DAIMLERCHRYSLER

Detroit Diesel Corporation

SCR Potential and Issues for Heavy Duty Applications in the USA

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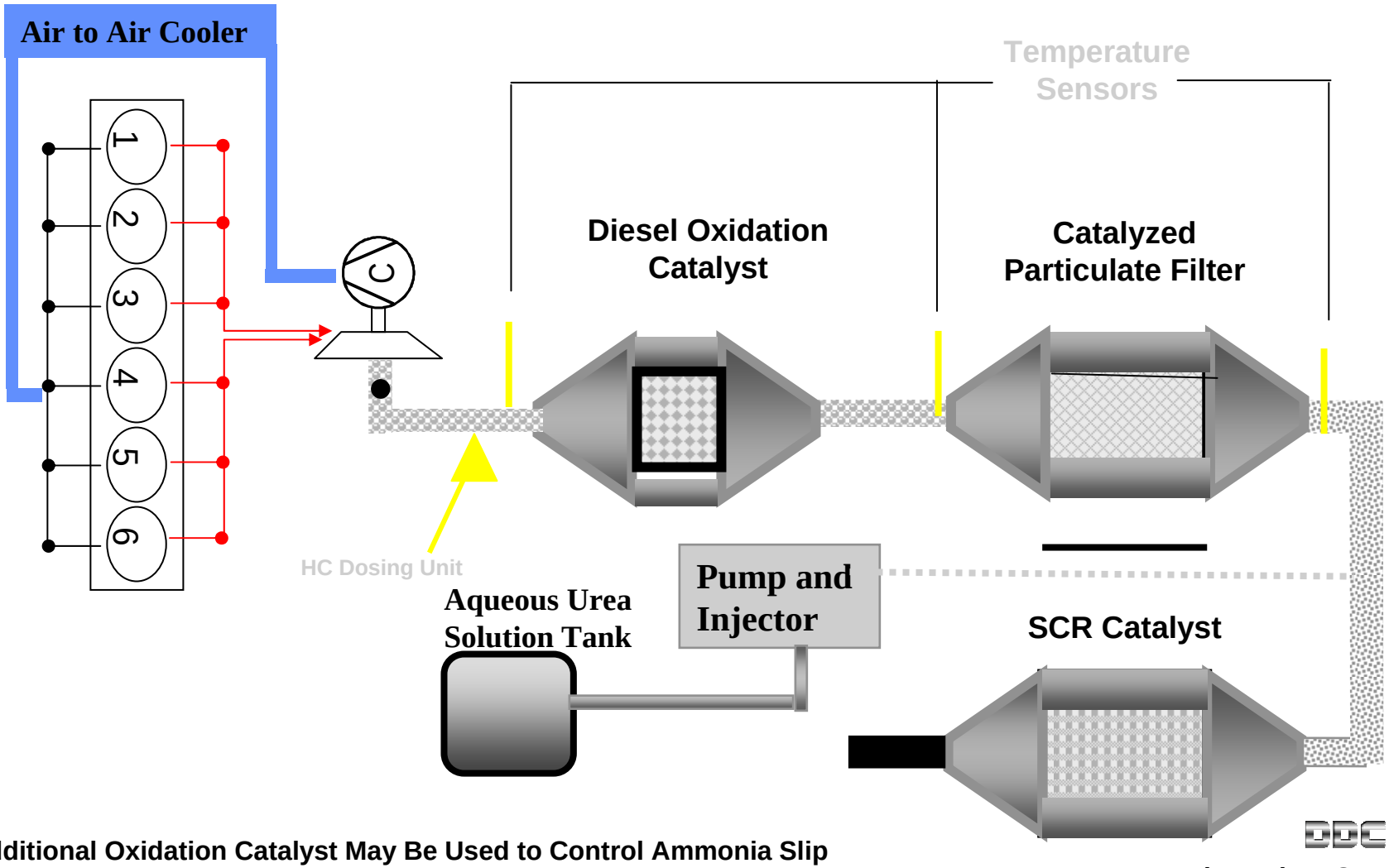
02 September 2004

10th Annual DEER Conference

Presentation Outline

- Global Emissions Potential & Strategy
- Lifecycle Cost Estimations & Trade-Offs
- Truck Application Issues
- Urea Infrastructure

SCR and DPF Filter Configuration



Additional Oxidation Catalyst May Be Used to Control Ammonia Slip

SCR Potential

Meeting Regulated Emissions While Providing Economic Advantage

- Improved Fuel Consumption
- Net Benefit on Energy Consumption
- Reduced Engine Heat Rejection Resulting in Simplified Vehicle Cooling Requirements
- No Impact on Vehicle Aerodynamics
- Increased Oil Drain Intervals
- Proven Technology
- Available for Fleet Testing

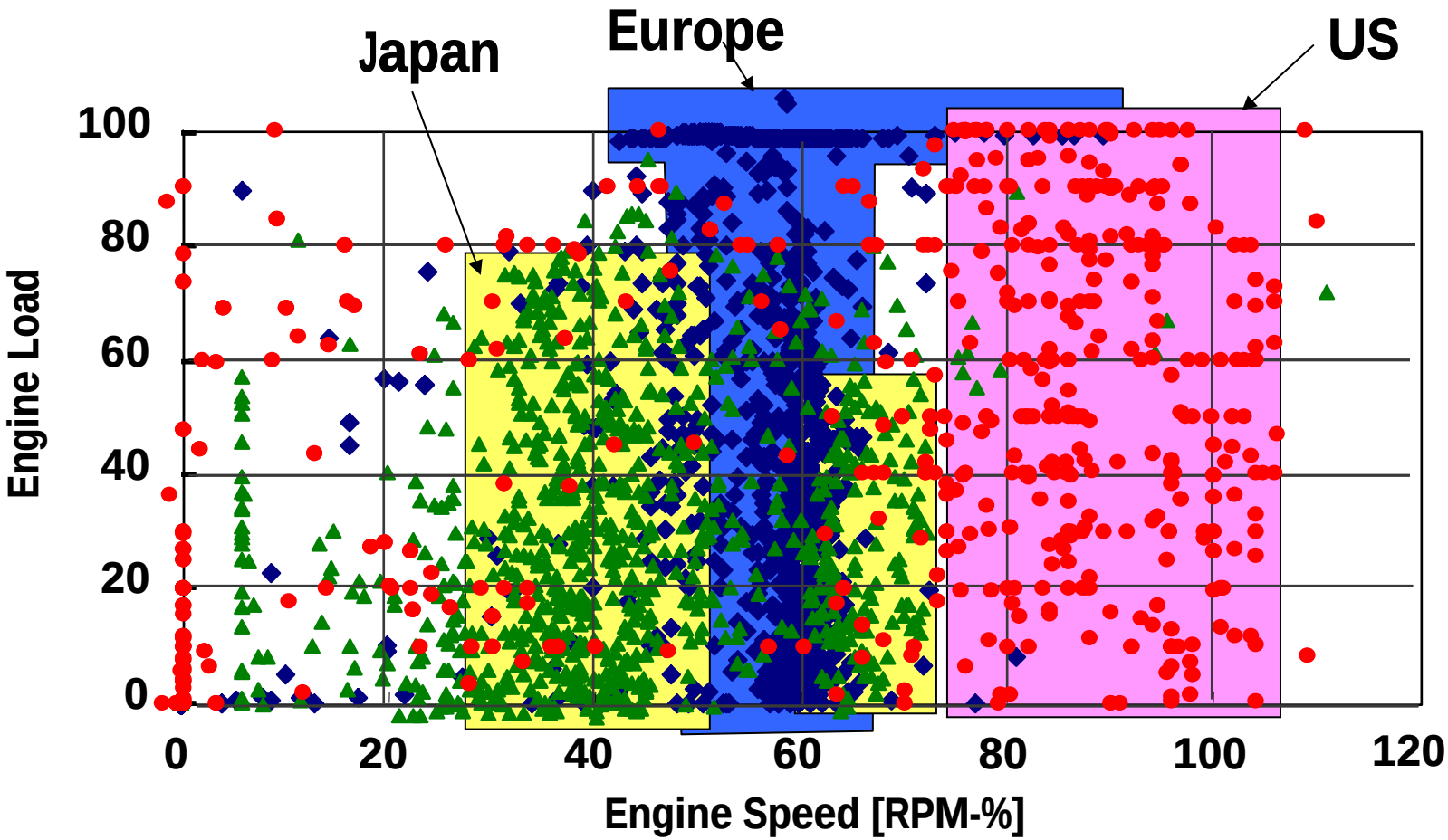
Global Emission Test Procedures

	Europe	USA	Japan
Steady-state test	ESC	ESC	D13
Transient test	ETC	FTP	MOE
Not-to-exceed	t.b.d. (EURO5)	NTE (additional ambient conditions)	Each mode of D13
Deterioration	DF (EURO4)	DF (435,000 miles ≈ 700,000 km)	DF (650,000 km)
Smoke test	Full load, ELR[1], free acceleration	STP[2]	Single full load points, free acceleration
OBD	Yes	Yes	Yes

[1]European Load Response

[2]Smoke Test Procedure

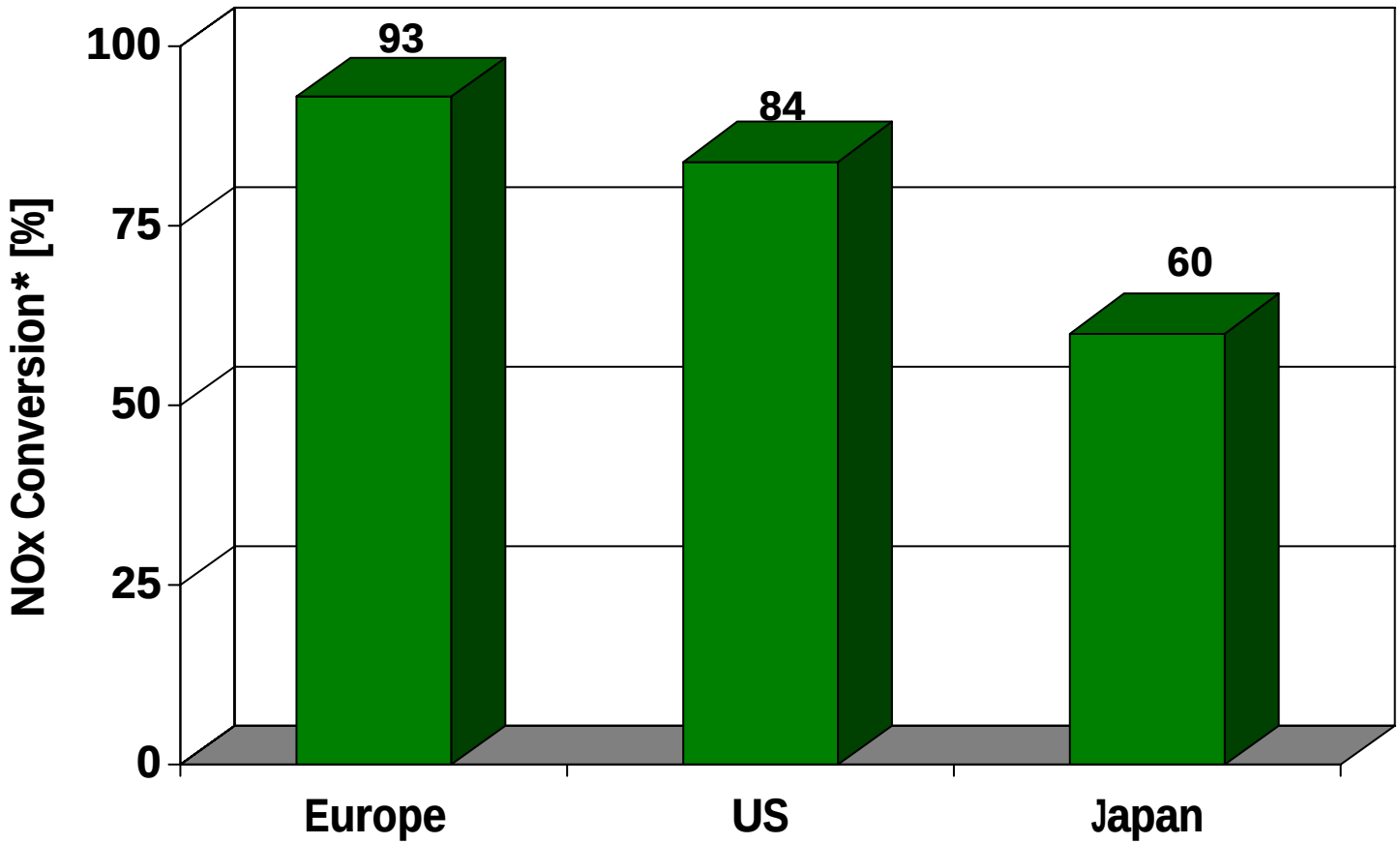
Comparison of Global Transient Emission Cycles



Truck Product Creation

SCR NOx Reduction Potential

Transient Test Cycles for Europe, US, Japan

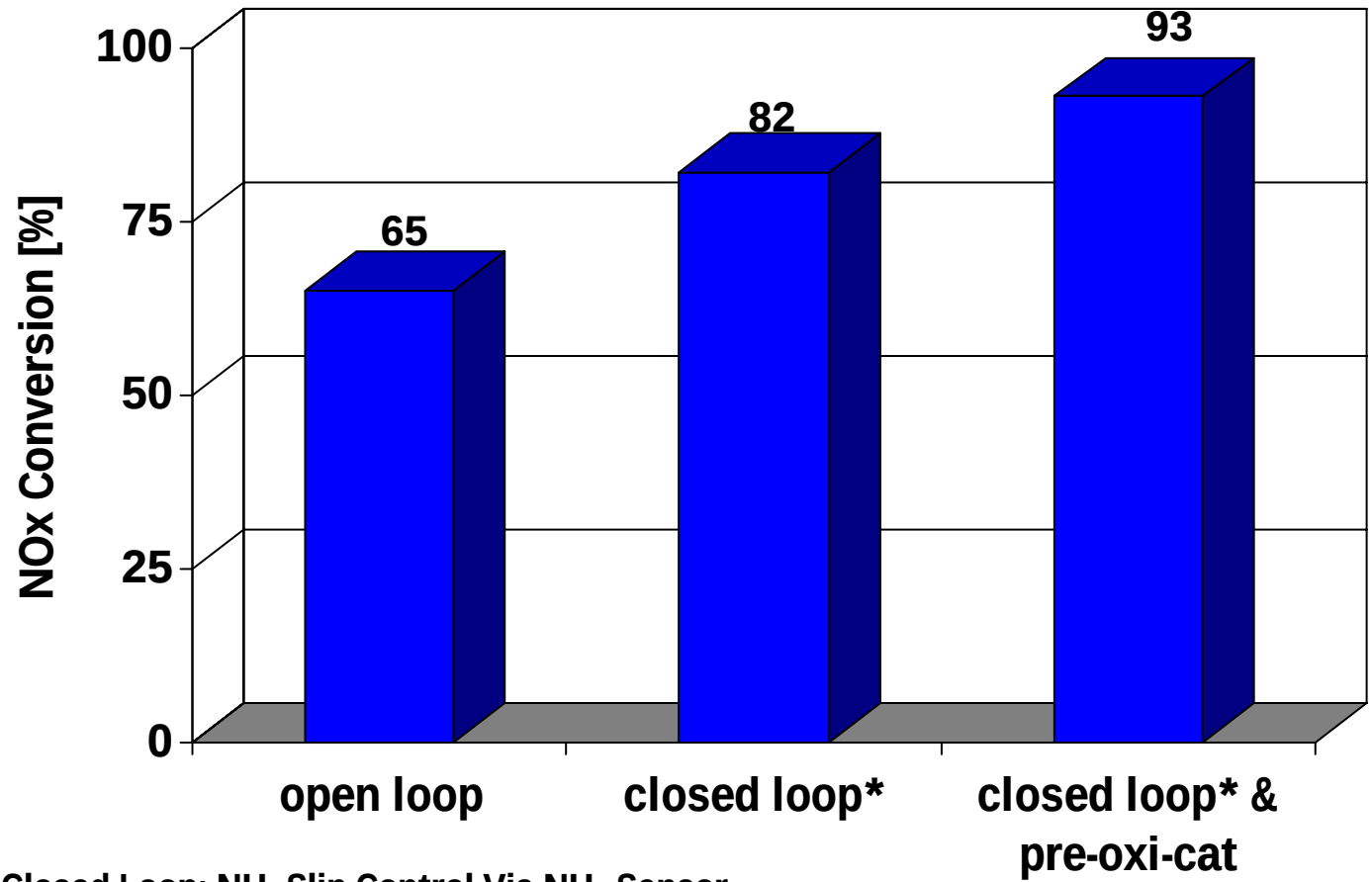


* Closed Loop: NH_3 Slip Control Via NH_3 Sensor

Truck Product Creation

SCR NOx Reduction Potential

European Transient Test (ETC) Cycle



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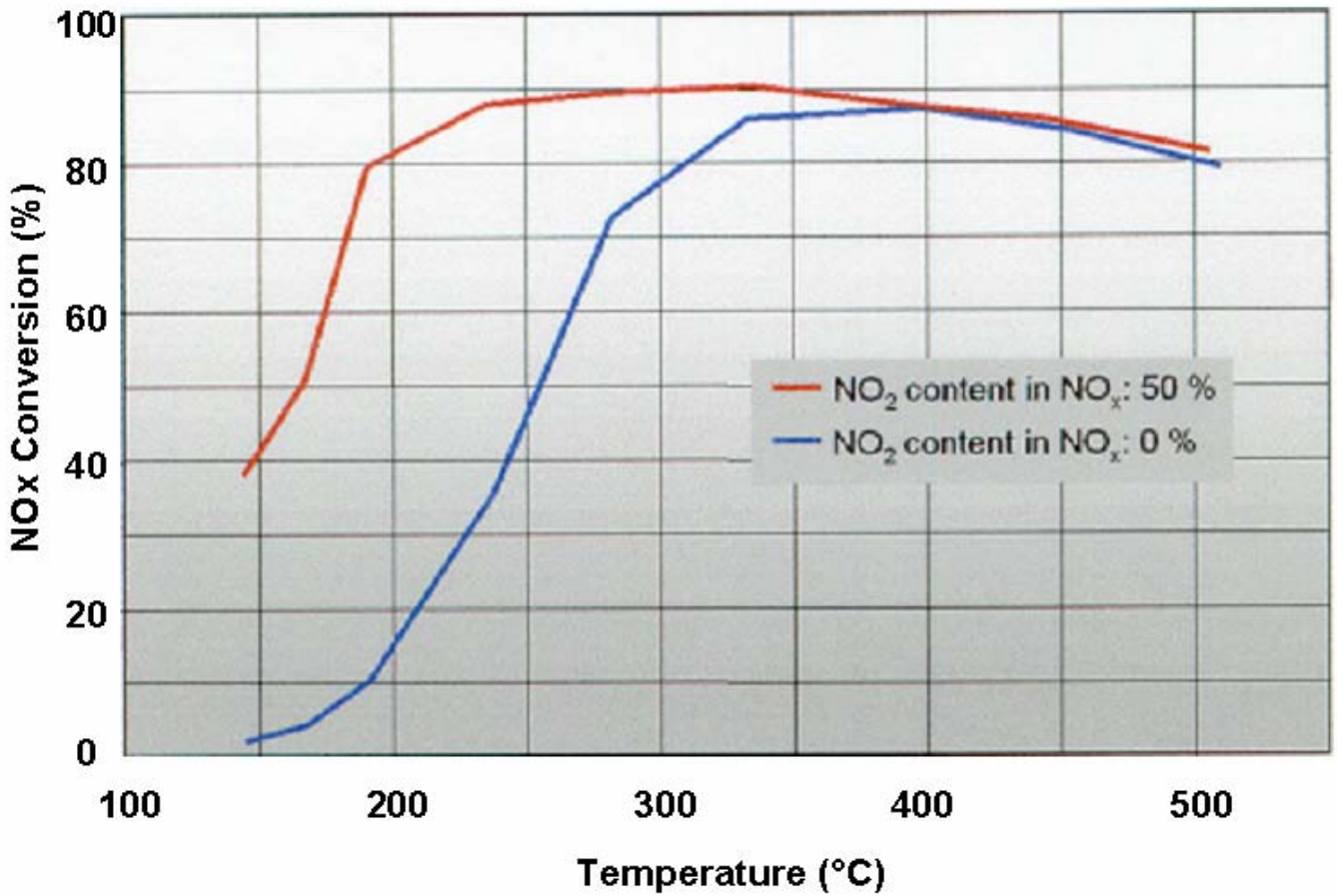
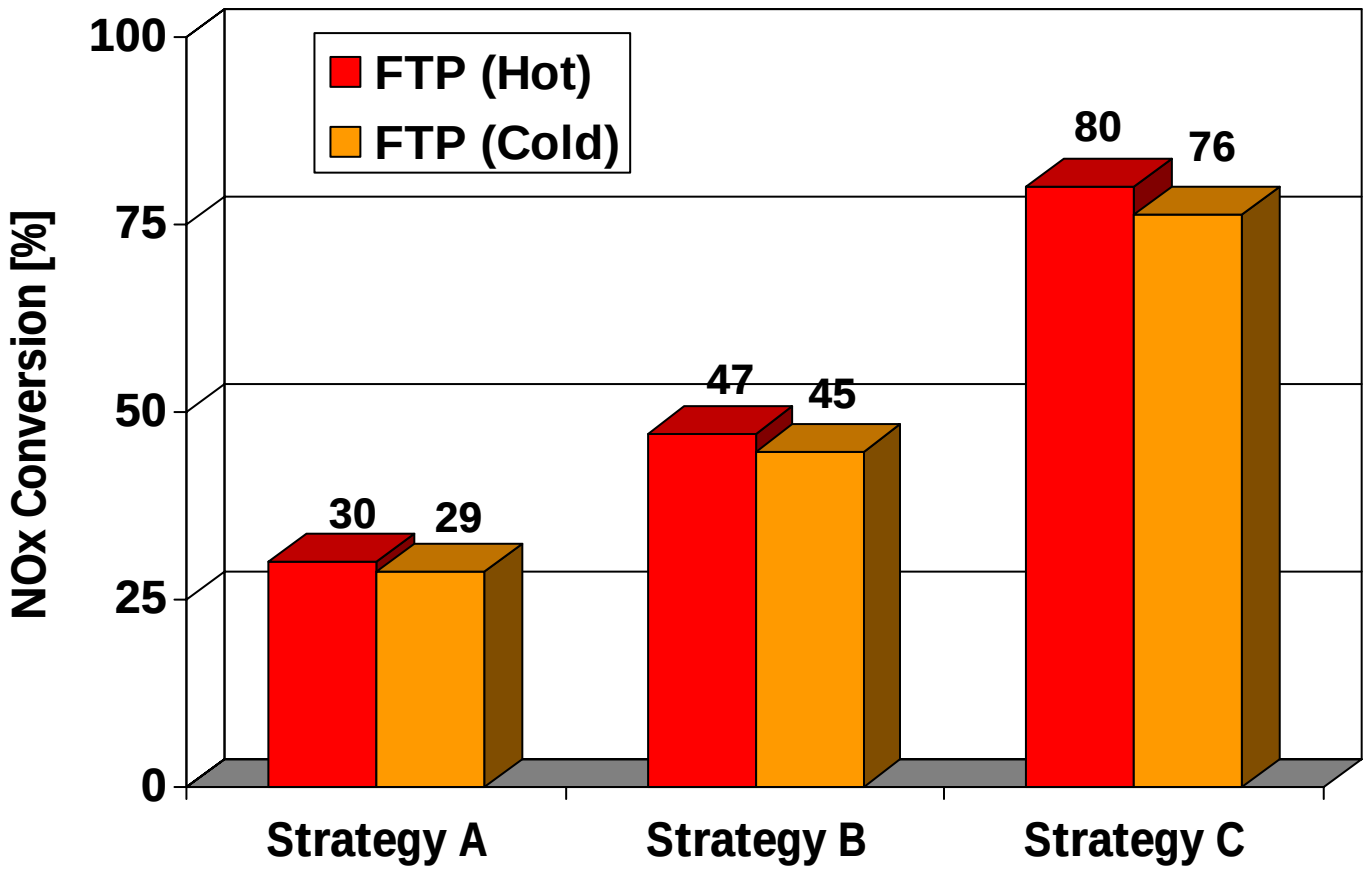
Truck Product Creation

Effect of NO_2 Ratio on NO_x Conversion Efficiency



SCR NOx Control Potential

US Transient Test (FTP) Cycle



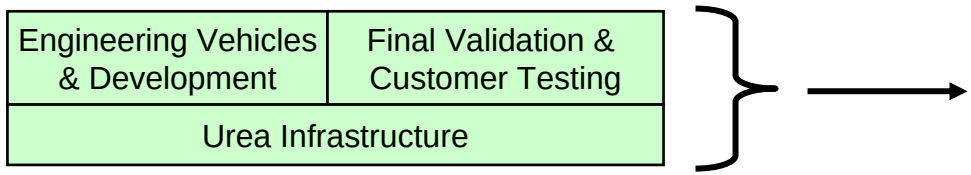
Additional NOx Reduction Possible via Precise Exhaust Temperature Management

Global Emission Control Scenarios

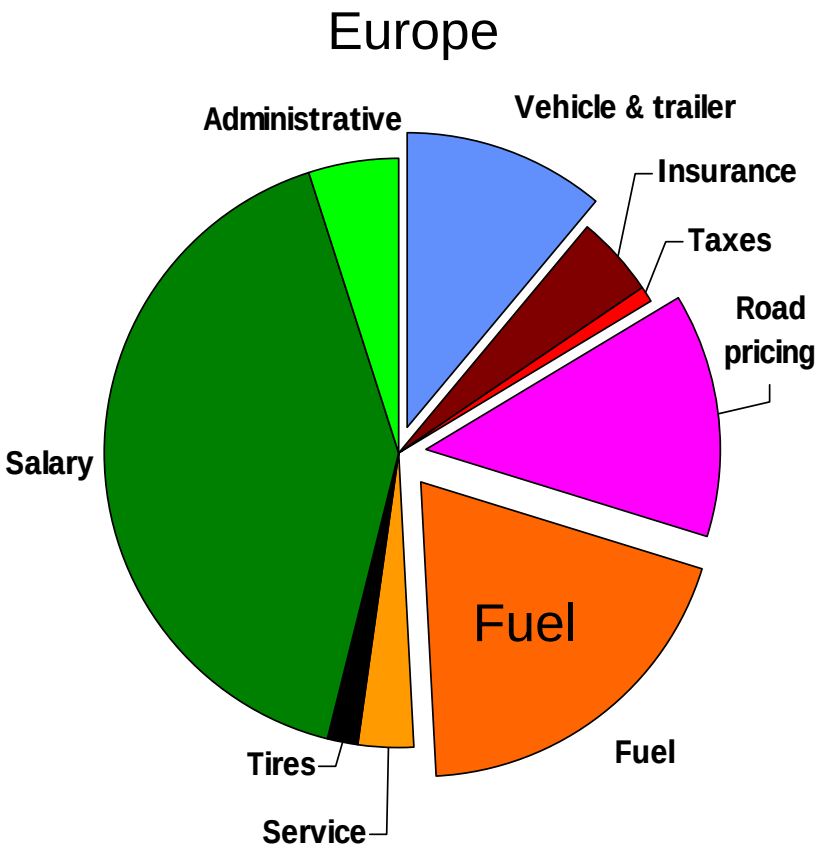
Medium and Heavy Duty Trucks

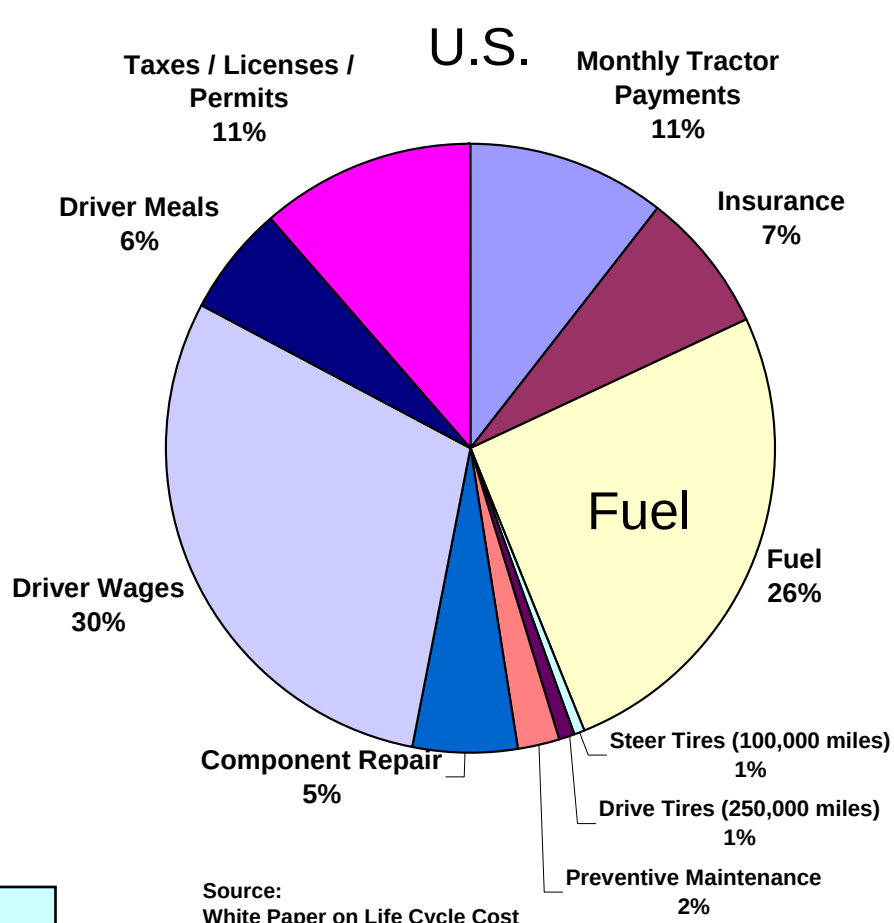
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Europe	**Heavy Duty**		SCR			SCR				DPF, SCR		
	Medium Duty		SCR			SCR				DPF, SCR		
USA	**Heavy Duty**	EGR			EGR, DPF			EGR, DPF, SCR				
	Medium Duty	EGR			EGR, DPF			EGR, DPF, NSC or EGR, DPF, SCR				
Japan	**Heavy Duty**	EGR			EGR, DPF			EGR, DPF, SCR				
	Medium Duty	EGR			EGR, DPF			EGR, DPF, SCR				

US SCR Implementation



Typical Lifecycle Cost Distribution
Line Haul Trucks





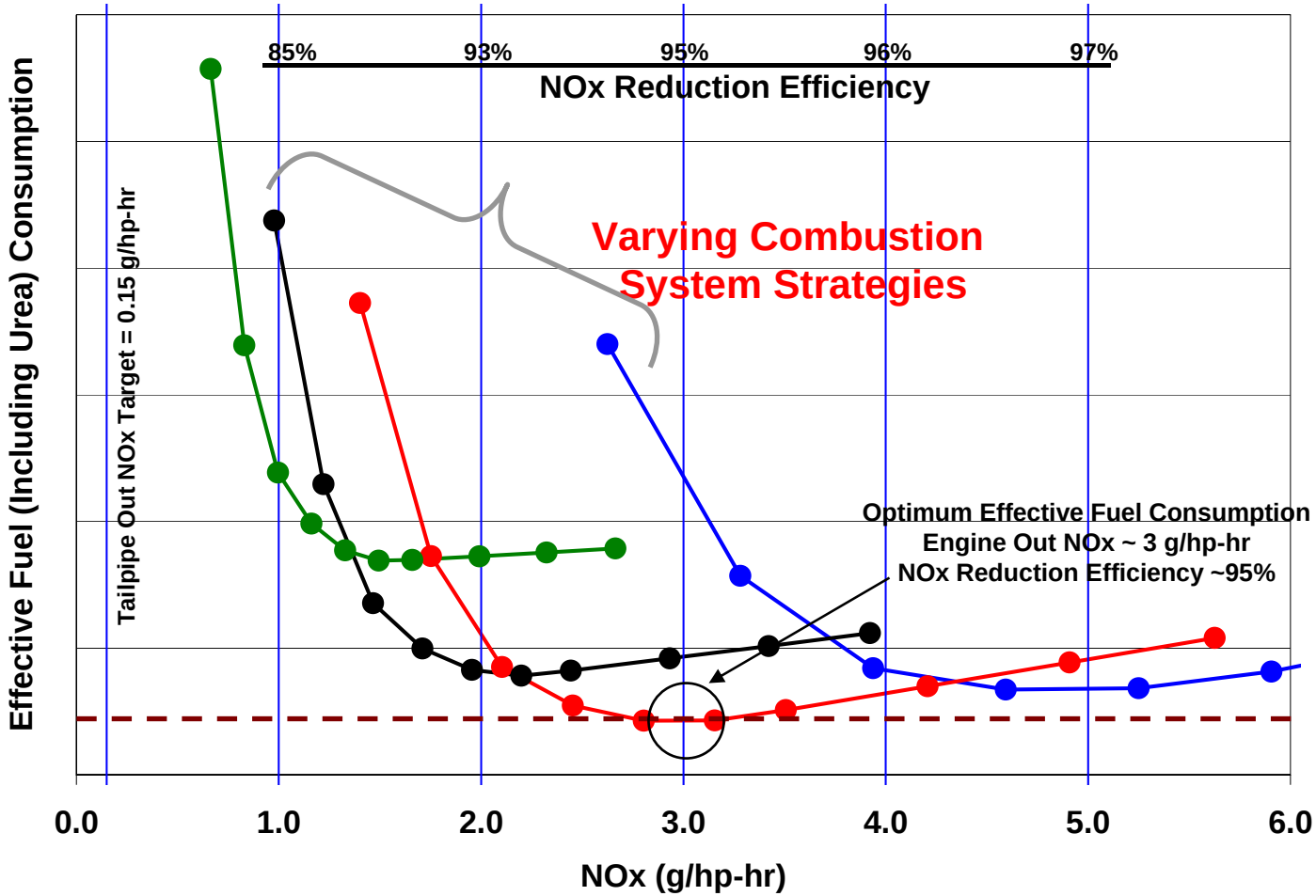
Fuel Expense Typically Constitutes 25% - 30% of the Lifecycle Cost

Source:
White Paper on Life Cycle Cost
Kenworth Truck Company
www.kenworth.com

Truck Product Creation

Combustion / Aftertreatment System Integration

Establishing An Optimum Combination for 2010

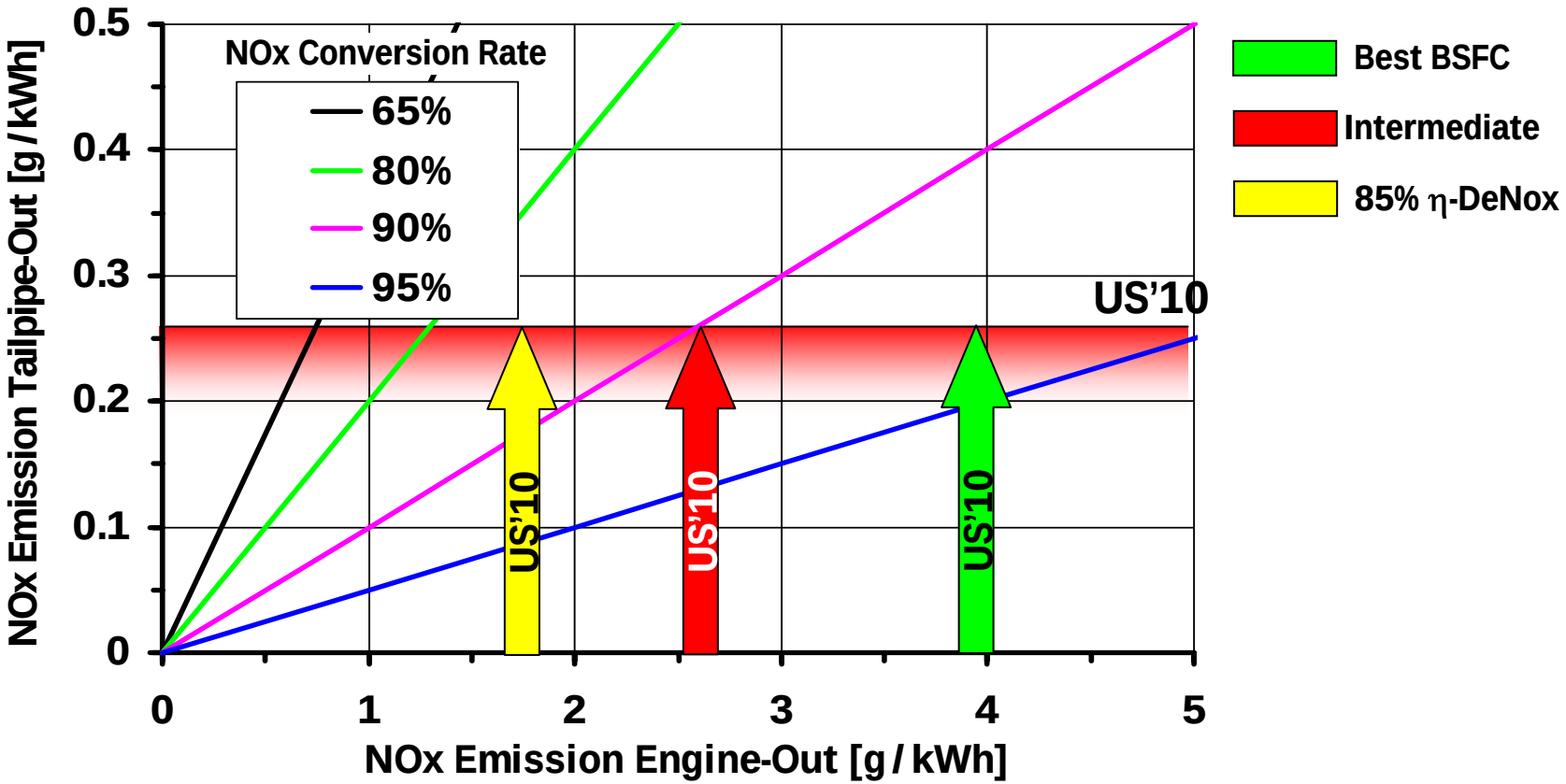


European Stationary Cycle

Urea Cost = Diesel Fuel Cost

SCR Conversion Efficiency

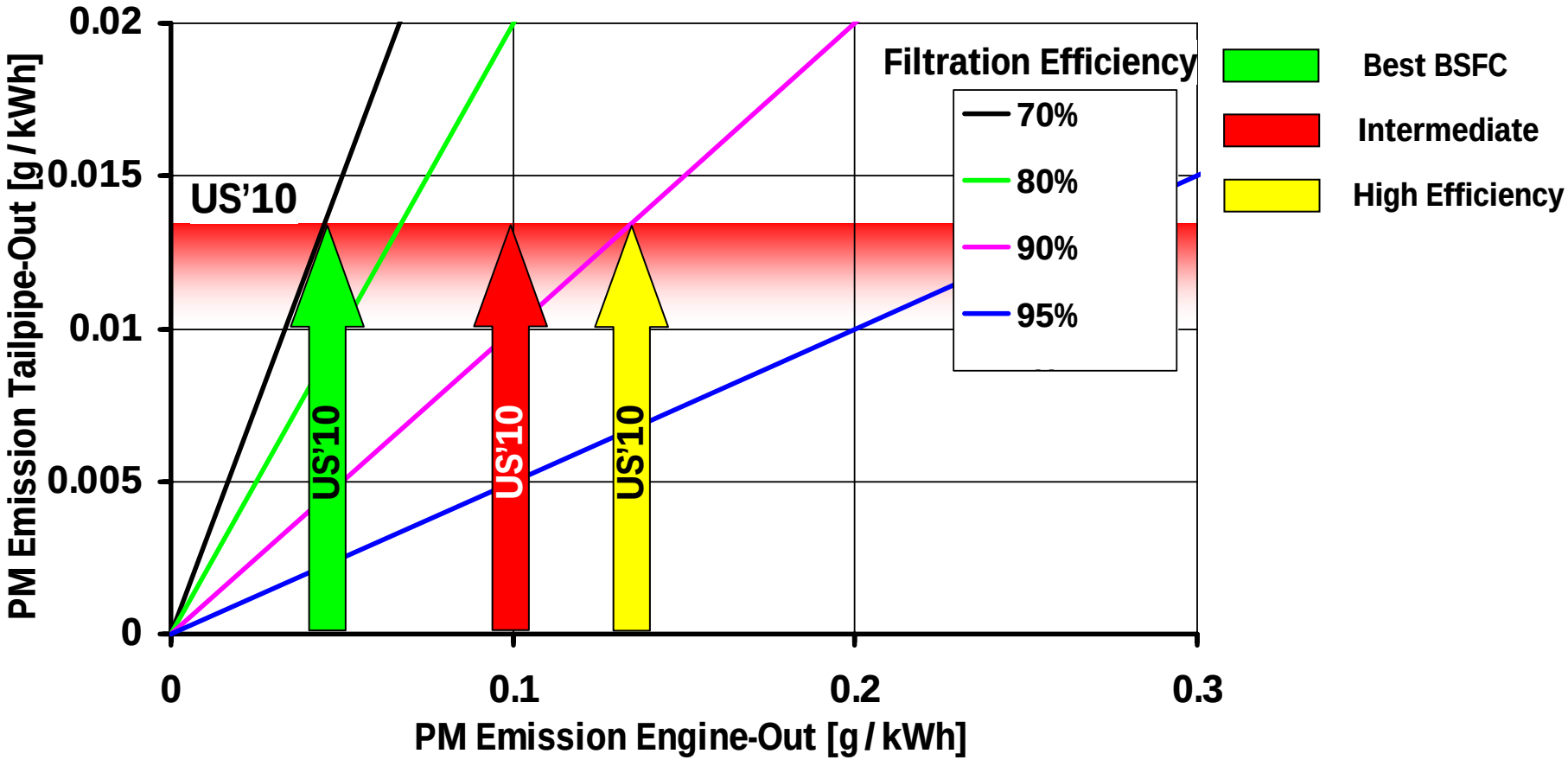
Engine-Out Versus Tailpipe-Out NOx



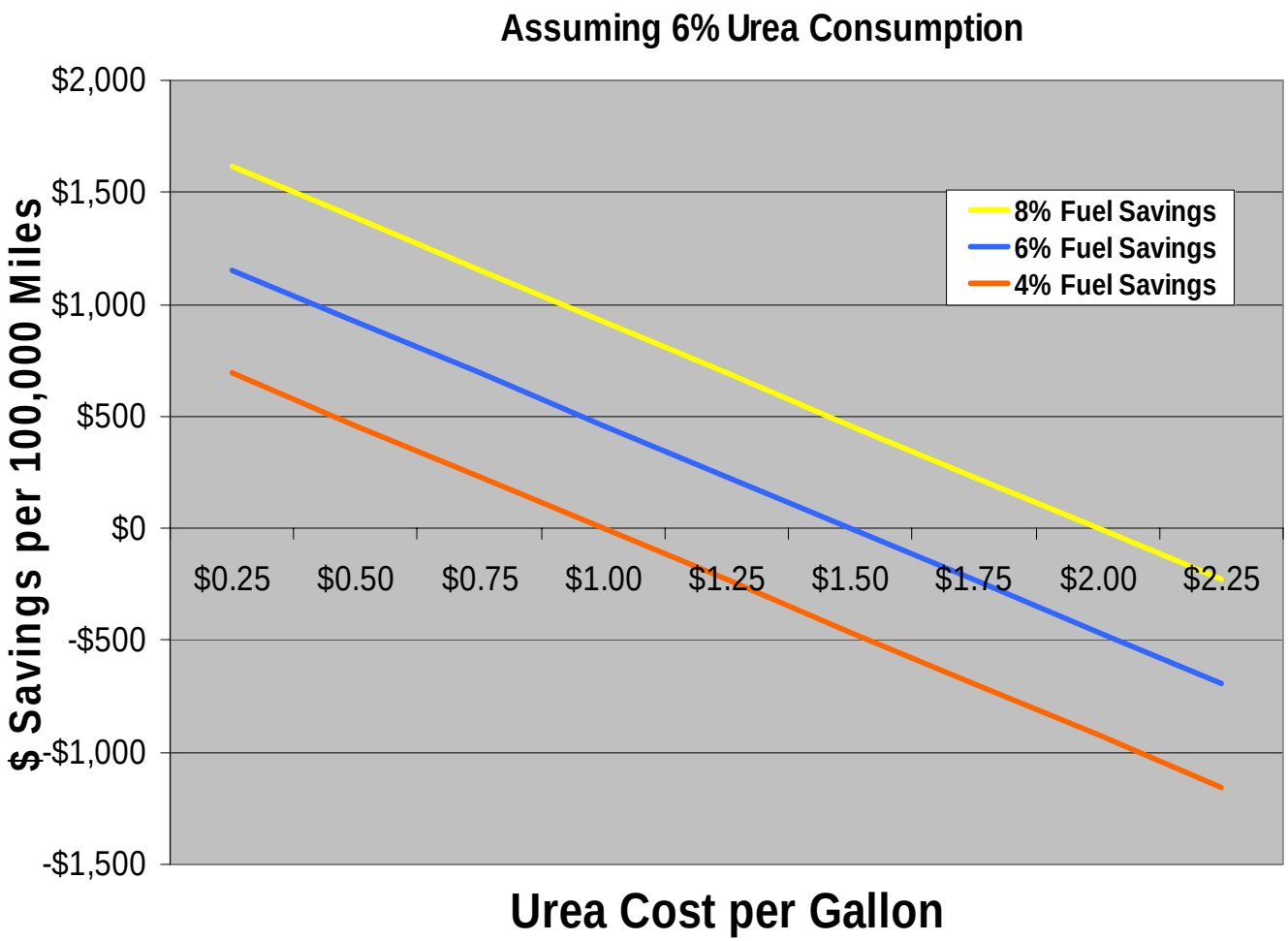
Truck Product Creation

DPF Conversion Efficiency

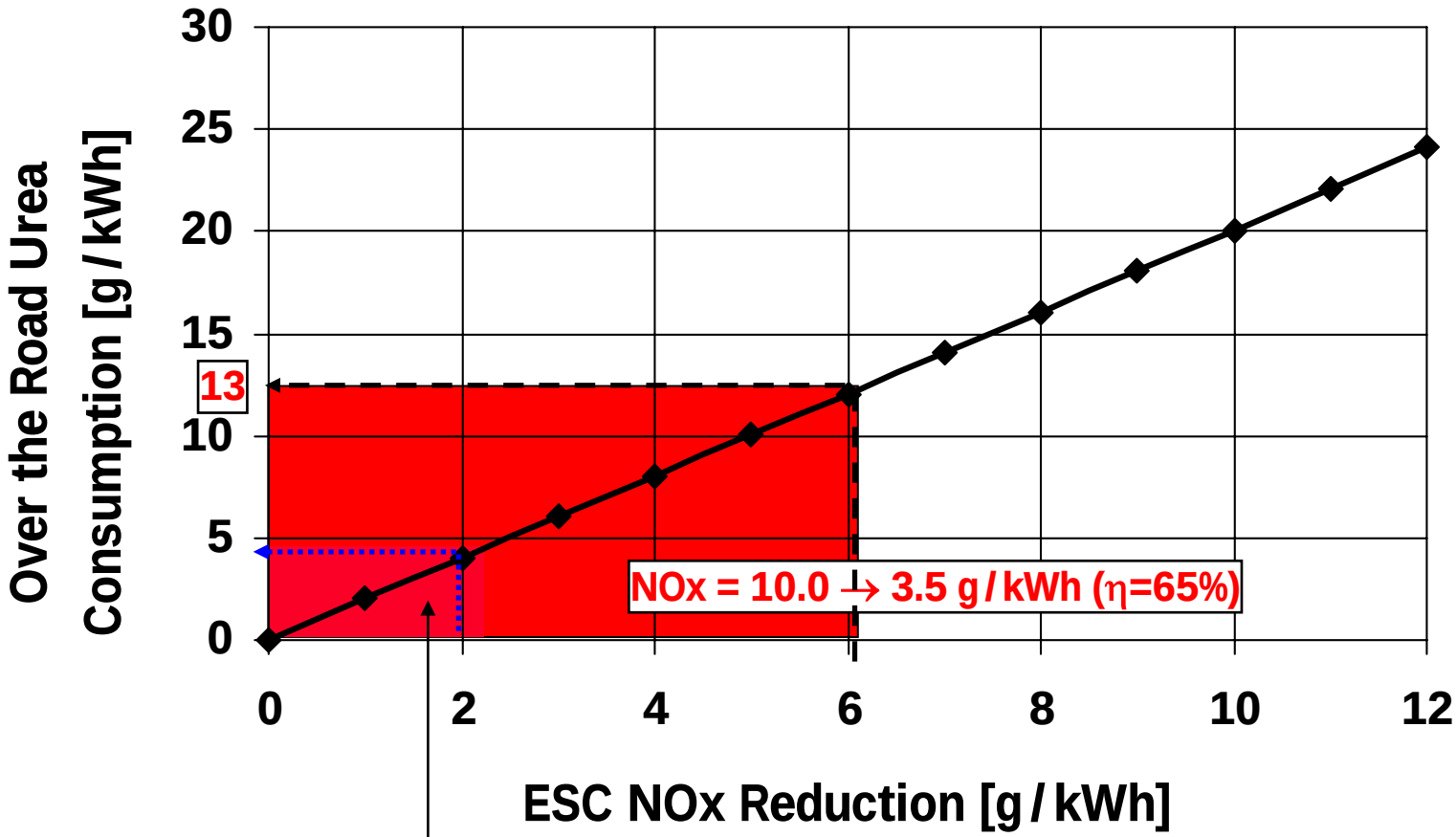
Engine-Out versus Tailpipe-Out PM



Urea Cost Sensitivity vs Fuel Savings



Urea Consumption Versus NOx Reduction



Typical US SCR Truck Application

Diesel Fuel Tank 200 Gallons

Urea Tank 30 Gallons

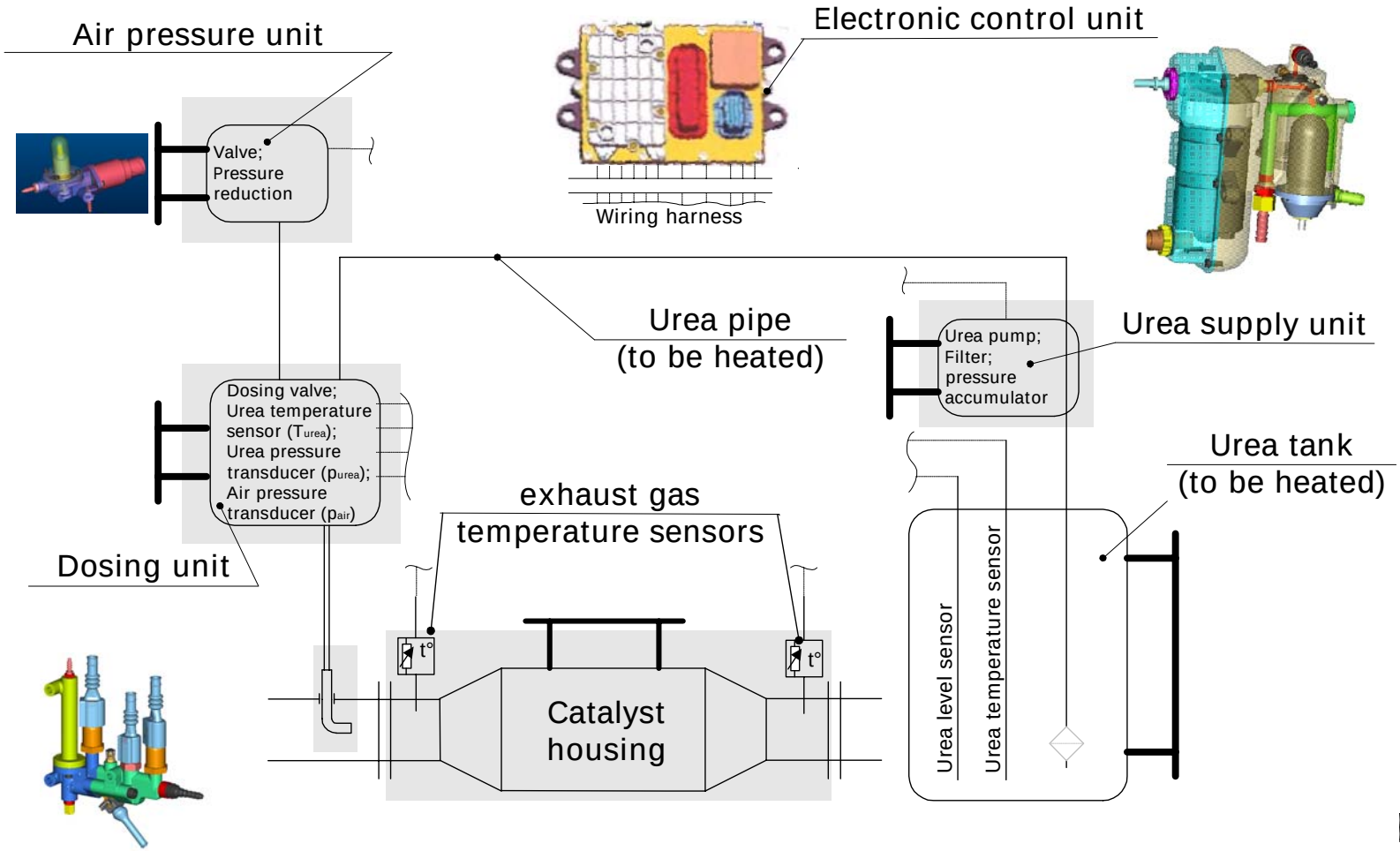
Vehicle Range Based on Diesel Fuel Capacity = 1360 Miles (6.8 mpg)

Vehicle Range Based on Urea Capacity = 5100 Miles

Assuming 4% Urea to Fuel Consumption Ratio

Ratio May Be Lower in 2010

Vehicle Mounted Elements of SCR System



Quality Control, OBD, and Anti-Tampering

- Control of Vehicle Urea Consumption is the Responsibility of the Engine Manufacturer.
- Control of Urea Quality is A Shared Responsibility Between Engine Manufacturer, Urea Dealer, Urea Supplier, and Truck Operator.
- Market Availability of Urea is A Shared Responsibility Between Urea Suppliers, Urea Distributors, and Authorities.

- As With Other Engine Systems, Prevention Measures Against Tampering Are Necessary.
  - Tampering Is Not Completely Avoidable: It Should Be Rare (and Costly).
  - Impact When Tampering Is Detected: The Operator Should Prefer Not to Tamper
  - Tampering Diagnostics Should Be Efficient, Independent of the Technology.
- OBD Cannot Necessarily Differentiate Between Tampering and Malfunction.
- Reliable / Durable Exhaust Emission Sensors Should Be Implemented.

Failure Mode Detection

- "Insufficient Ammonia Feed Rate"

  - ➔ Symptom: Urea Supply Rate Is Lower Than Anticipated
  - ➔ Possible Causes:

    - ☐ Diluted or Altered Urea Solution
    - ☐ No Urea
    - ☐ Plugged Lines
    - ☐ Leakages
    - ☐ Actuator Failure

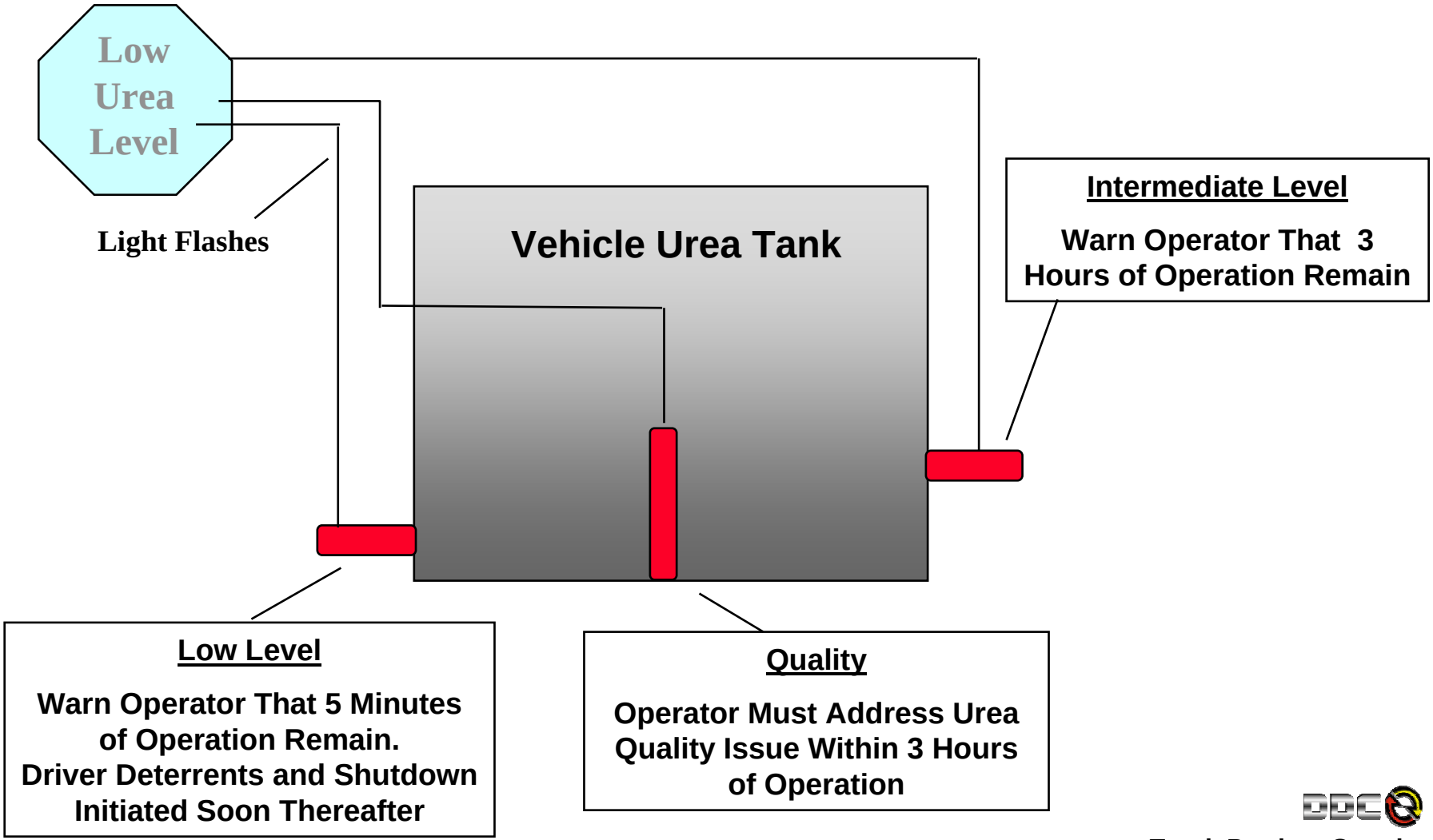
- "Inadequate Catalyst Efficiency"

  - ➔ Symptom: Urea or NOx Conversion Rate Is Lower Than Anticipated
  - ➔ Possible Causes:

    - ☐ Catalyst Aging
    - ☐ Catalyst Failure
    - ☐ Removal of Catalyst
    - ☐ Loss of Air Pressure

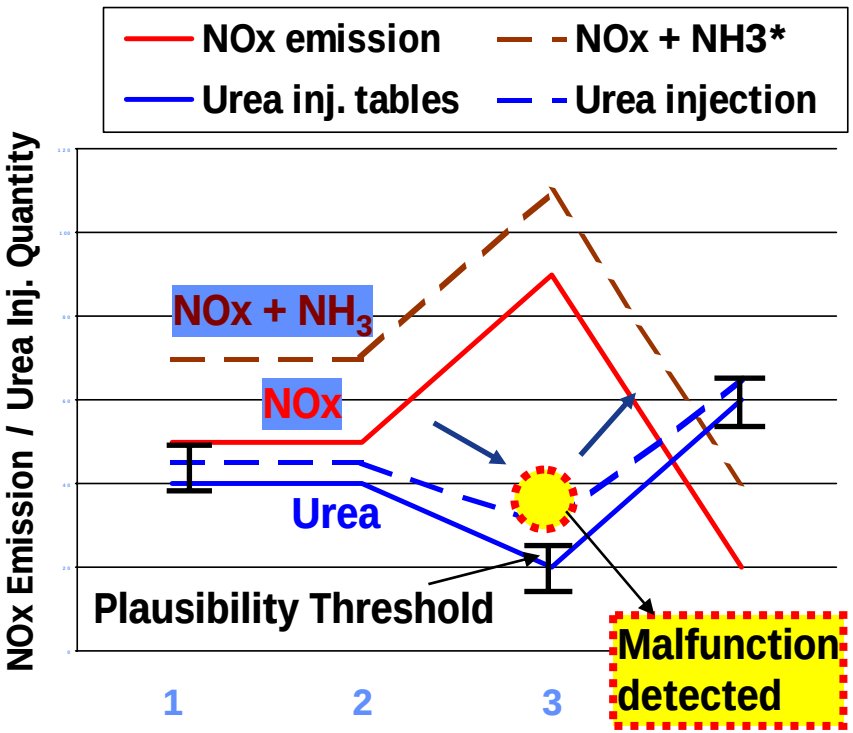
Urea Sensing and Action Scenario

Scenario: Insufficient Ammonia Feed Rate



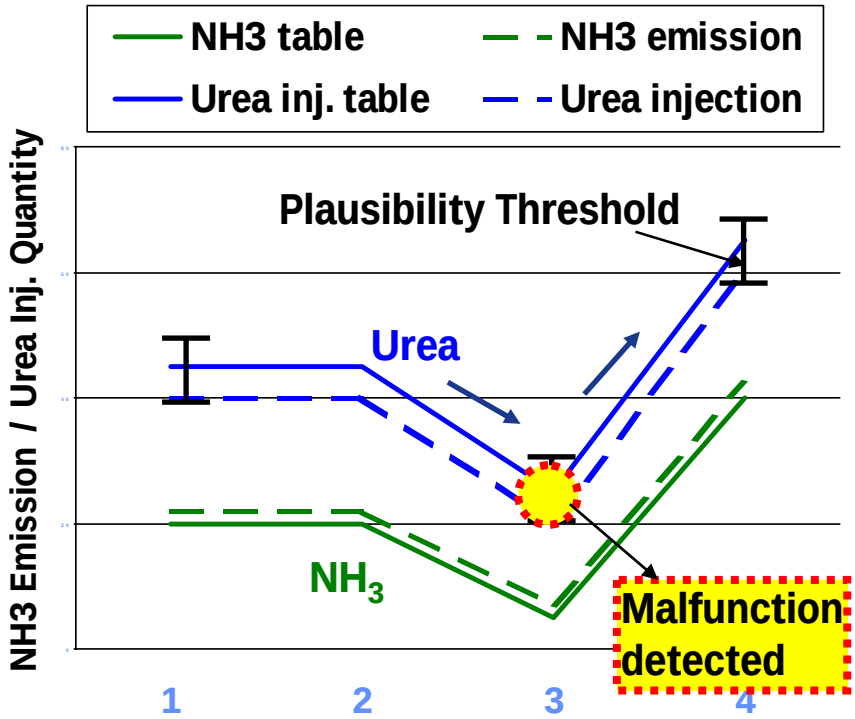
Plausibility Checks Using NO_x or NH_3 Sensors

Scenario: Inadequate Catalyst Efficiency



NOx sensor

"negative feed back control"



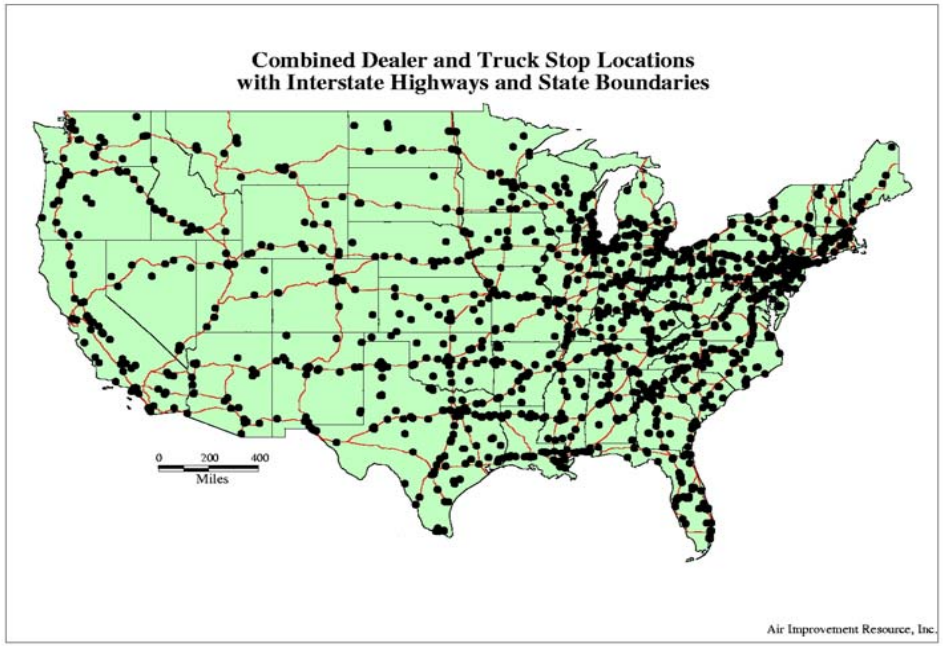
NH_3 sensor

"positive feed back control"

Truck Product Creation

Urea Infrastructure Plan

- Affiliated Truck Stop Locations
- Other Large Chains
- Independent
- Establish Agreements to Provide Urea
- Target More Than 1000 Locations
- Provide Safety Net (Emergency Supply)



Industry Stakeholders

Urea Producers

Commercial Distributors

Truck Stop Operators

Fleet Operators

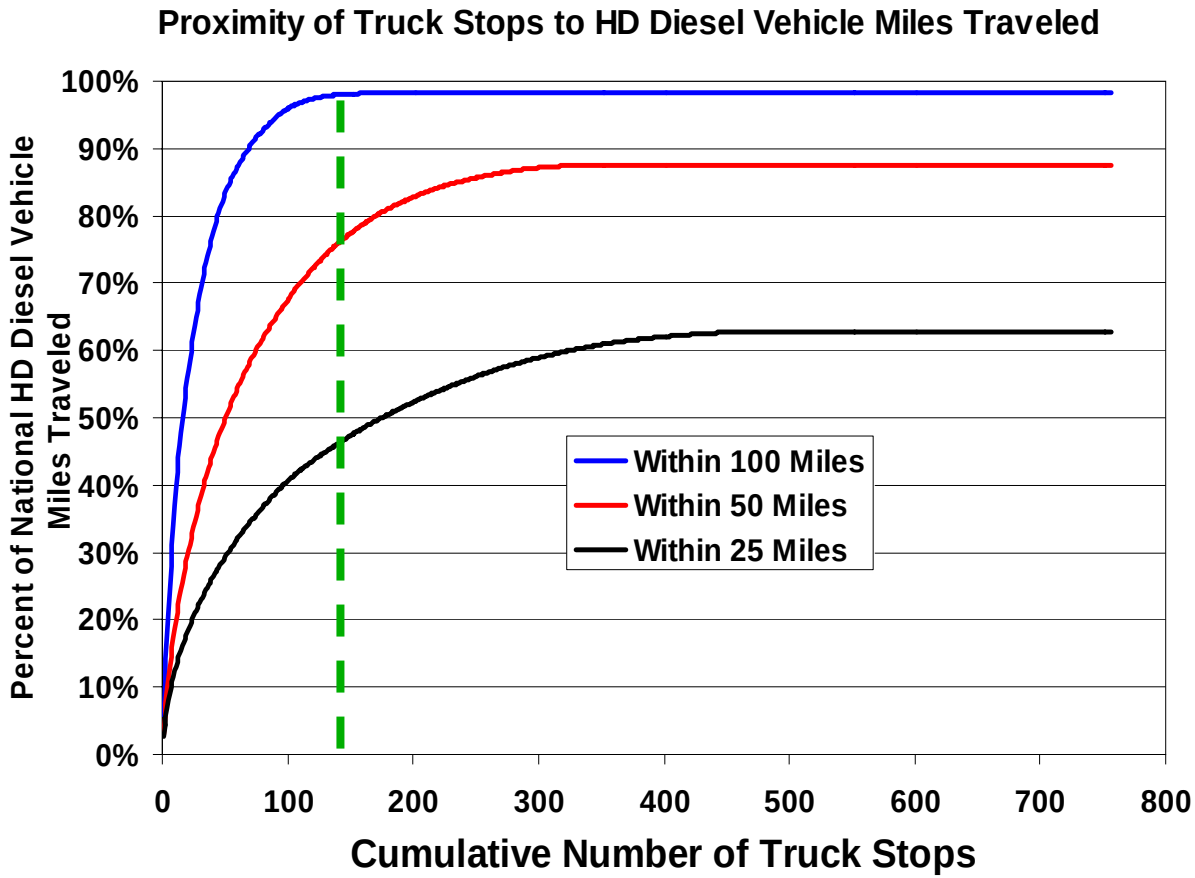
Component Manufacturers

Engine Manufacturers

Vehicle Manufacturers

Progressive Urea Infrastructure Implementation

≈ 6000 Truck Stops in the US



140 Truck Stop Locations (Less Than 3% of All Truck Stops) Can Ensure Urea Availability Within a 100 mile Radius for Greater Than 95% of the Heavy Duty Vehicle Miles Traveled

DDC

Truck Product Creation

Urea Infrastructure
European Approach

- The urea supply industry has a major interest to establish a urea infrastructure.
- 80% of the entire heavy duty truck diesel fuel is being distributed by local fuel stations which are operated by the fleets themselves.
- Fleet owners will install urea filling stations at their places. Financial support through urea manufacturing companies is in discussion.
- Large highway truck-stops will be equipped with urea filling stations. Other fuel filling stations will install urea supply gradually.

supply of the most important intersections

supply along the most important routes

area-wide supply with minimal distances

Urea (AdBlue) Filling Equipment

Indoor Version

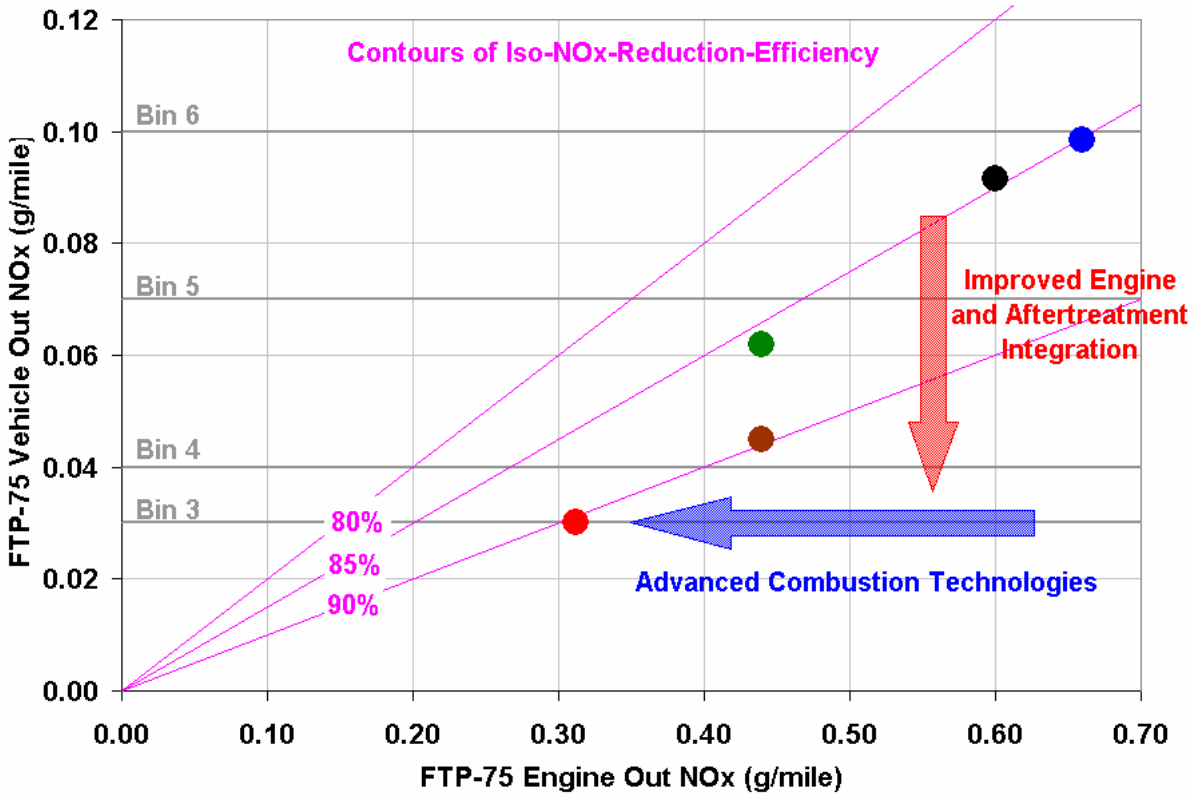
Outdoor Version

A Variety of Urea Filling Equipment Solutions Are Being Established, Depending on Type of Station and Need.

How to Prevent Vanadium Slip?

1) More Precise Exhaust Temperature Management

2) Non-Vanadium SCR Catalyst Materials

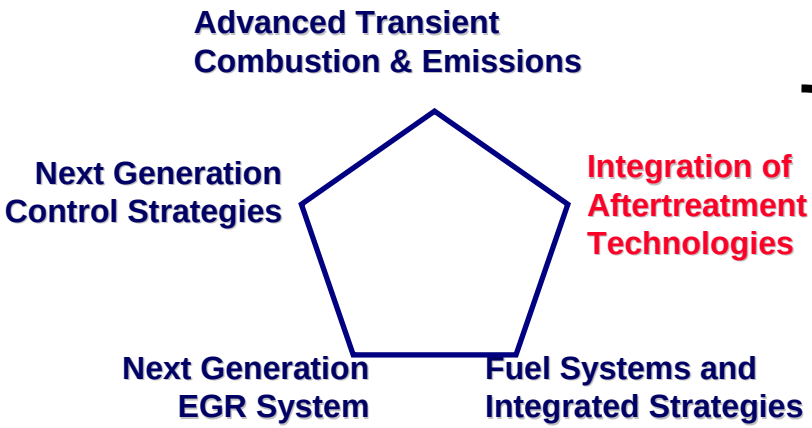


Experimental Data From DOE Funded Light Truck / SUV Engine Test Platform with Non-Vanadium SCR Systems

Summary

- Model Based Control Systems with Feedback Sensors Will Enhance NOx Conversion Efficiencies, Determine Plausibility, and Help Detect NH3 Slip, Failure Modes, and Tampering.
- Strategic Arrangement of Aftertreatment System Components And More Precise Management of Exhaust Temperature and NOx/PM Ratios Will Enhance NOx Conversion Efficiency.
- Investigations for Urea Freezing and Heating Were Conducted During Winter Testing in Finland With Very Good Results.
- Customer Vehicles in Europe With Prototype Samples Revealed No Cracks or Contamination After Several Years of Operation. Product Release Is Planned for Euro IV and/or Euro V by Most European HD Truck Manufacturers.
- Engineering Vehicles Now Operating in the US With SCR & CDPF Technology.
- The SCR & CDPF System Is An Advantageous Technical and Economic Choice for Many Worldwide Applications, Including Euro IV, Euro V, JP05, and US2010, If Not Earlier.

Thank You



Truck Product Creation