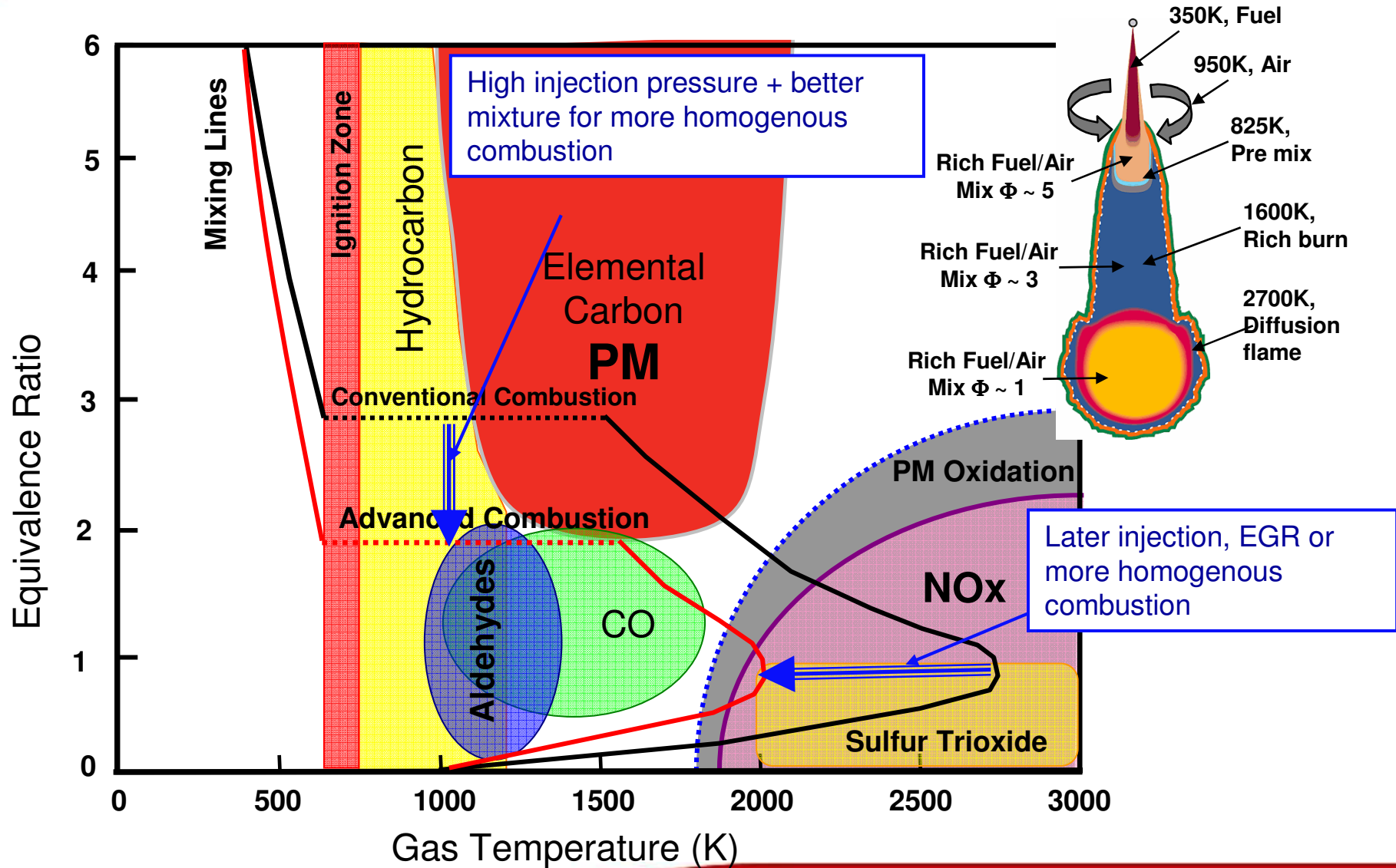
Integrated Control



- **ENGINE + A/T + TRANSMISSION + VEHICLE**
- Cummins electronic control modules enable higher capacity & faster processing speeds
- In-house design of core programs & algorithms
- Seamless electronic integration enhances operating reliability & faster diagnostics
- Highly robust ECM, wiring harness & sensor design



Diffusion Flame Combustion Kinetics



Fuel Systems



High Pressure Common Rail

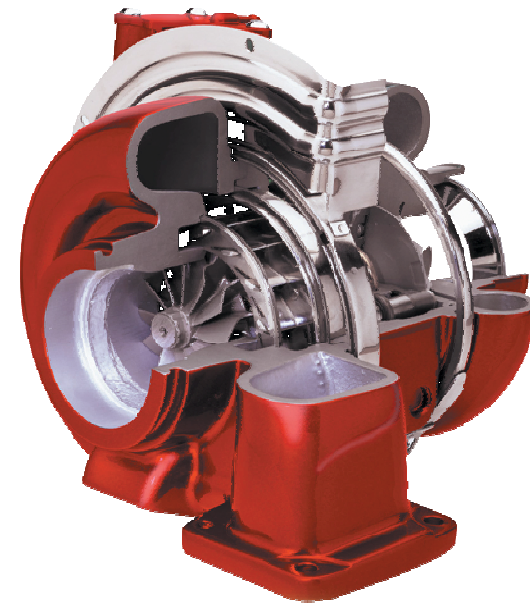
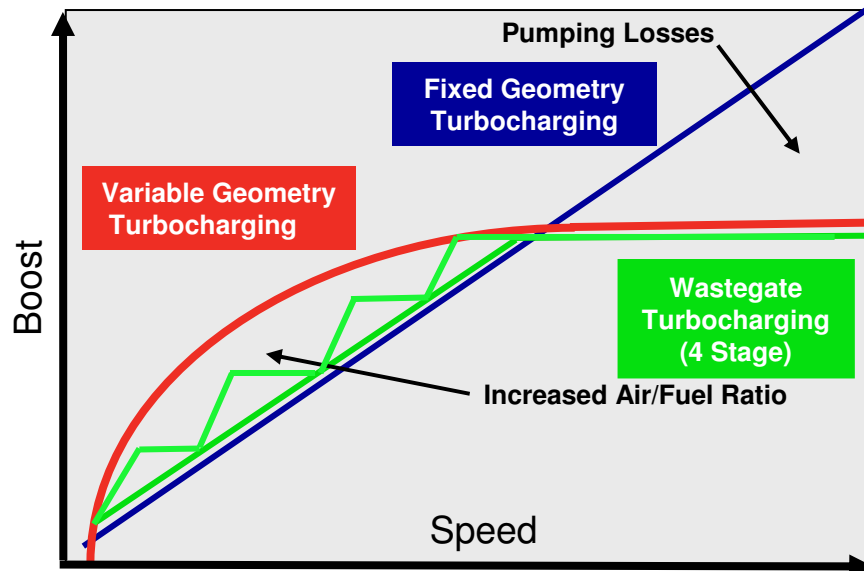
- Increasing pressure capability (1800 bar +)
- Provides more precise control of the combustion process. Multiple Injection Capability.



Cummins VGT



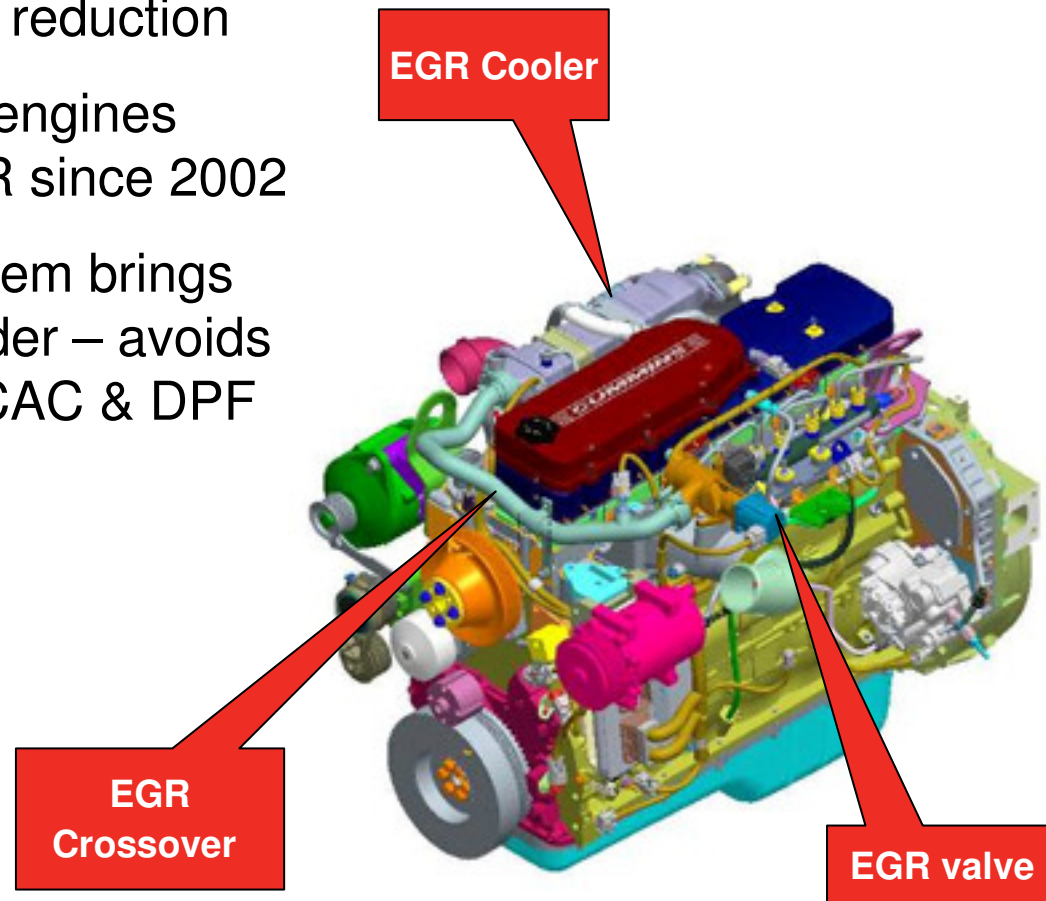
- Cummins variable geometry turbocharger with patented sliding nozzle design
- Improves boost efficiency across all engine speeds/loads
- Proven technology. Integral component for EGR engines.



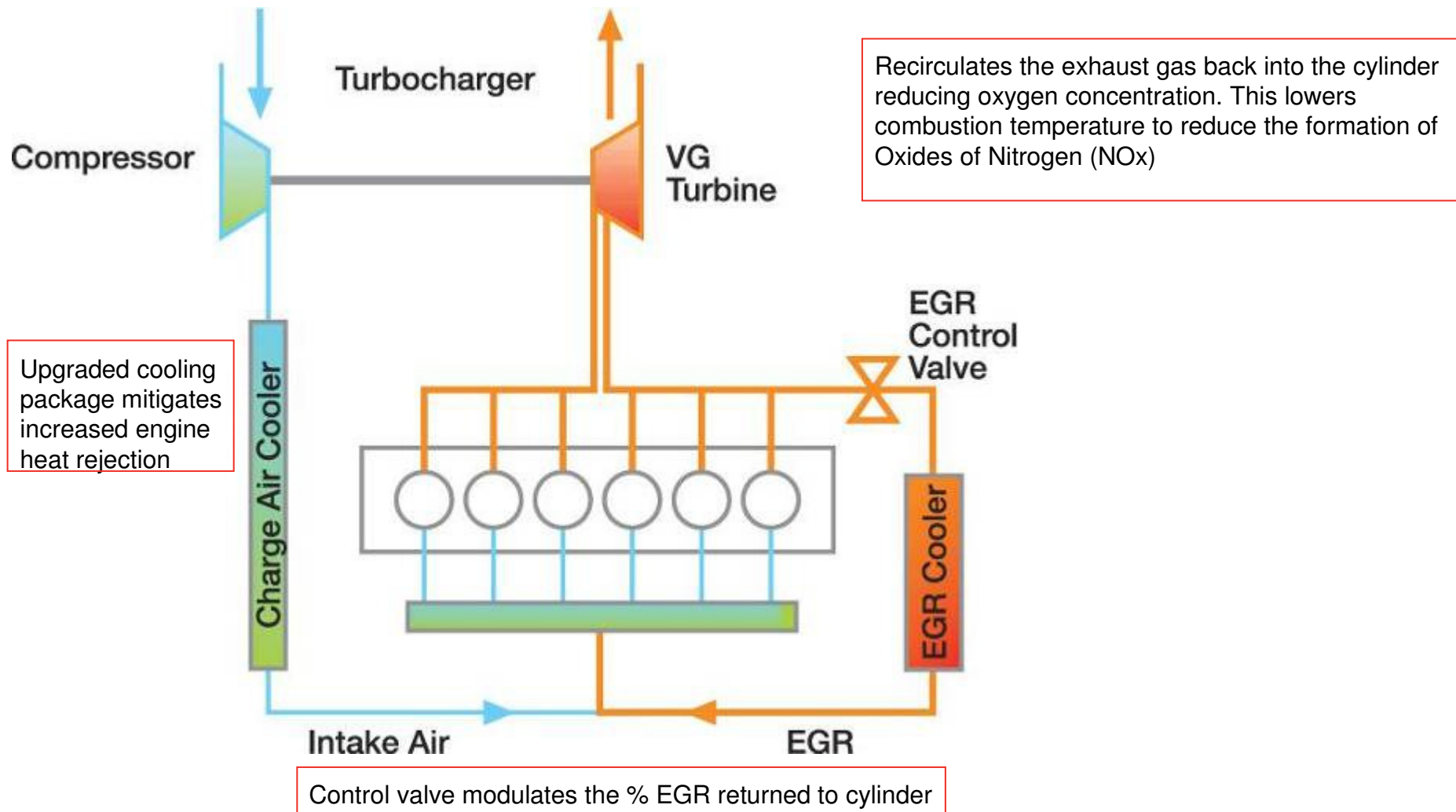
Cummins CEGR



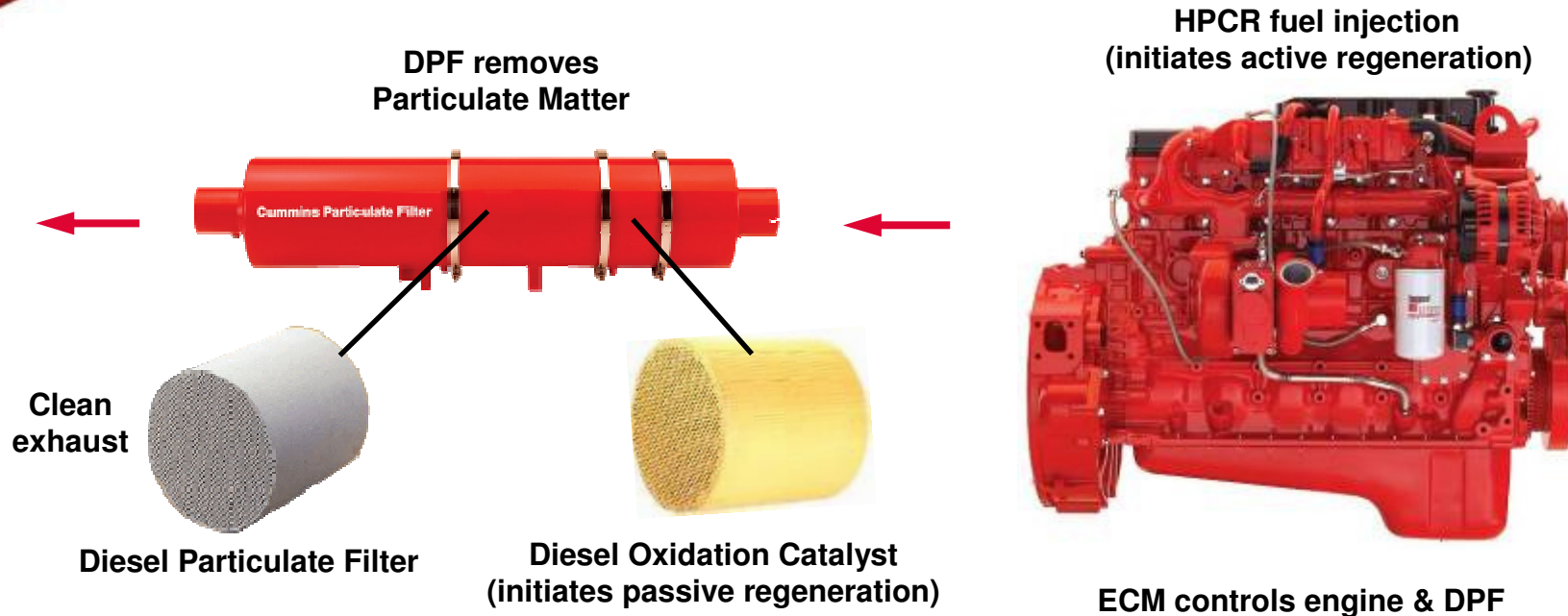
- Cooled Exhaust Gas Recirculation enables very efficient NOx reduction
- Over 600,000 Cummins engines in-service with cooled EGR since 2002
- Cummins short-loop system brings EGR directly back to cylinder – avoids long route through turbo, CAC & DPF



NOx Reduction - EGR

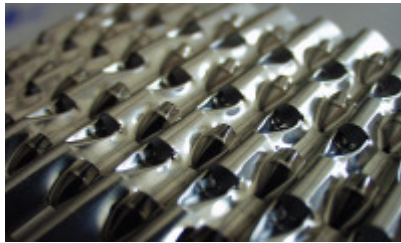


Aftertreatment - DPF

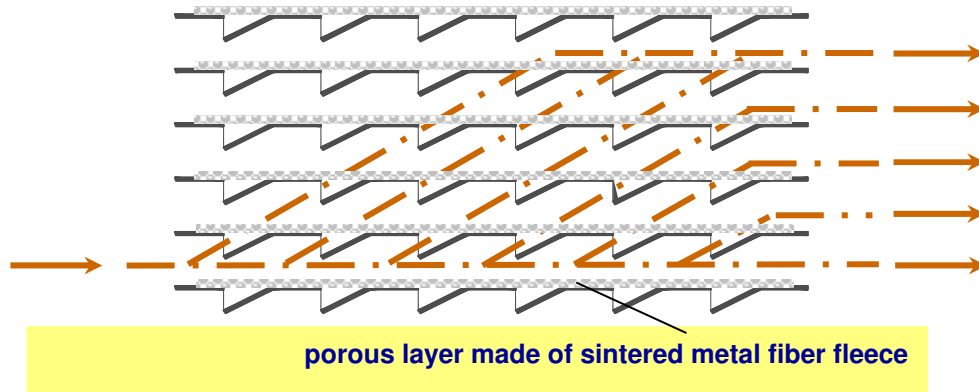


- Diesel particulate filter acts as a single integrated system with the engine
- Surface area of the filter is equal to that of two football fields – providing a huge holding capacity
- Efficient regeneration enables long service intervals before filter cleaning of residual ash

Partial Filter (POC)

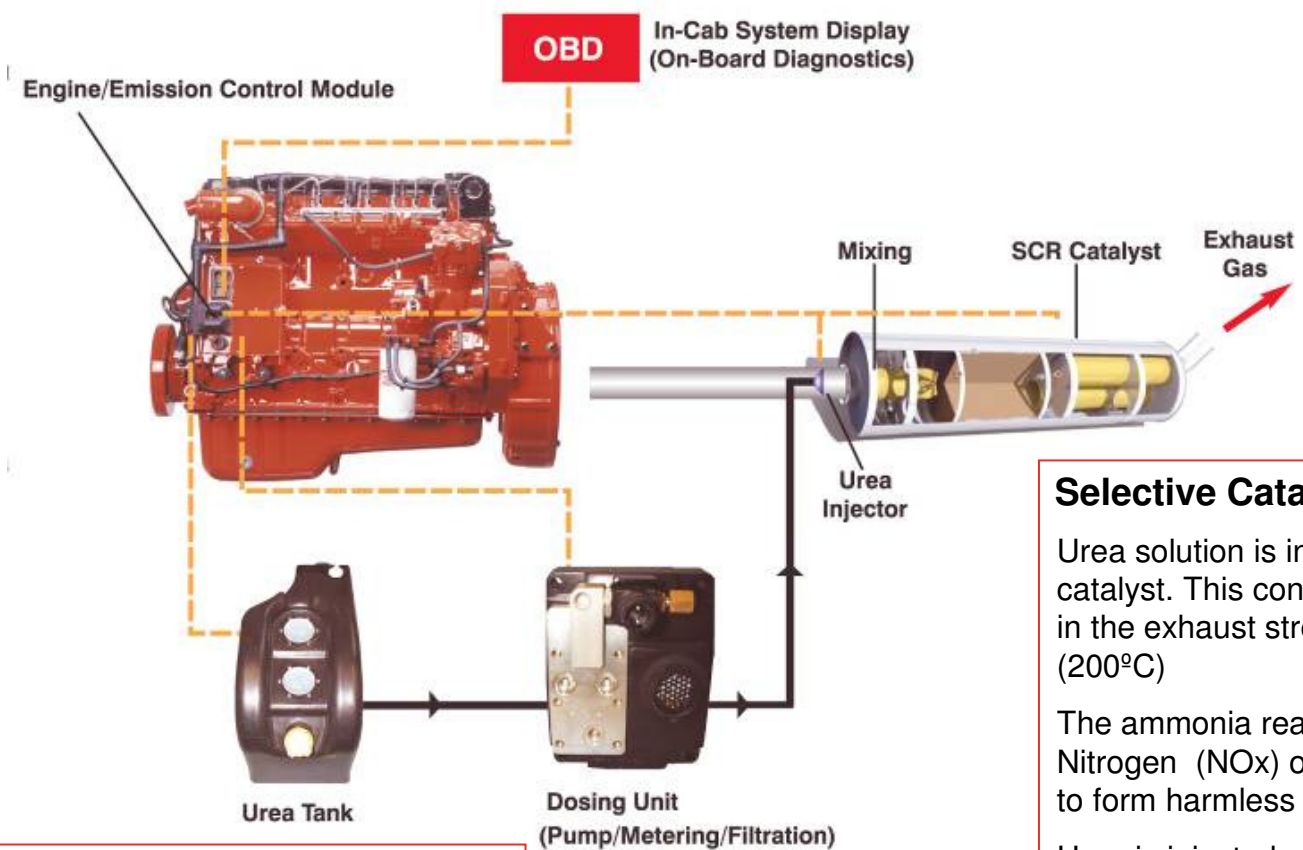


Step to filtration activity:



- Reduces PM about 50%
- Effective at removing unburned fuels and lube (soluble organic fraction) and some insolubles
- Compatible with higher level sulfur fuels (<500ppm)
- Maintenance free (if less than 500ppm sulfur fuel used with well maintained engine)

Aftertreatment - SCR



Urea Solution
The urea-water solution (AdBlue in Europe) is a clear liquid, non-hazardous & non-flammable with a 12 month shelf life. Heaters are required to prevent urea freezing at 11°F (-11°F)

Selective Catalytic Reduction

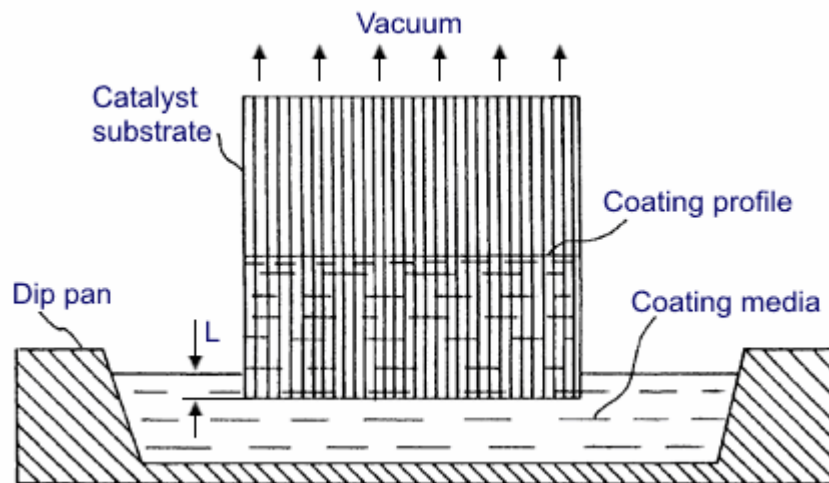
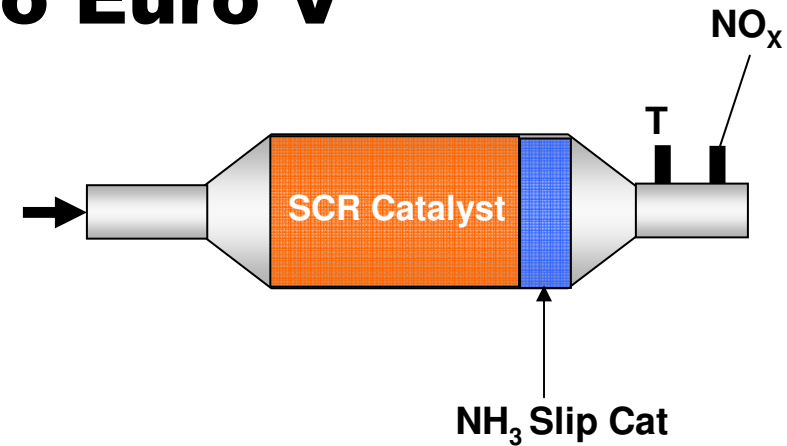
Urea solution is injected ahead of the catalyst. This converts to ammonia in the exhaust stream above 392°F (200°C)

The ammonia reacts with Oxides of Nitrogen (NOx) over the SCR catalyst to form harmless nitrogen & water

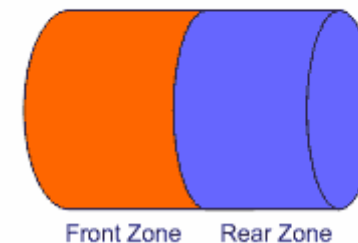
Urea is injected at a ratio of typically 5% to diesel fuel use, depending on duty cycle. Urea tank sizes vary, but must be refilled to ensure emissions compliance

Post-SCR Oxidation Catalyst (“AMOX”) – Euro IV to Euro V

- AMOX catalyst is most often ‘zone-coated’, meaning the SCR catalyst and AMOX catalyst share the same physical substrate



Zone Coating (Axial)



Integrating Technologies -Flow Distribution



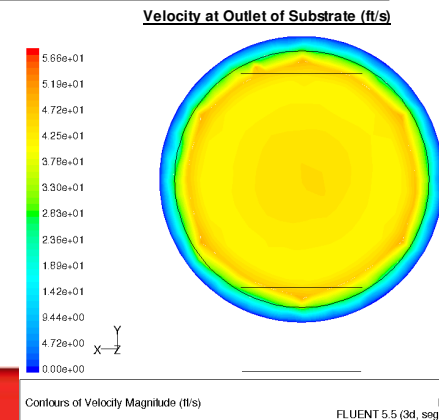
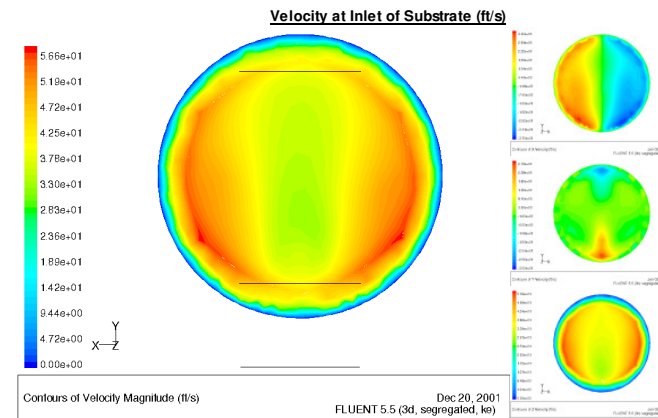
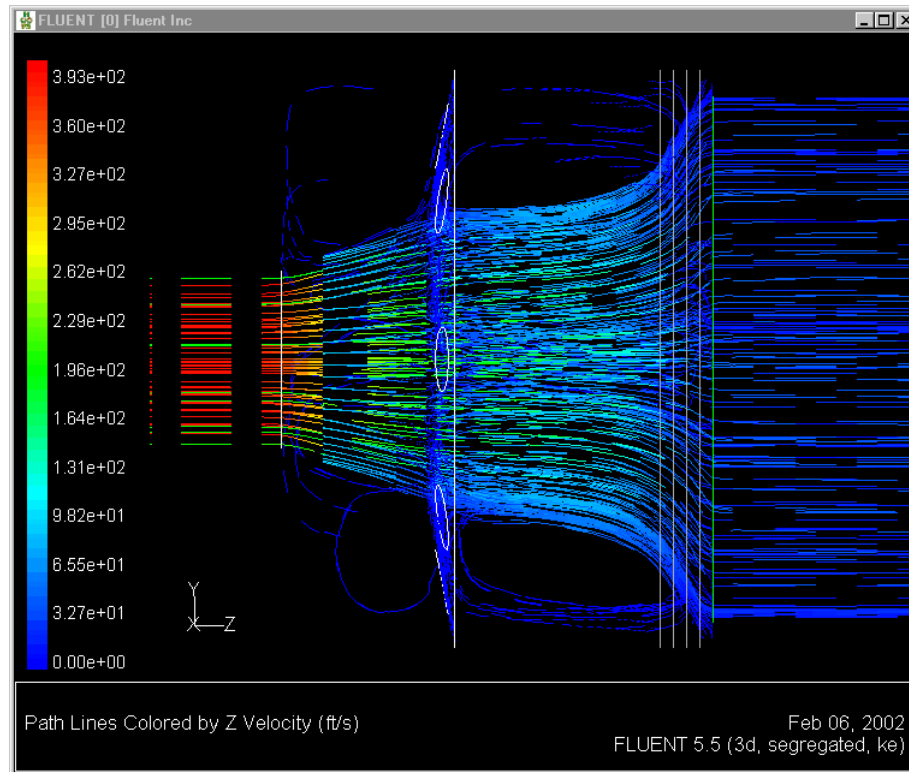
CFD Analysis for Aftertreatment Devices
Analysis Results Data Sheet

CFD Request No.: 00000
 CFD Engineer: Jeff Sharp Phone: 931-372-9819 Email: jeffrey.b.sharp@fleetguard.com
 Analysis completed on:
 Device Nelson P/N: 29331A Rev.: A
 Inlet/Outlet configuration: SIEO
 Inlet Type: Perf. Tube

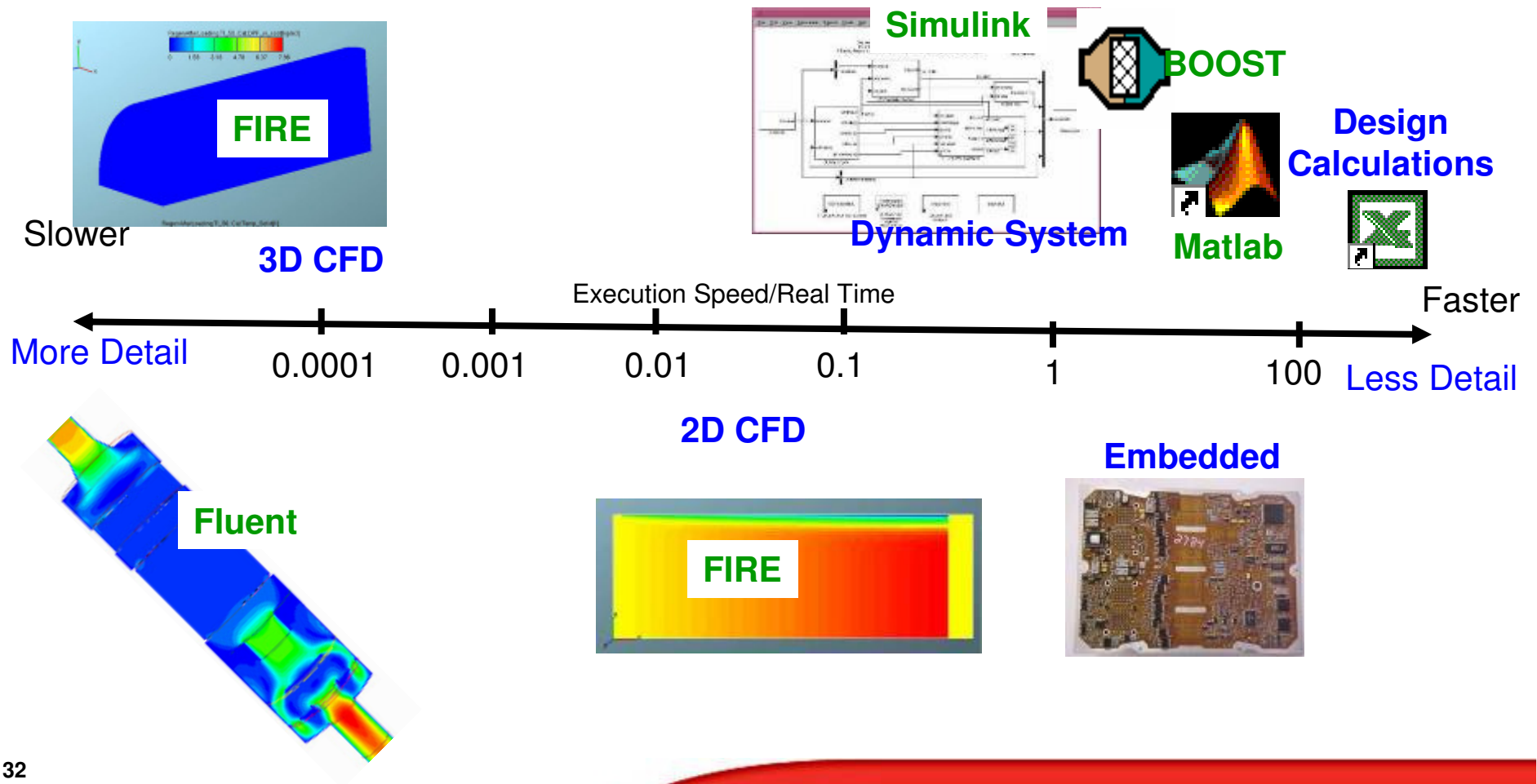
Flow Distribution

velocity profile (ft/s) across inlet and outlet of substrate

Distance from substrate face: 0.5 in.
 Exhaust flow rate (@ peak power): 1670 CFM
 Exhaust temperature (@ peak power): 600 deg. F

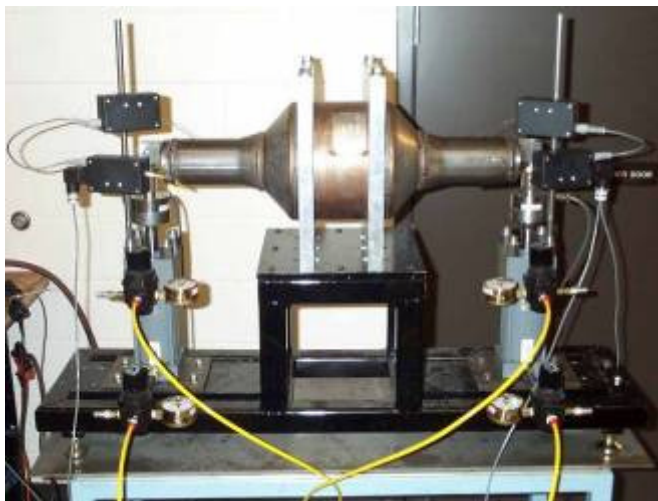
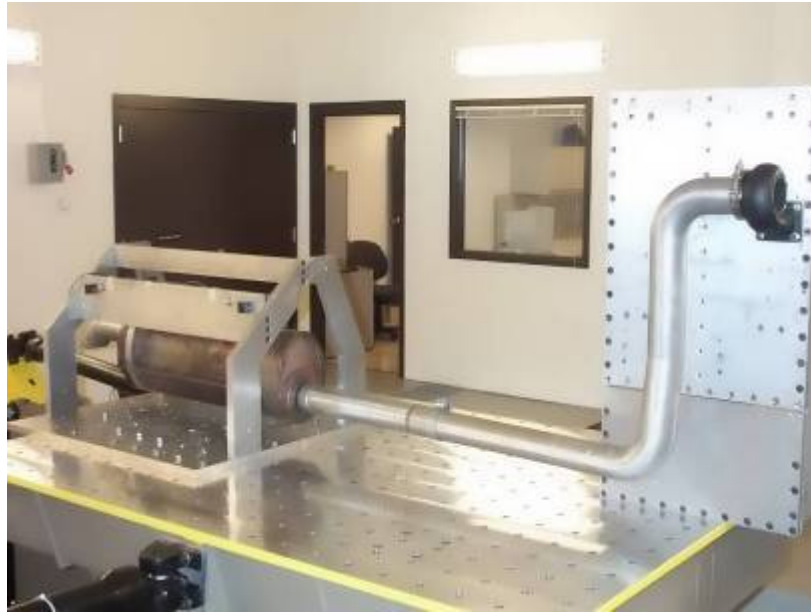


Integrating Technologies -System Analysis Tools



Integrating Technologies

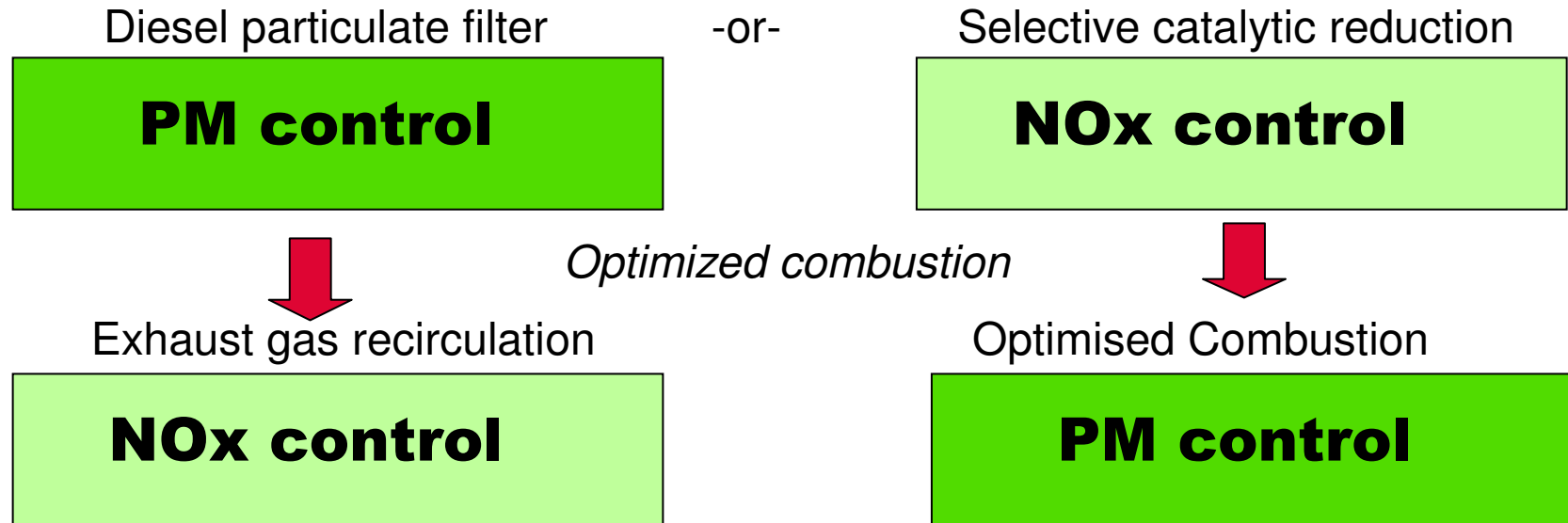
- Structural Testing



Exhaust Aftertreatment

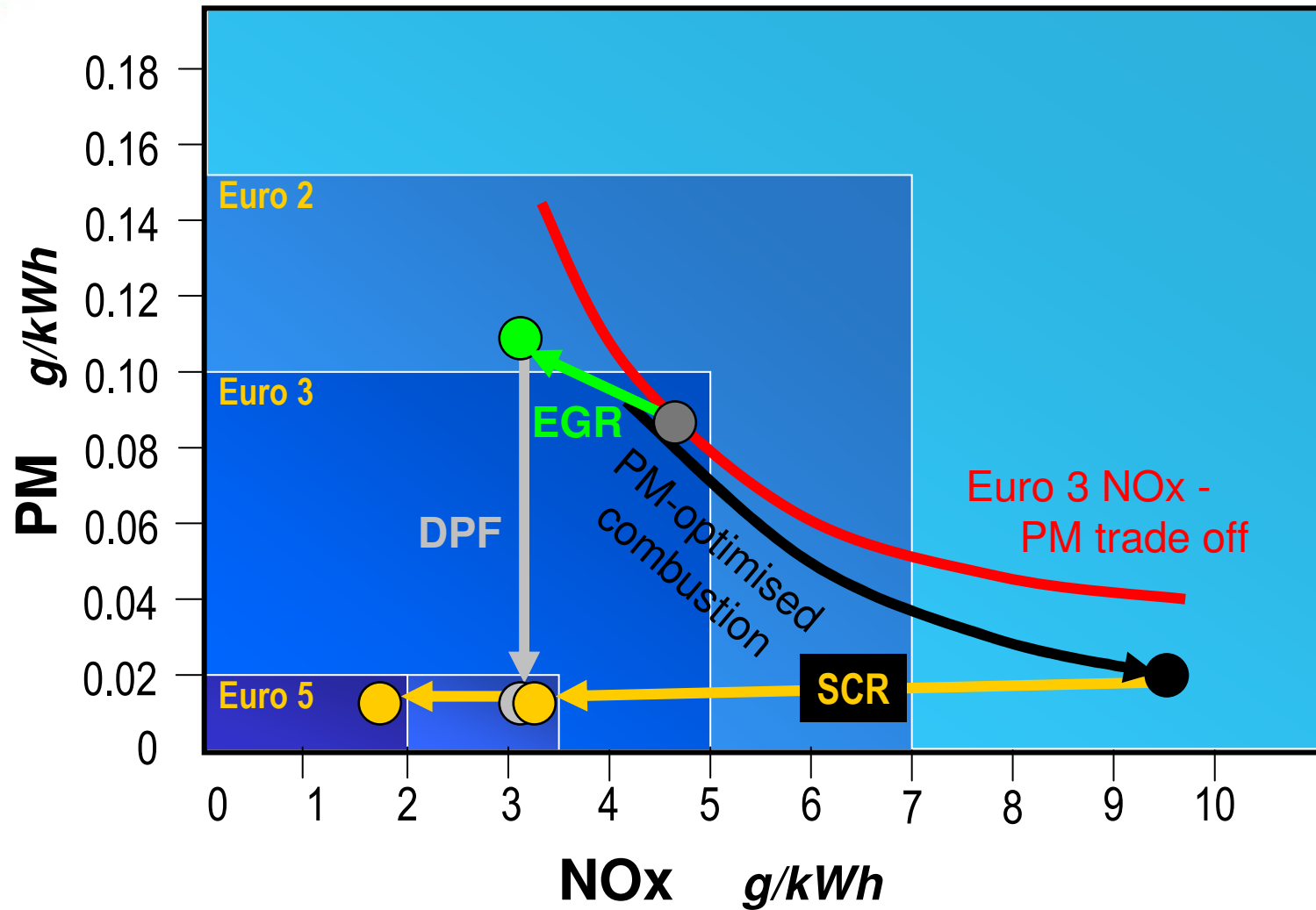


Exhaust Aftertreatment Options



- Using either system requires a combustion recipe to optimize PM or NOx reduction
- May require both systems at Euro 6

Technology Options





Technology and Fuel

- Emissions reduction technologies are impacted by sulfur levels in fuel
 - Conventional combustion accepts > 350 ppm
 - EGR technology accepts < 350 ppm
 - SCR technology capable < 500 ppm**
 - PM DOC technology accepts < 500 ppm
 - PM DPF technology capable < 30 ppm

*** Cummins SCR solutions validated to >1500ppm*



Agenda

- Cummins Inc. – Overview
- HD Diesel Engine Emissions
- Clean Diesel Technologies
- Cummins Euro 4 and 5 Products

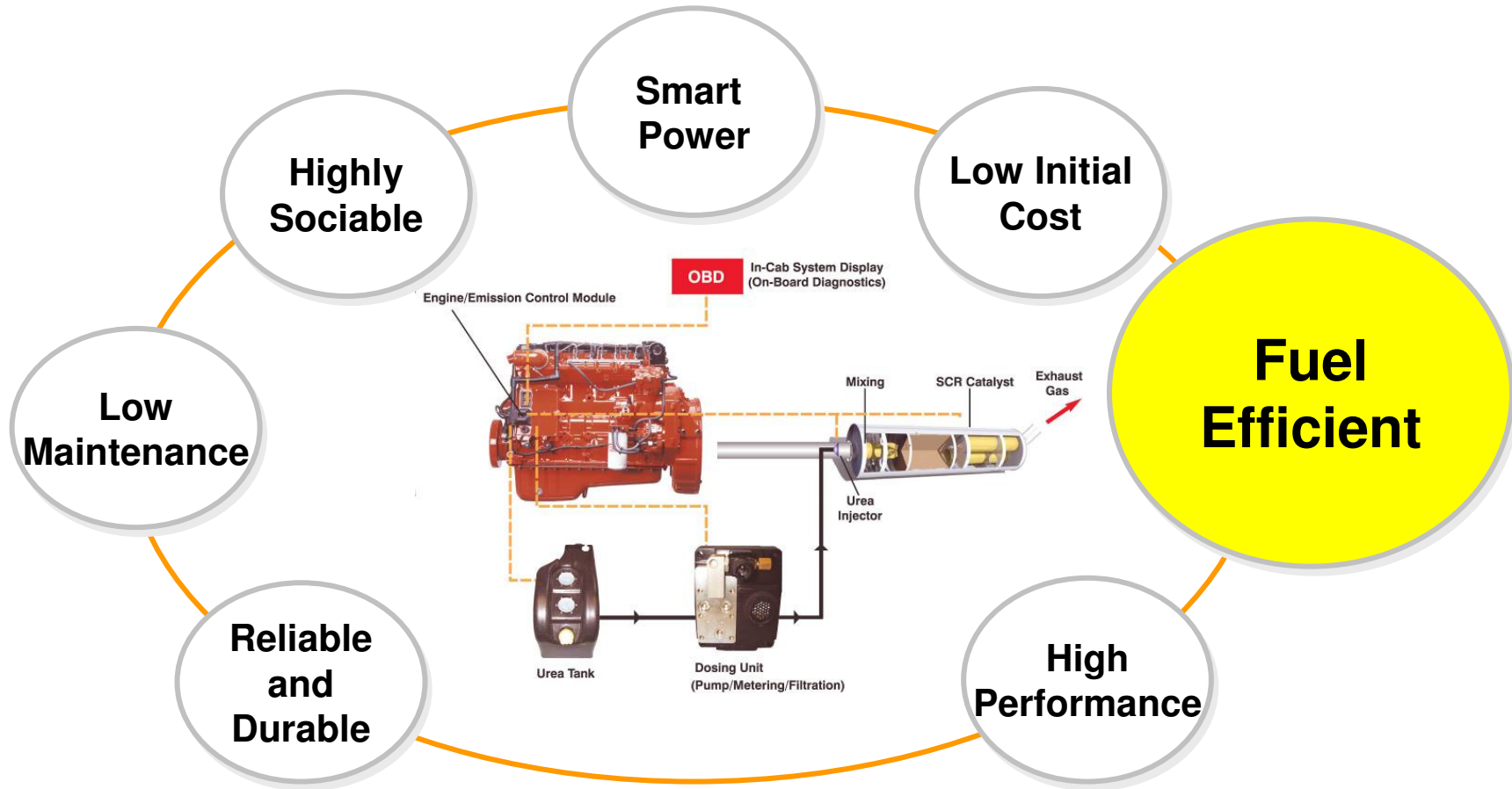


Emissions Technologies

- Cummins in World Market

Application	In-Cylinder Only	Cooled EGR	NOx Adsorber	SCR	PM Filter
EPA Tier 3 / EU Stage IIIA	●				
EPA Tier 2 > 751 hp	●				
EPA 07 Truck & Bus		●			●
Euro IV Truck & Bus 06				●	
EPA 07/10 Pickup Truck		●	●		●
Euro V Truck & Bus 09				●	
EPA 2010 Truck & Bus	under development				
EPA Tier 4 / EU Stage IIIB	under development				

Market Requirements - Truck and Bus



EGR vs SCR



EGR

SCR

EGR Con's

- Increased engine cost
- Engineering challenges
- Worse fuel economy
- Power density limited
- Low sulphur fuel is required
- High heat rejection (+25% over Euro3)
- PM filtration

- EGR Pro's
- Self contained package
- No onboard reagent

SCR Con's

- AdBlue
 - Packaging
 - Infrastructure
 - Cost of AdBlue

SCR Pro's

- Power density
- Lower heat rejection
- Engine simplicity
- Fuel economy improvement
- Service interval improvement



Why SCR not EGR for Euro 4 and Euro 5?

1. SCR provides the **lowest operating cost solution**.
2. **SCR enables up to double the oil drain interval** of Euro 3 engines. EGR products will struggle to maintain Euro 3 oil drains
3. **Future Proof** – Euro 4 and Euro 5 from one technology platform.
4. **10% differential in fuel economy** between a Euro 4 EGR and SCR engine in favour of SCR.
5. Lower stress on the SCR engine due to lower operating temperature which will translate to **improved durability**

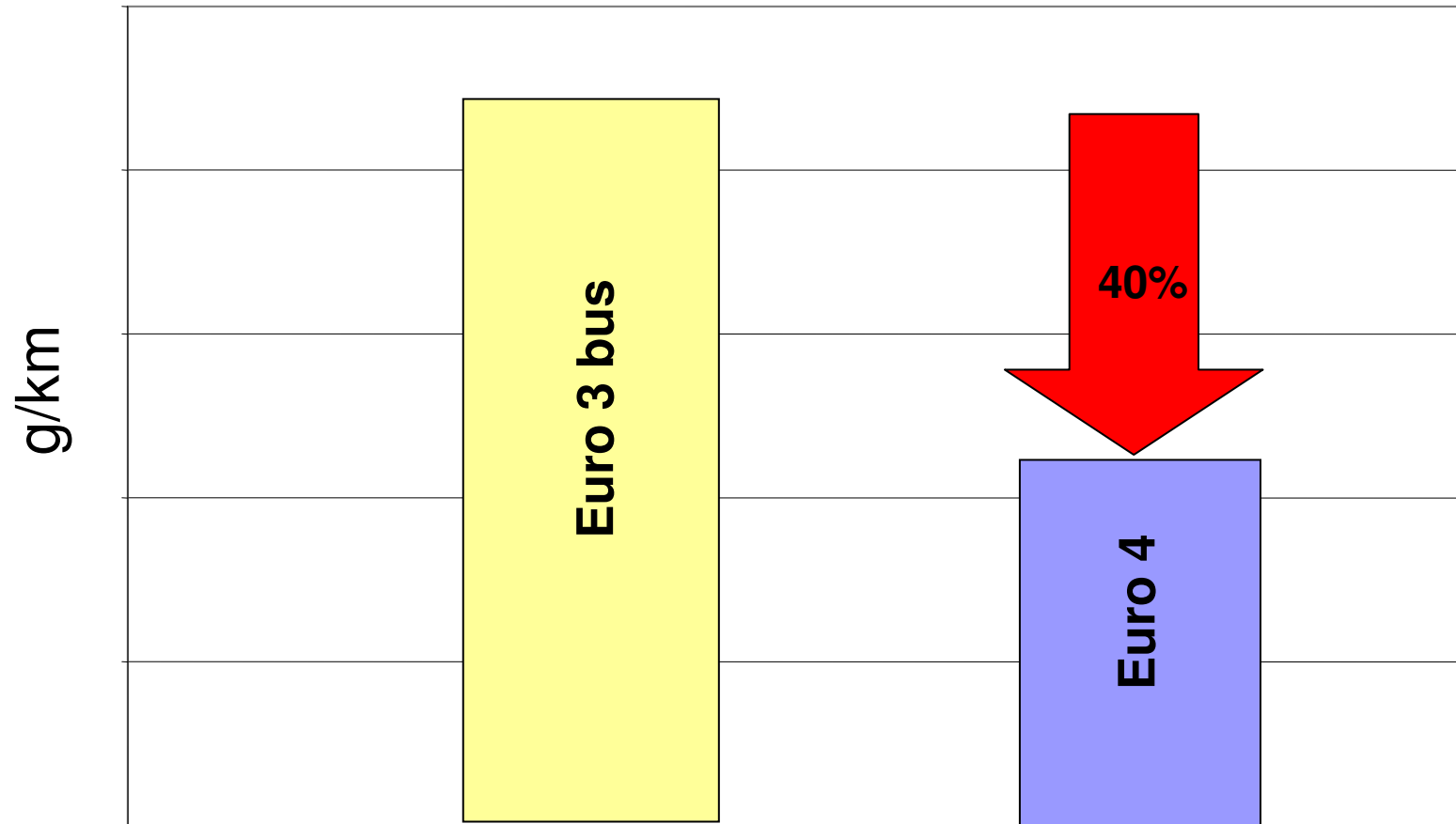
Does SCR work in bus duty cycles?



- SCR is a temperature dependant process and dosing does not start until ~ 200°C.
- PM traps are also temperature dependant. They require 350°C periodically for regeneration.
- A significant portion of our Euro IV development program has focused on ensuring that the system works even on the most difficult duty cycles.
- ISBe4 was the first Euro IV power unit 'qualified' by TFL – Transport For London.



Real world NOx Reductions





Euro IV Lowers Operating Costs

	Midi bus	Full size single deck	Double Deck bus
Annual Mileage (miles)	50000	50000	50000
Operating hours per day	13.5	13.5	13.5
Average speed (mph)	8	8	8
Fuel consumption Euro 3 (mpg)	6.2	6	5.5
Fuel consumption Euro 4 (mpg)	6.7	6.5	6
Fuel price / litre	? .37	? .37	? .37
Oil price / litre	? .75	? .75	? .75
AdBlue price / litre	? .32	? .32	? .32

RESULTS / ESTIMATED EURO 4 IMPACT			
TOTAL SAVINGS PER ANNUM INCLUDING ADBLUE COSTS	? 44.94	? 94.10	? 07.26



ISF 2.8



ISF 3.8



ISB 4.5



ISB 6.7



ISL 9



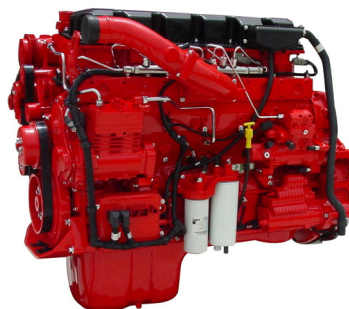
	ISF 2.8	ISF 3.8	ISB 4.5	ISB 6.7	ISL 9	
E2				<i>Available Now</i>	<i>Available Now</i>	E2
E3	2010	2009	<i>Available Now</i>	<i>Available Now</i>	<i>Available Now</i>	E3
E4	2010	2009	<i>Available Now</i>	<i>Available Now</i>	<i>Available Now</i>	E4
E5	2012	2011	2009	2009	2009	E5



ISM 11



ISX 13



ISX 15



	ISM 11	ISX 13	ISX 15	
E2	Available Now		Available Now (EPA98/ E2)	E2
E3	Available Now		Available Now (CN3)	E3
E4	2010	2010		E4
E5		2011		E5



Summary

- SCR has been proven as the “right technology” for Cummins customers in current Euro 4 and Euro 5 emissions equivalent markets.
- Over 50,000 Cummins powered Euro 4 SCR vehicles in operation.
 - EU, China, Brazil
- Euro 4 vehicle fuel consumption shows 5-10% compared to previous Euro 3 vehicles.
- Further Euro 4 and 5 Cummins products will be released to the market by 2010.

Innovation You Can Depend On™

- 您可信赖的创新 ▪ L'innovation Sur Laquelle Vous Pouvez Compter
- 期待に答える技術革新 ▪ Innovación En La Que Usted Puede Confiar ▪ 신뢰할 수 있는 혁신
- Inovação Que Você Pode Confiar
- नवयुक्ति जिस पर आप निर्भर कर सकें ▪

**One World. One Mission.
Technical Excellence.**



Thank You

