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International Truck and Engine Technology and Emissions Strategy

Environmental Stewardship

Overview

- Legacy
- Emissions Reduction
- Engine Technology for 2007 and Beyond
- Advanced Technologies

Legacy

- Demonstrated 1994 Compliant Smokeless Diesel – 1989
- Demonstrated 2004 Compliant Diesel – 1996
- Demonstrated Green Diesel School Bus with lower PM and HC emissions than CNG – 1999
- Certified GDT Diesel Engine at 2010 PM and HC levels - 2001
- Technology Path decisions for 2007 - 2003

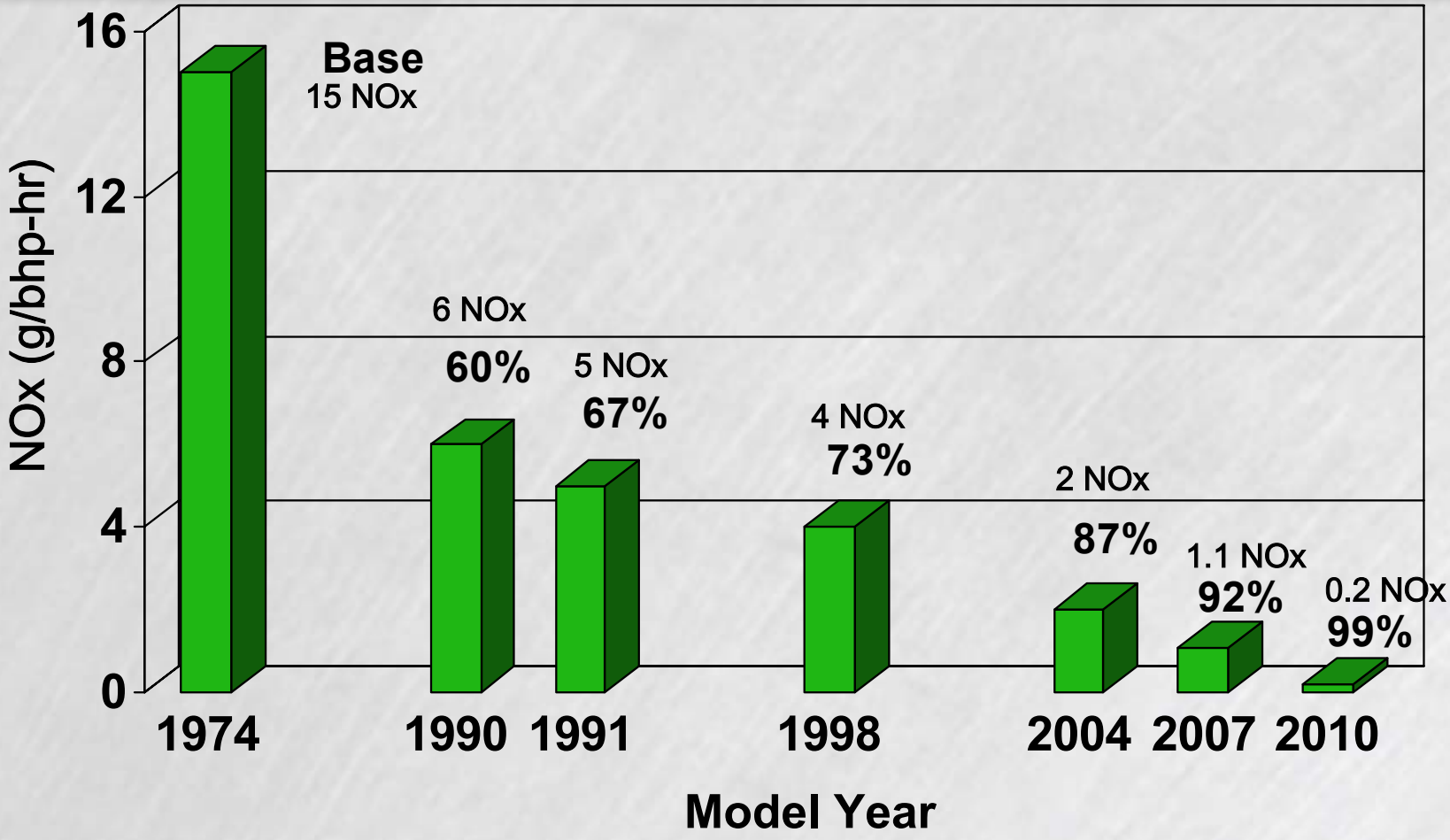
Benefits of Diesel

- 40-60% better fuel efficiency
- Durability
- Performance (pulling power)
- Contributes less to greenhouse gas emissions
- Lower hydrocarbon (HC) emissions
- Lower carbon monoxide (CO) emissions

How Far Diesel Technology Has Come:

Progress In Reducing Nitrogen Oxides Emissions

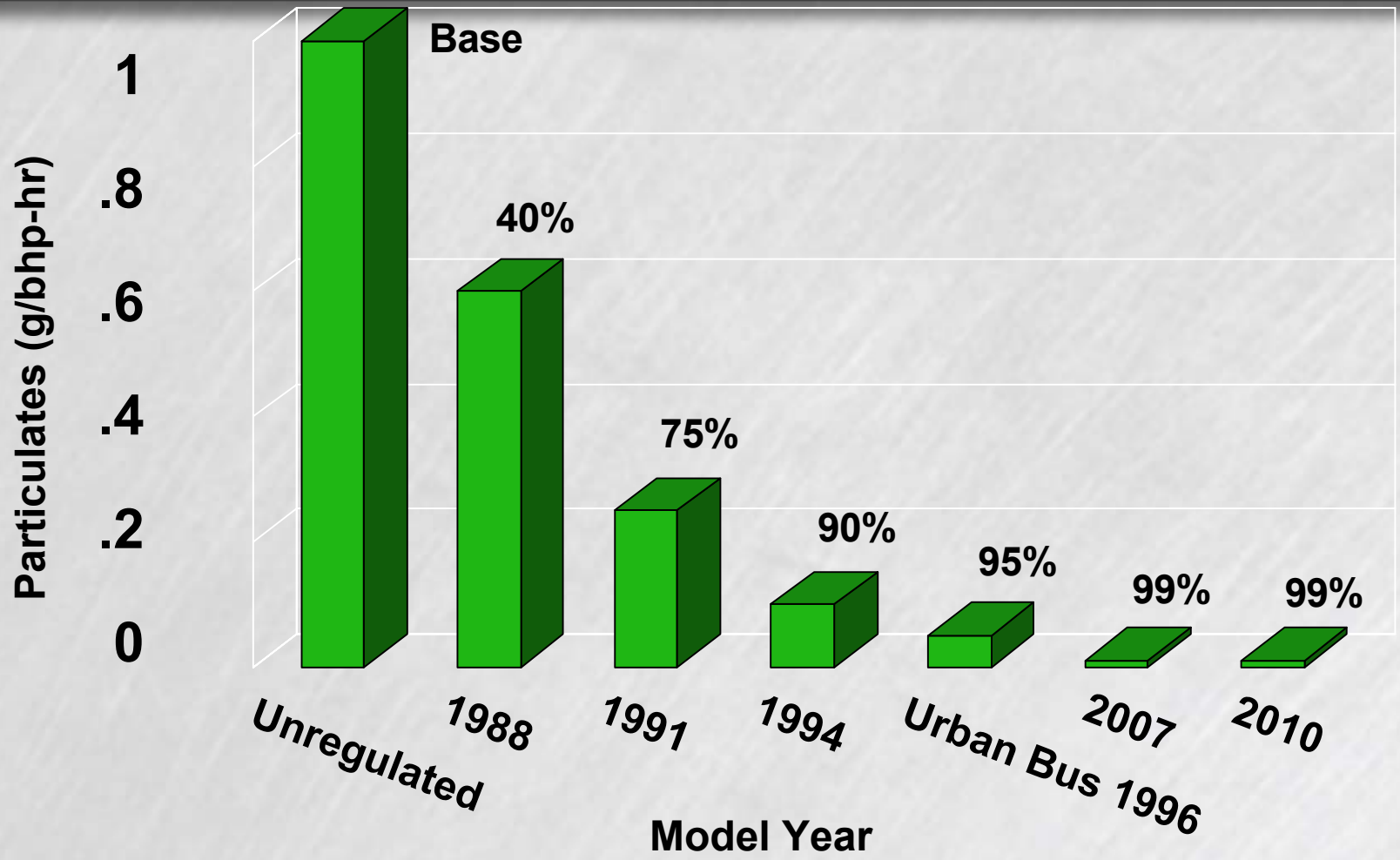
Industry Reductions



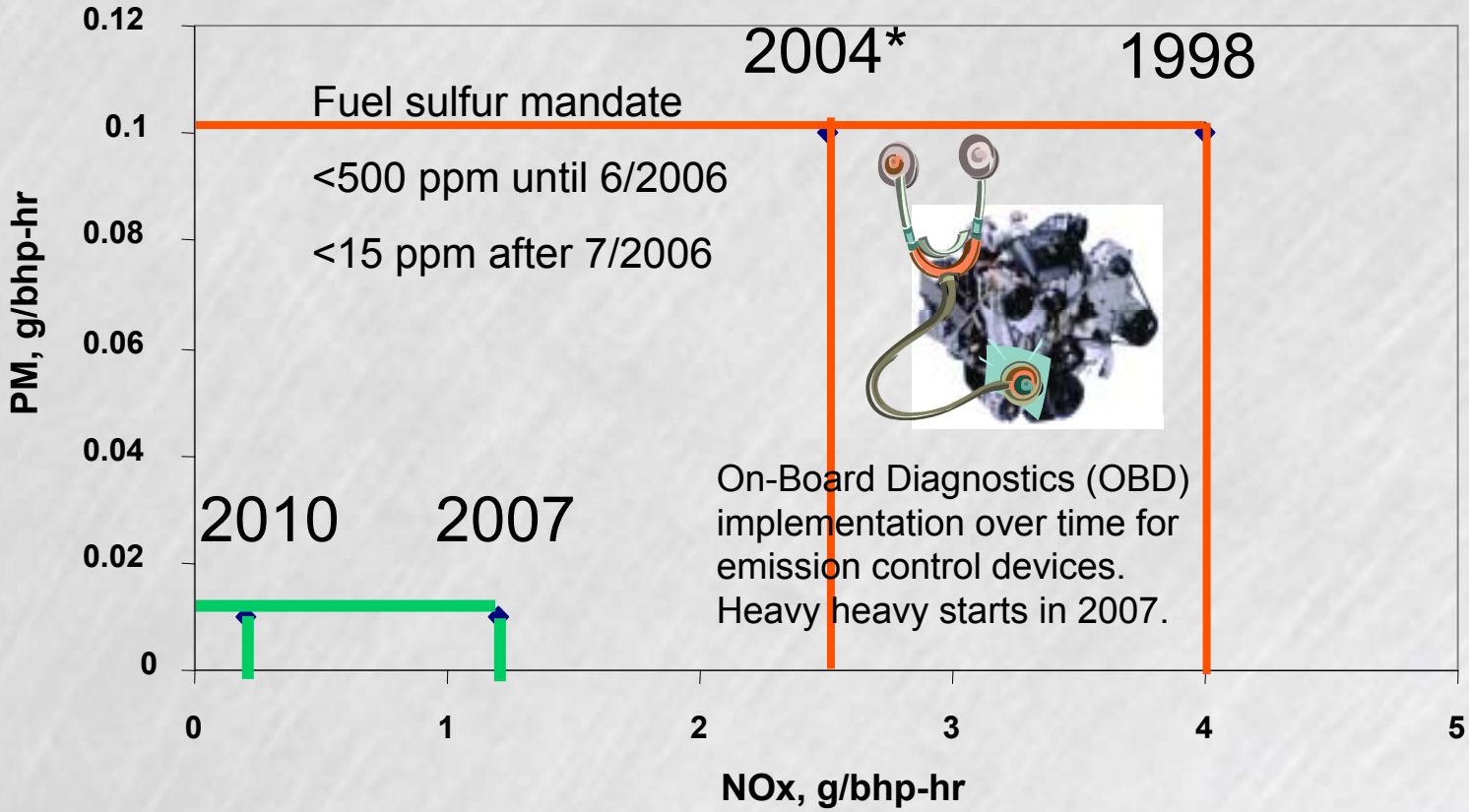
How Far Diesel Technology Has Come:

Progress In Reducing Particulate Matter Emissions

Industry Reductions



HD Diesel Emissions Requirements



* 2004 requirements is NOx+HC. Consent decree implementation is October 2002.

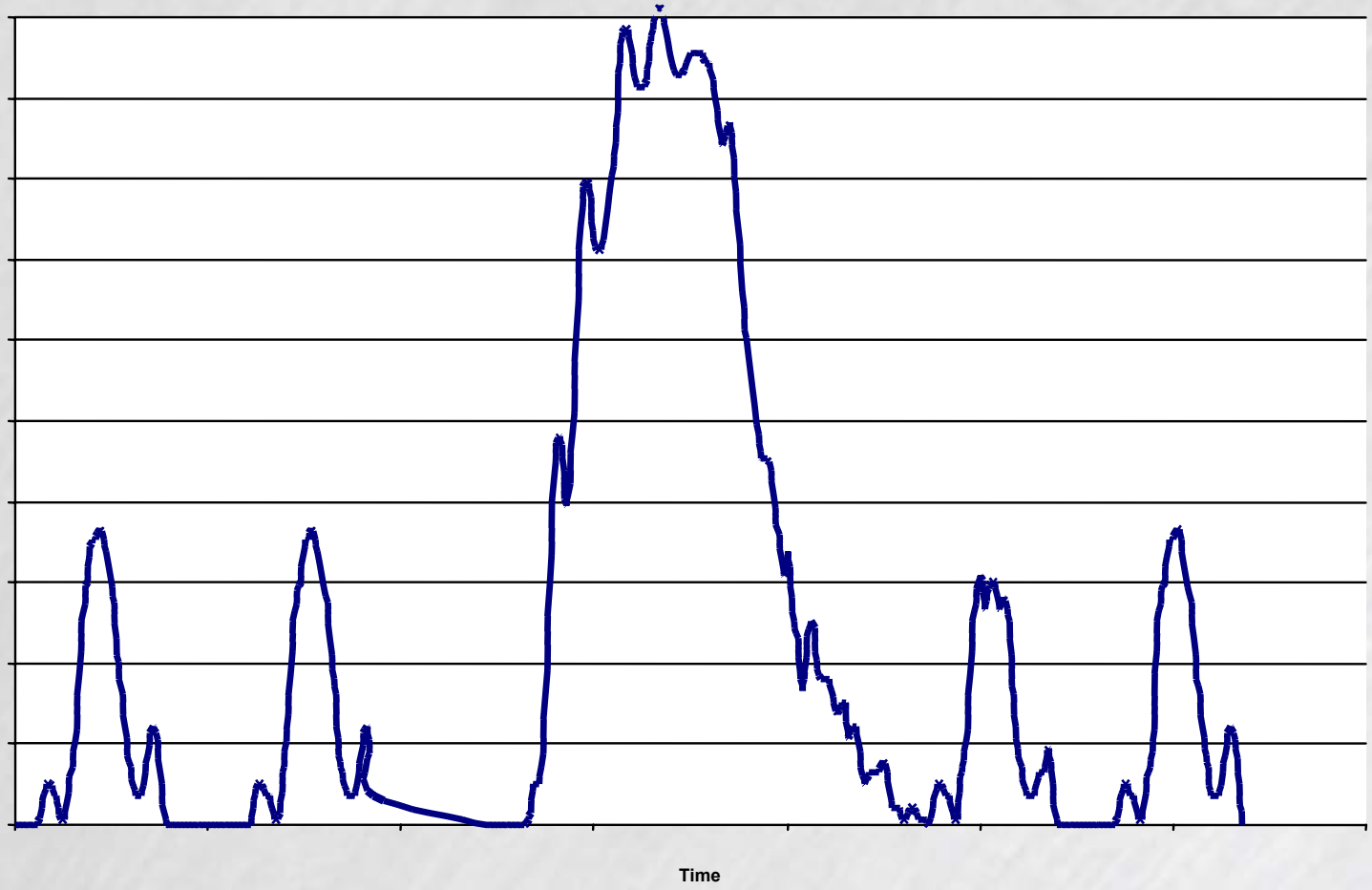
Evolution of 5 Technologies

- Fuel System
- Air System
- Combustion
- Electronics / Controls
- Aftertreatment

How Diesel Technology Will Reduce Emissions to Meet the Requirements

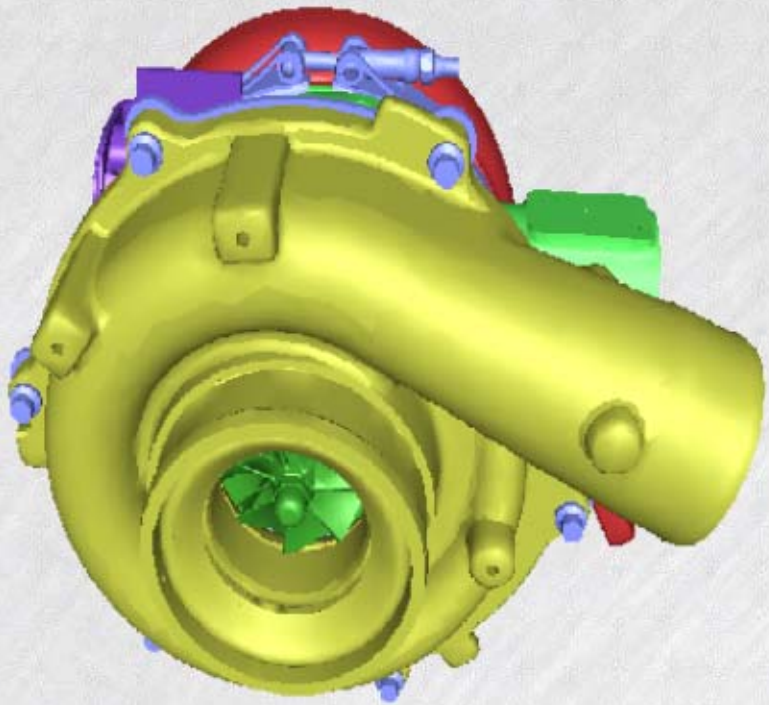
Emissions Reduction

Fuel Systems
(Fuel Systems of the Future)



2007 Turbocharger Refinements

- Variable geometry
- Demand tailored performance
- Improved response
- Increased capacity

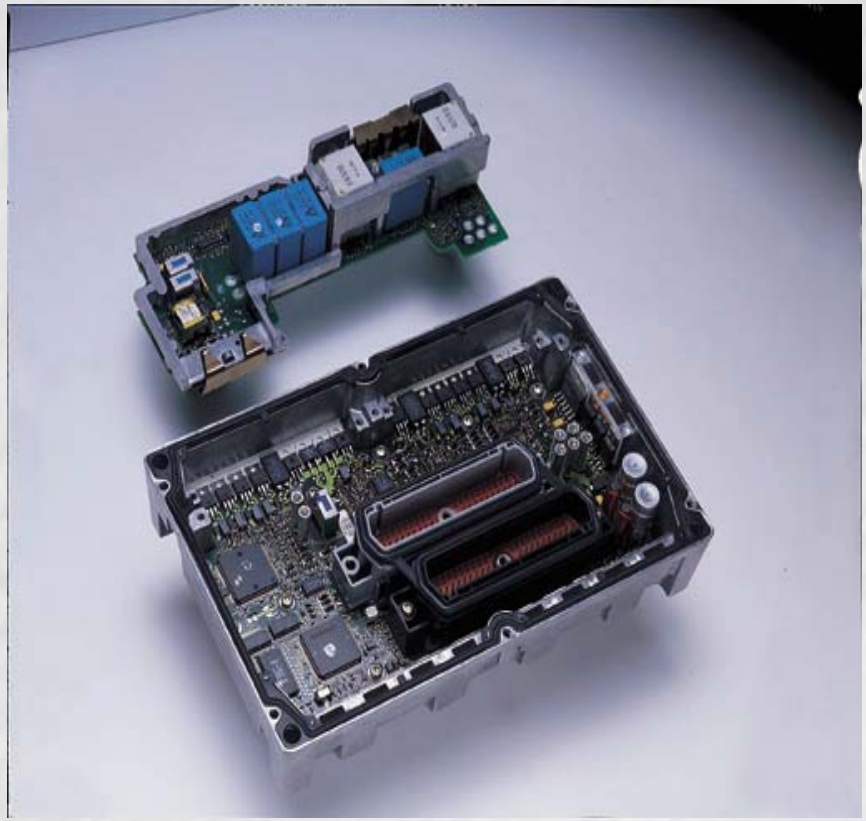


Combustion Chamber

- Continuing development
  - Bowl shape
  - Swirl
  - Injector position

2007 Electronics

- More sensors
  - Aftertreatment monitoring
- More computing power
- On-Board Diagnostics



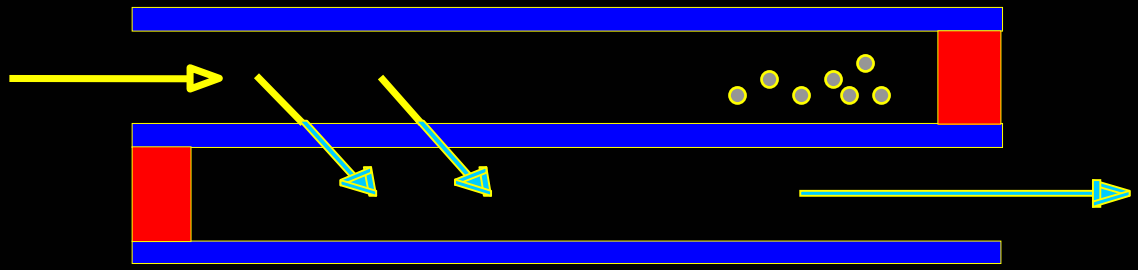
Electronics and Electrical Systems

- Sensors
- Computing Power
- Model Based Control Systems
- 42 Volt

Aftertreatment

Absorption of NOx, PM & HC emissions during normal operation

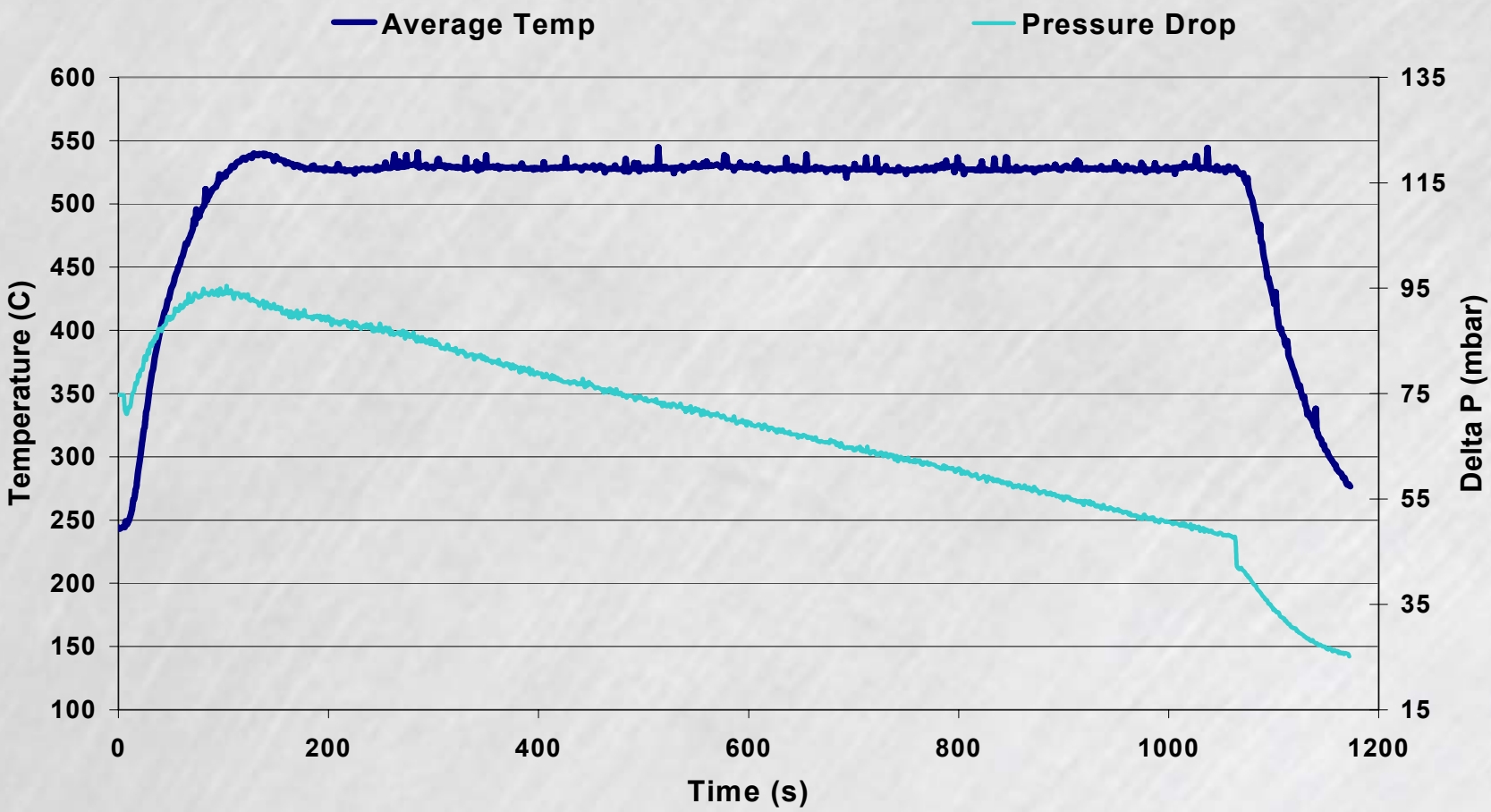
Periodically add detergent (diesel fuel) and squeeze



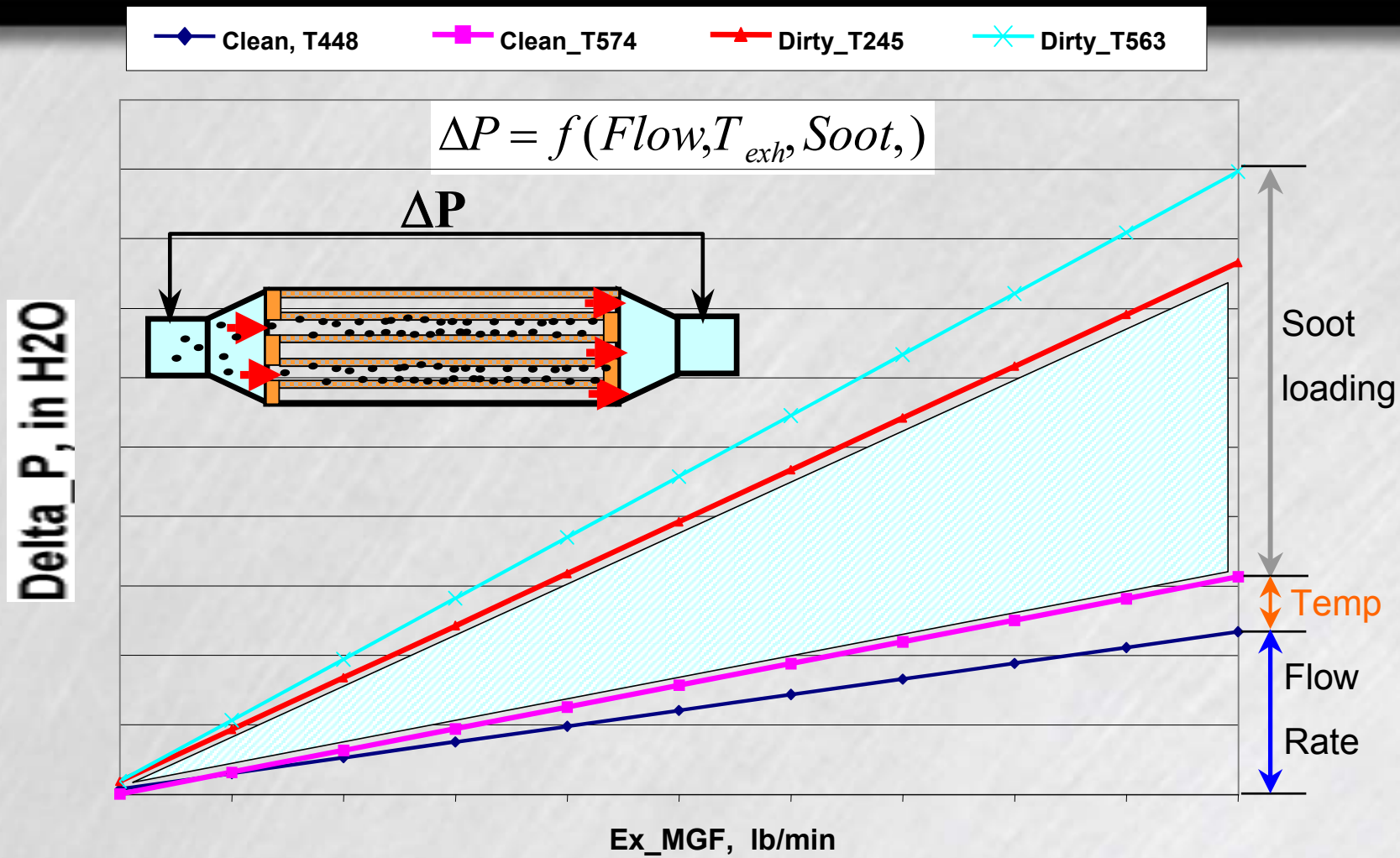
Soot filter traps all soot particles and hydrocarbon.
It needs to burn off the trapped soot particles.
A key measure of its performance is the balance point temperature.
The balance point temperature varies from engine to engine.

Balance point temperature: the engine operating condition and the exhaust temperature where soot burn off rate is greater than or equal to the engine soot output.

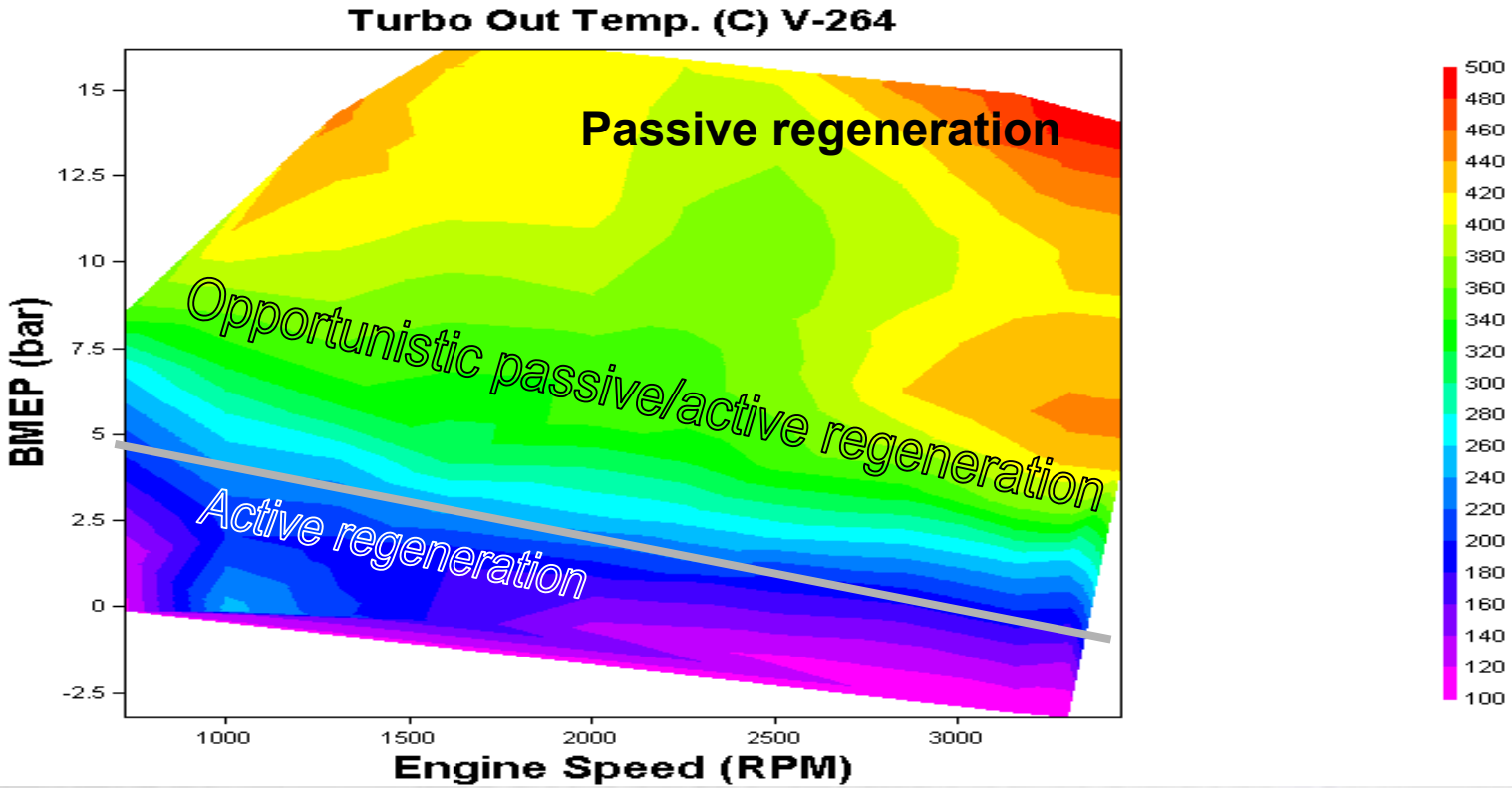
PM Filter Regeneration



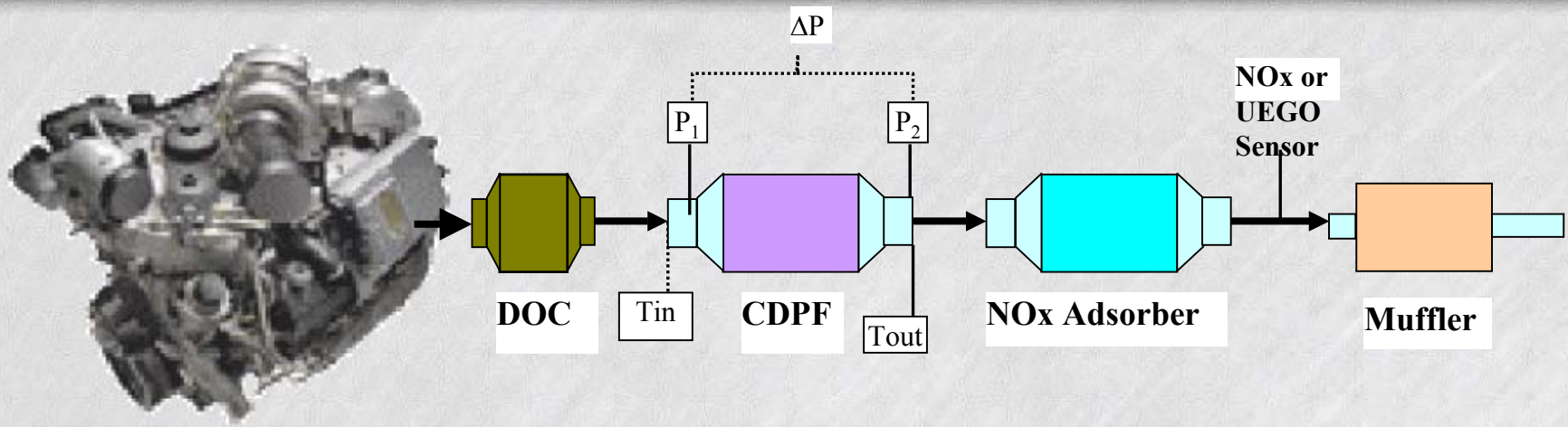
CDPF Delta P Correlation with Parameters



Strategy for DPF Regeneration



NOx Adsorber



2010 HD / 2009 LD

NO_x Adsorber - How Does It Work?

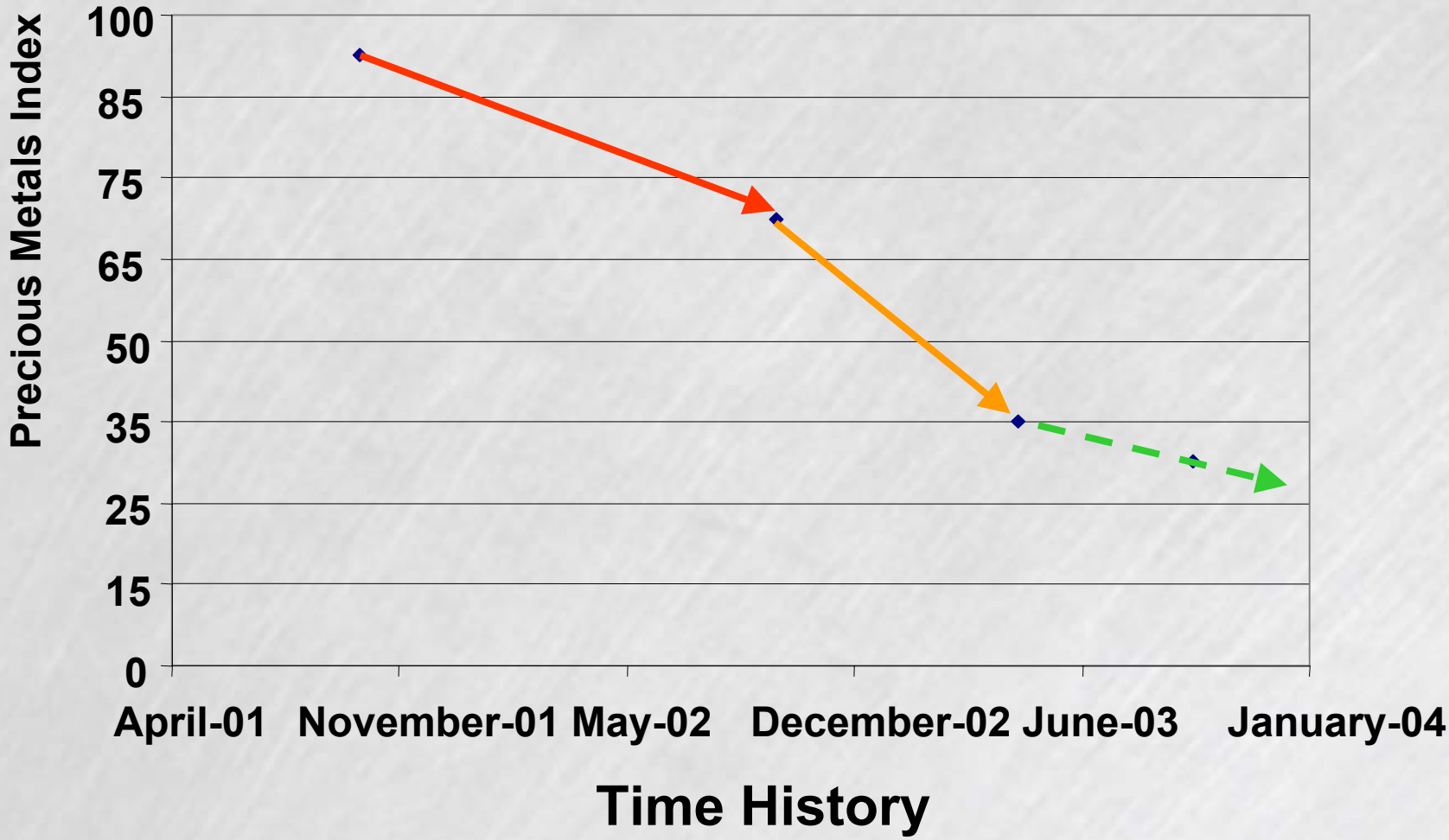
It works in three simplified steps:

1. It stores NO_x with normal diesel exhaust (Lean).
2. It releases NO_2 when it is starved of O_2 (Rich).
3. Under the rich condition, CO, HC, and H_2 reduce the released NO_2 into N_2.

Nox Adsorber

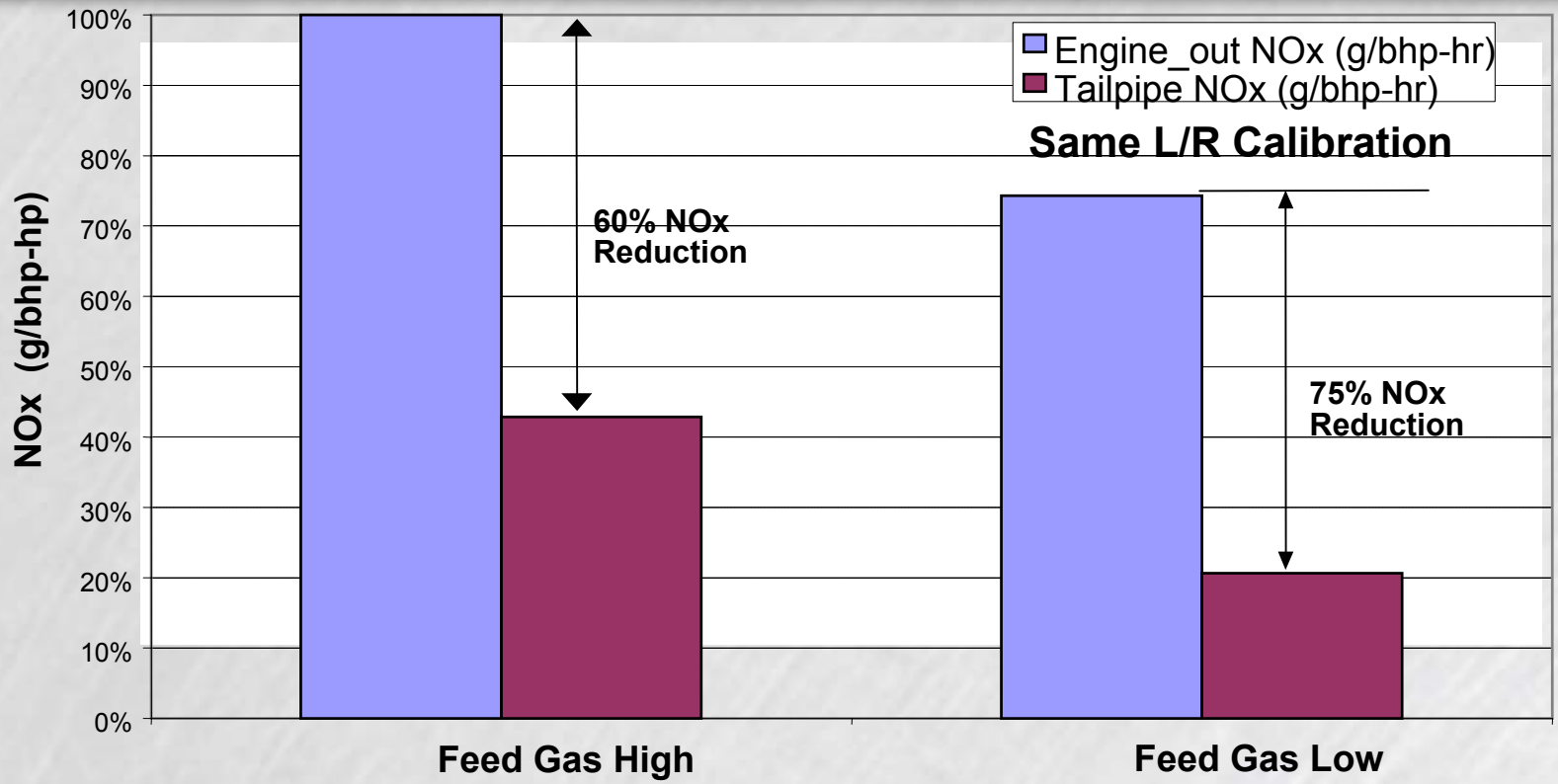
- Cost Improvements
- Efficiency Improvements

NOx Adsorber Progress



Effect of Feed Gas NOx Emission Level on LNT Performance

(HD FTP with Engine-aged LNT)



•LNT Absorbs About the Same Amount of NOx Regardless of Feed-gas Level, Resulting In Higher Efficiency with Lower Feed-gas Level

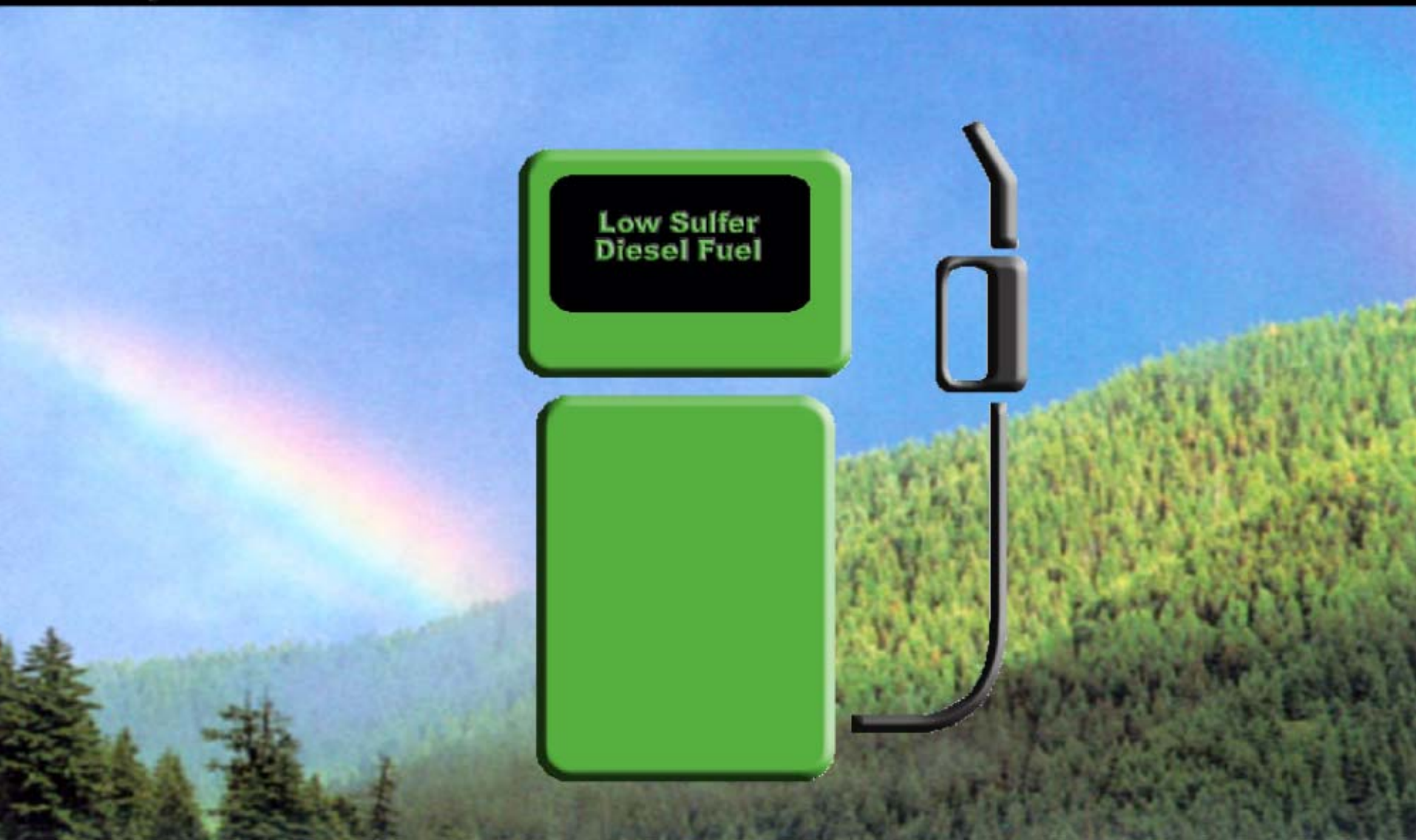
NOx Adsorber Conclusions

- Precious Metals Content continues to Decline
  - Costs Improve
- The NOx Adsorber Acts like a NOx Capacitor
  - Lower engine out NOx means Higher efficiency Catalyst

Urea SCR System

- Urea provides ammonia for reduction of NOx
- Automatic injection
- Separate storage tank
- Refilled with each fuel fill
- 5% by volume with the fuel
- Cost per gallon of fuel ?
- To be utilized in EU without PM filter

Fuel



2007 Technology Decisions

- International set the technology path in 2003
  - 2007 is an evolution of the 2004 product with a Particulate filter
  - No Nox Adsorber or SCR catalyst required
- Structured program management approach to 2007
- 2005 test vehicles in customers hands
- 2004 “pre-certification” dialogue with EPA and ARB

Implications of the Low-Emitting Diesel Technology Road Map

- Technology can be applied to all engines:
  - Heavy-duty trucks, buses
  - Light-duty vehicles
- 2004 technology is foundation for 2007
- Some 2007 technology is available today
- Use of 2007 technology requires ultra-low-sulfur fuel
- Widespread supply of ULSF is crucial to this technology, now and in 2007

Green Diesel Technology® School Bus:

- Demonstrated to U.S. EPA in 1999
- Now being sold in California

Green Diesel Technology® School Bus: 2007 Technology Today

- International 530E 275HP diesel engine with special low-NOx calibration
- Catalyzed diesel particulate filter
- Must use ultra-low-sulfur (<15ppm) diesel fuel
- EPA/CARB emission certifications granted March 2001
- Customer deliveries began December 2001

Conclusions

- PM filters are successful in commercial vehicles today
  - Proper regeneration will provide functionality as well as reliability
  - The typical class 8 truck load factors will induce passive regeneration (like Green Diesel Buses)

Green Diesel Team

- Multi-disciplined approach to changing people's minds about diesel
  - Engine Engineering
  - Public Affairs
  - Health and Safety
  - Legal
  - Communications
- Relevant, timely, and accurate information

Green Diesel Team

- Key States Program
  - Facts about diesel: today and tomorrow
  - Do No Harm: 2007 implementation
  - Funding availability for GDT
  - The “white hanky” test
  - NY, NJ, Az, Georgia, Texas, Ma, Il, Ohio, Ind
  - Canada
  - Personnel located in California

Green Diesel Team

- School Bus Interior Study
  - Iridium Tracer
  - Correct findings of erroneous NRDC Report
  - 1995 Model Year Technology Tested
- CNG vs Green Diesel Technology School Bus Emissions comparison
  - CNG did not have lower emissions of any toxic air contaminants
  - Corroborated by California ARB study

Communications

- GreenDieselTechnology.com
  - A source for facts on diesel technology
- 2007 facts – Pupil Trans associations and school bus business communicators and their web sites
- NAPT Foundation workshops – 2007 requirements and funding
- Our demonstration of technology is driven by our customer's needs

Advanced Technologies

- Hybrid Electric Diesel Vehicle – UPS Van - DOE
- Hydraulic Hybrid diesel Vehicle – F350 - EPA
- EPA / International CRADA – 2010 emissions without NOx aftertreatment
- Camless Engine

Conclusions

- Design and operation of diesel engines will be an evolution of the 2004 product
- High volume PM filters will be in production for 2007 MY
- Ultra-low-sulfur diesel fuel is the technology enabler to move to near-zero emissions targeted by EPA/CARB

Low-Emitting Diesel Engines and Vehicles Become a Clean Air Solution

- Equivalent or better emissions than gasoline or alternative fuels
- Still more fuel efficient with lower greenhouse gas emissions
- Performance and reliability that customers depend on

The Result

- Diesel becomes an environmental solution