

**Cummins/DOE
Light Truck
Clean Diesel Engine
Progress Report**



August 2003

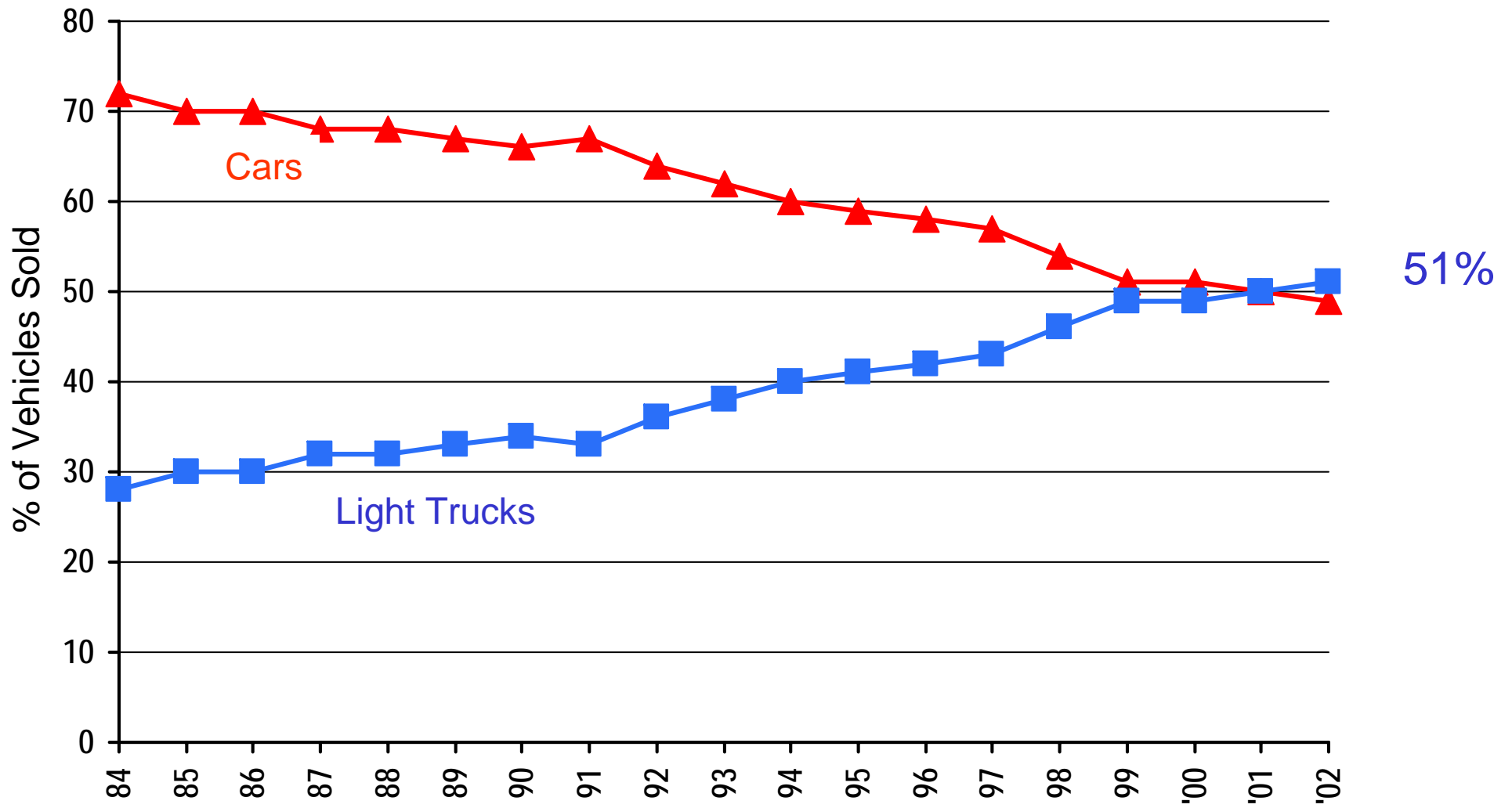


Technical Program Overview

- **Partnership, Cummins and U.S. Department of Energy**
- **Focus**
 - **Development of technologies that will result in a product in the near term**
 - **Emissions**
 - ~ **U.S. Tier 2 6000-8500 lb GVW**
 - ~ **NO_x = 0.07 g/mi; PM = 0.01 g/mi**
 - **Fuel economy - 50 percent MPG improvement over 1997 gasoline powered vehicle it replaces**
- **Acknowledgment**
 - **Partnership funding from DOE**
 - **Vehicle and installation design assistance from Dodge Truck Engineering**
 - **Engine Development Team at Cummins**



US Passenger-Car & Light-Truck Market





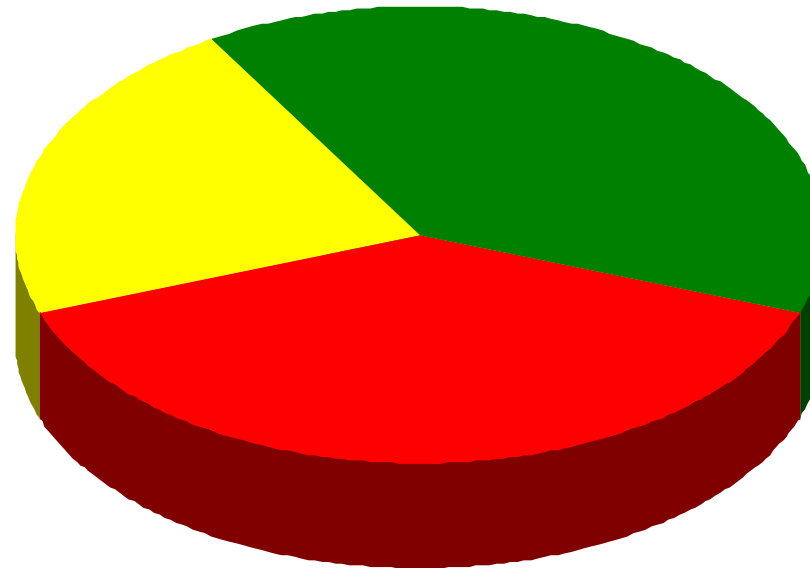
Light Truck Major Segments

8.4M Vehicles

Vans 22%



Sport Utility Vehicles 39%



Pickup Trucks 39%

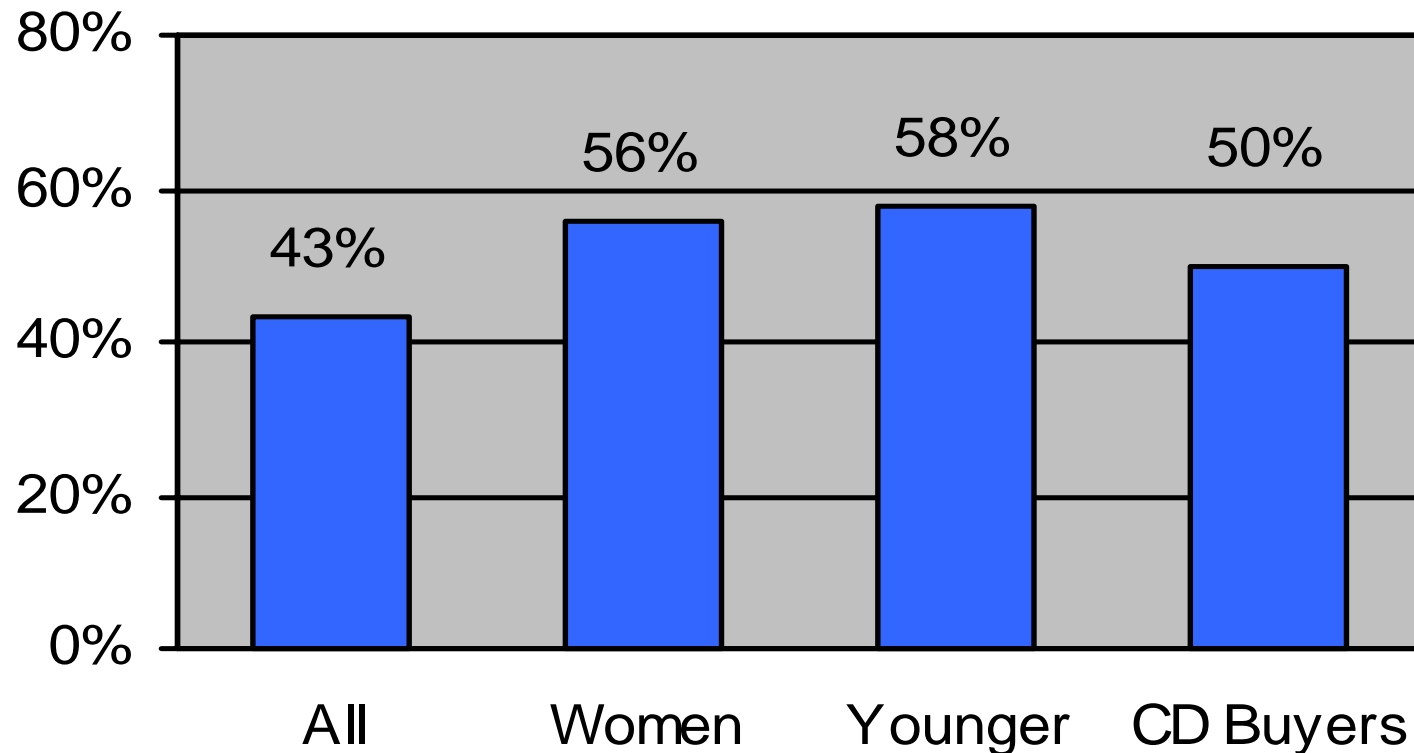


2001 Sales



Importance of Fuel Economy Over Time

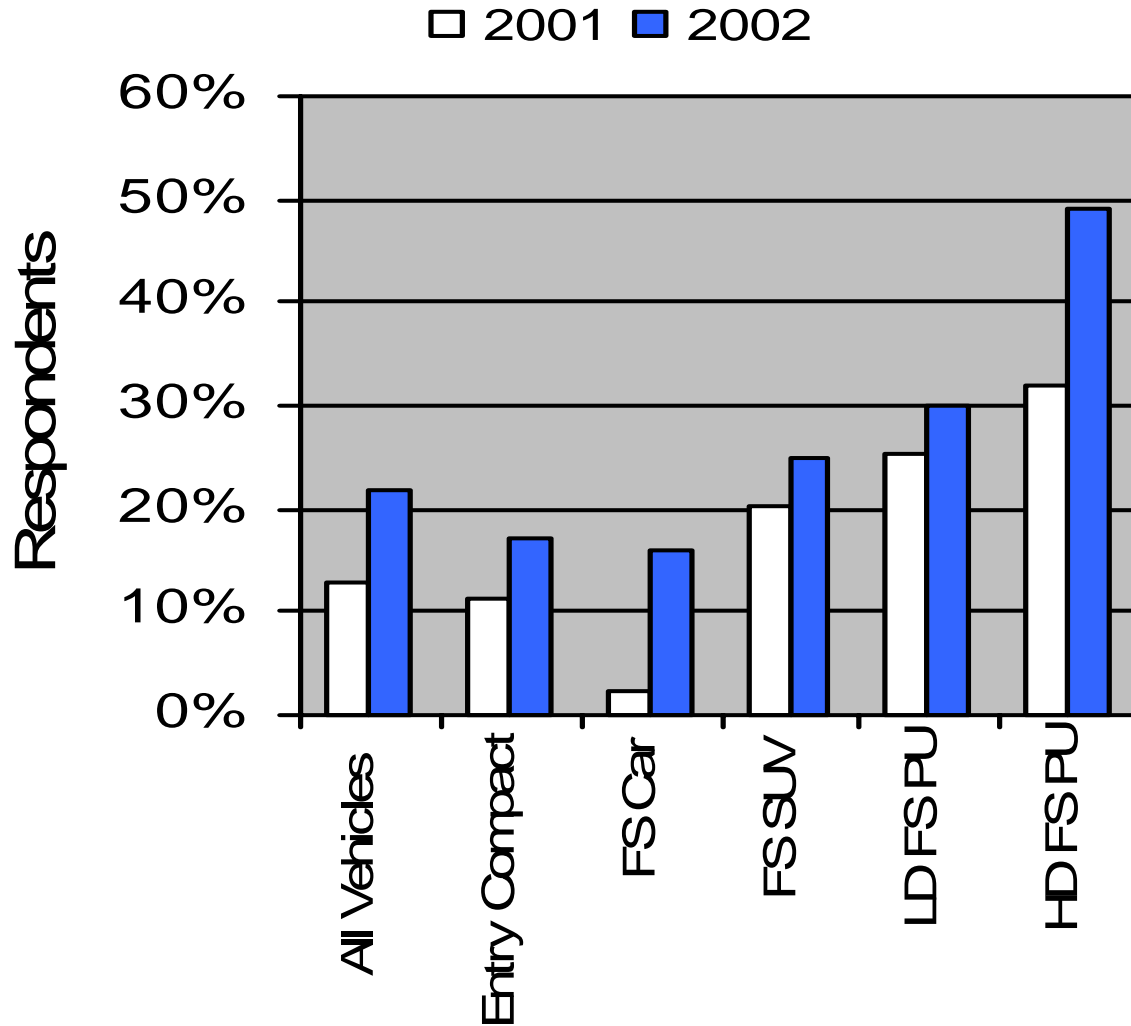
Percent of respondents who declared fuel economy to be very important or critical to them.





Consumer Demand for Clean Diesels

Definite willingness to consider buying clean diesels.



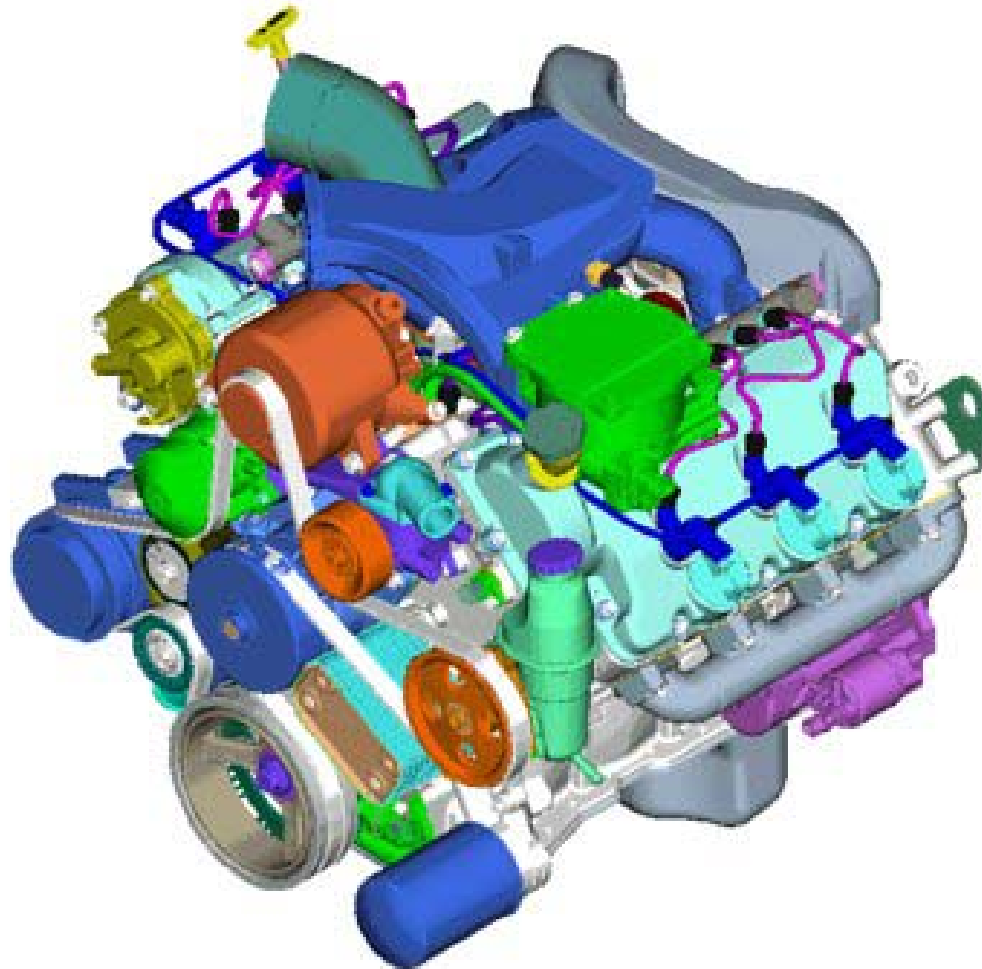


V Family Goals and Status

Description	Actual (status)	
	V6	V8
Emissions	Tier 2 Interim Demonstrated, Tier 2 Bin 5 Final, Met in Vehicle	
Noise, dBa	72.7, Bare Engine in Test Cell	49.7 Interior Idle Park Ram1500 Pickup
Fuel Economy, MPG	22.1 Combined, Durango (+60%)	21.7 Combined, Ram1500 (+60%)
Quality/Reliability	Current Work Focus	
Rated Speed	4000 rpm (5000 max.)	
Useful Life km(mi)	8000 hr Total Development Testing (equivalent usage >1.9M(1.2M))	
Performance	10.7 sec, 0-60 mph, 5500 # PTW	9.6 sec, 0-60 mph, Ram1500, 6000 # PTW
Displacement, liter	4.2	5.6
Power, kW(hp) @ rpm	177(237) @ 3600 WG 201(270) @ 3800 VNT	224(300) @ 4000 Interim target met.
Torque Peak, Nm(ft-lb)	584(430)	623(460)
Warm-Up	34C in 200 sec @ -10C	Future Work
Serviceability	No Adjustments Diesel fuel filter added.	
Cold Start	3.2 sec (10 sec glow) @ -10C	Future Work
Weight, kg(lb)	301(663)	357(788)

- Meets Goal
- Partially Meets Goal;
Plan in Place

Light Duty Automotive Engine - V6



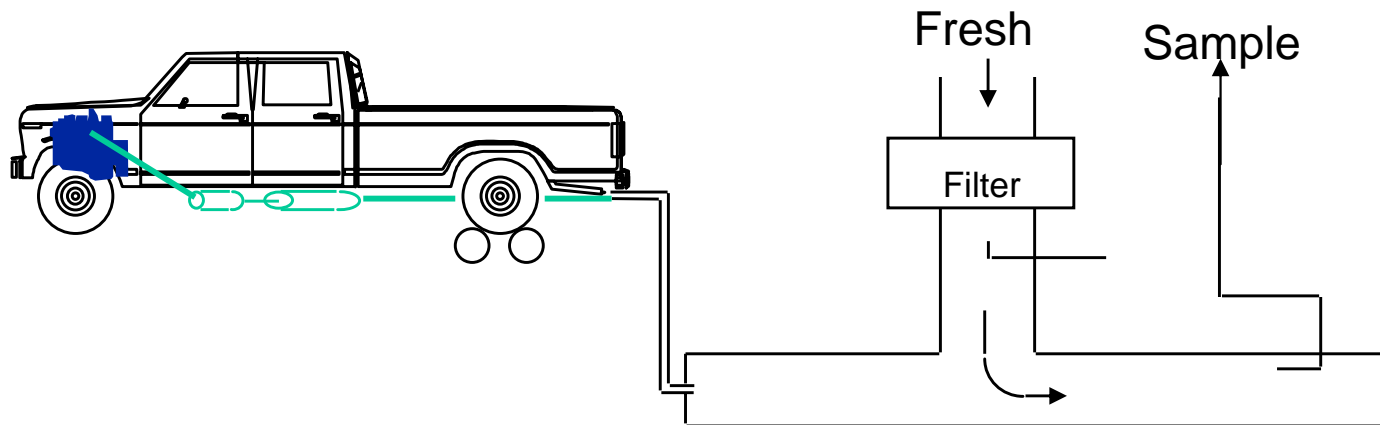
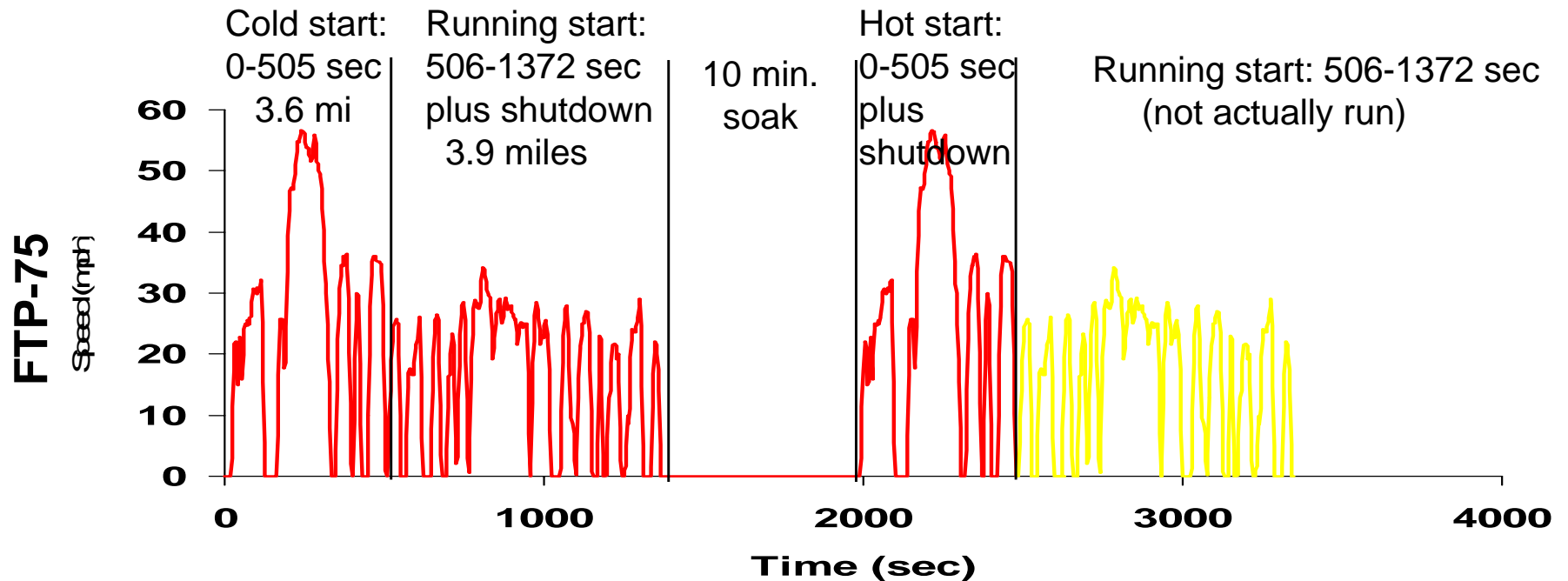
Light Truck Diesel Subsystem Description



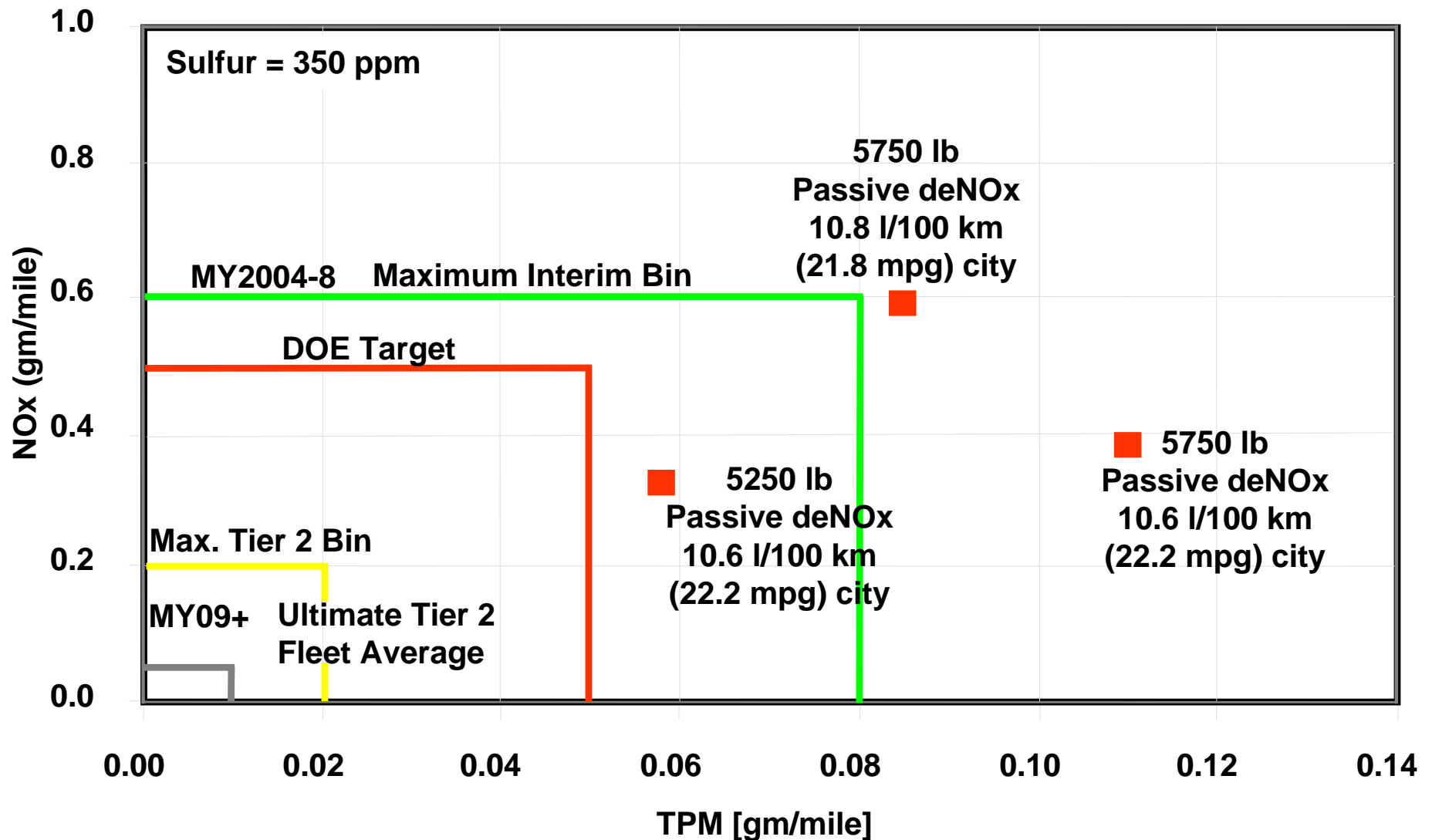
<u>Subsystem</u>	<u>Description</u>
Configuration	90° V
Displacement	4.2 L V6 5.6 L V8
Bore and Stroke	94 X 100 mm
Valvetrain and Drive	Single overhead cam, chain-driven
Valve System	Four valves per cylinder with hydraulic lash adjustment
Fuel System	High-pressure common rail (HPCR)
Control System	Full electronic
Emissions Control	Modulated-cooled EGR plus deNOx catalyst (Bin 10) 4-Way Catalyst (Tier 2, Bin 5)
Aspiration	Wastegated turbocharged
Intercooling	Vehicle mounted air-to-air
Block	Cast iron, thin-walled
Head	High temperature alloy aluminum
NVH Control	Deep skirted block, with bedplate
Accessories	Common automotive V-8 gasoline
Accessory Drive	Single serpentine belt, self-adjusted



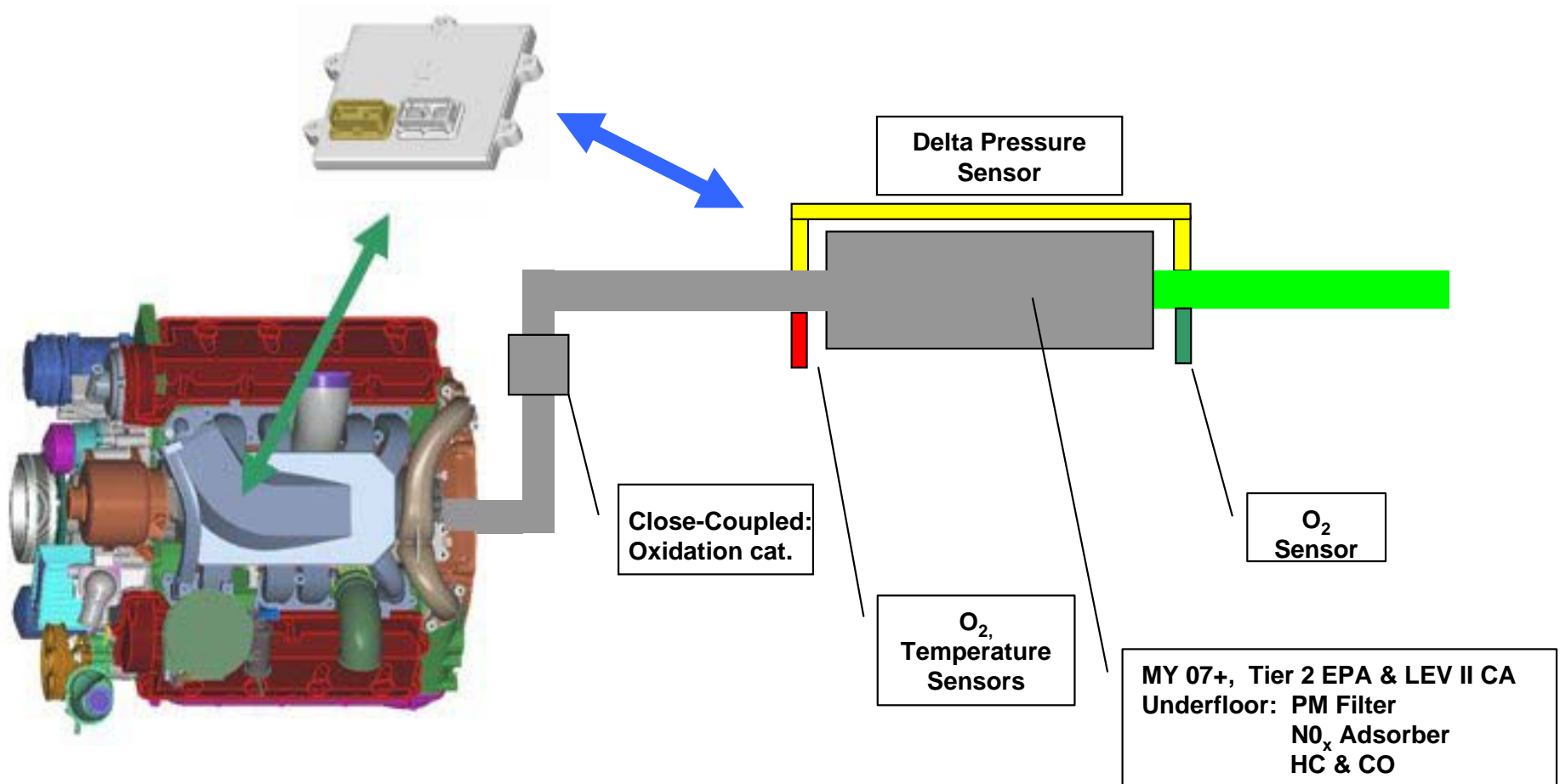
Chassis Certification Method



Demonstrated Emissions Interim Results



Prime-Path-System with 4-Way Catalyst System





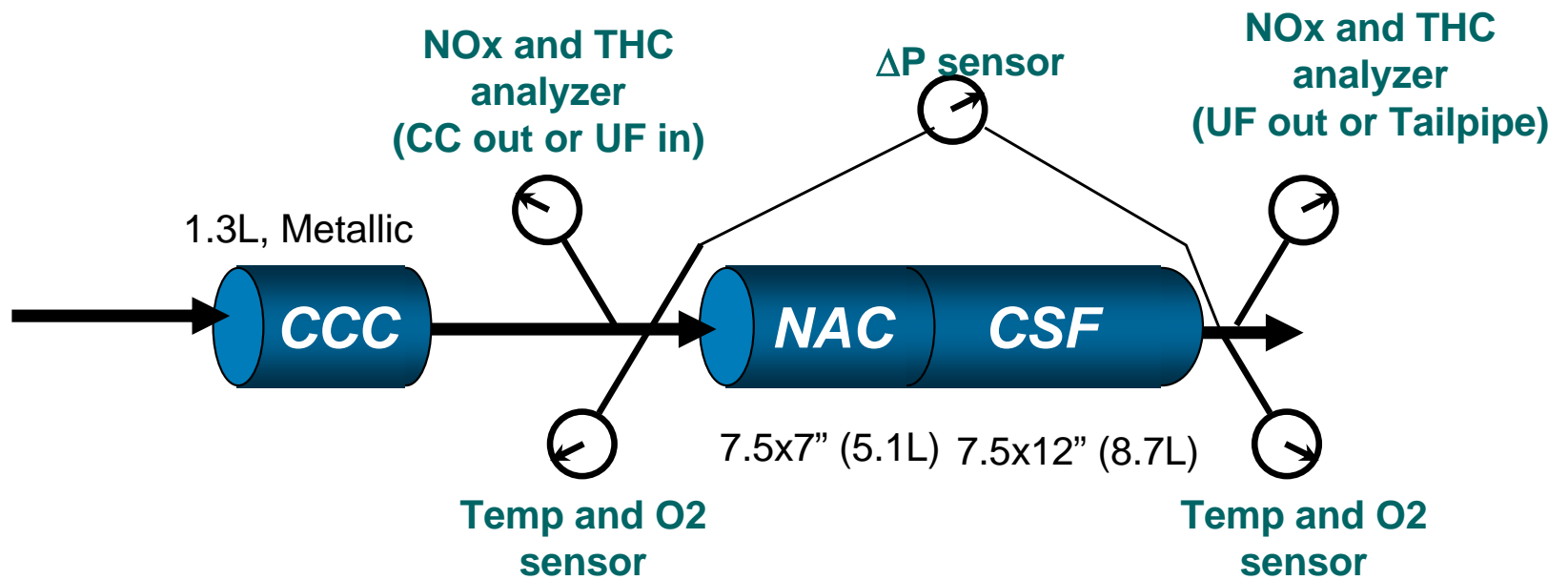
Regeneration Strategy

<u>Condition</u>	<u>Engine Out</u>	<u>Combustion Condition</u>
NO _x Regen	Rich	Thermal Management + { Pilot + Main Injection Pilot + Main + Post Pilot + Main + Post
Soot Regen	Lean	
Sulfur Regen	Rich	



Demonstration Emission System

- CCC (Pt); NAC (Pt & Rh); DPF (Pt)



Chassis Test Results - Bag Results

V6 - 5000 lb. - 12.7 hp@50 mph



Test	CO [g/mi]	CO2 [g/mi]	NOx [g/mi]	NMHC [g/mi]	FE [mpg]	PM [g/mi]
FTP-75 FUL limits	4.2	-	0.07	0.090	-	0.01
FTP-75	0.399	480.27	0.033	0.089	21.12	0.006
FTP-75	0.367	491.67	0.038	0.056	20.32	-
bag 1	0.971	547.87	0.141	0.222	18.47	0.008
	1.051	583.44	0.181	0.269	17.08	-
bag 2	0.272	475.03	0.003	0.057	21.37	0.004
	0.200	475.27	0.000	0.000	21.04	-
bag 3	0.207	439.17	0.009	0.049	23.11	0.007
	0.166	453.40	0.003	0.000	22.05	-

Start
+1600 mi

Chassis Test Results - Bag Results

V6 - 5000 lb. - 12.7 hp@50 mph

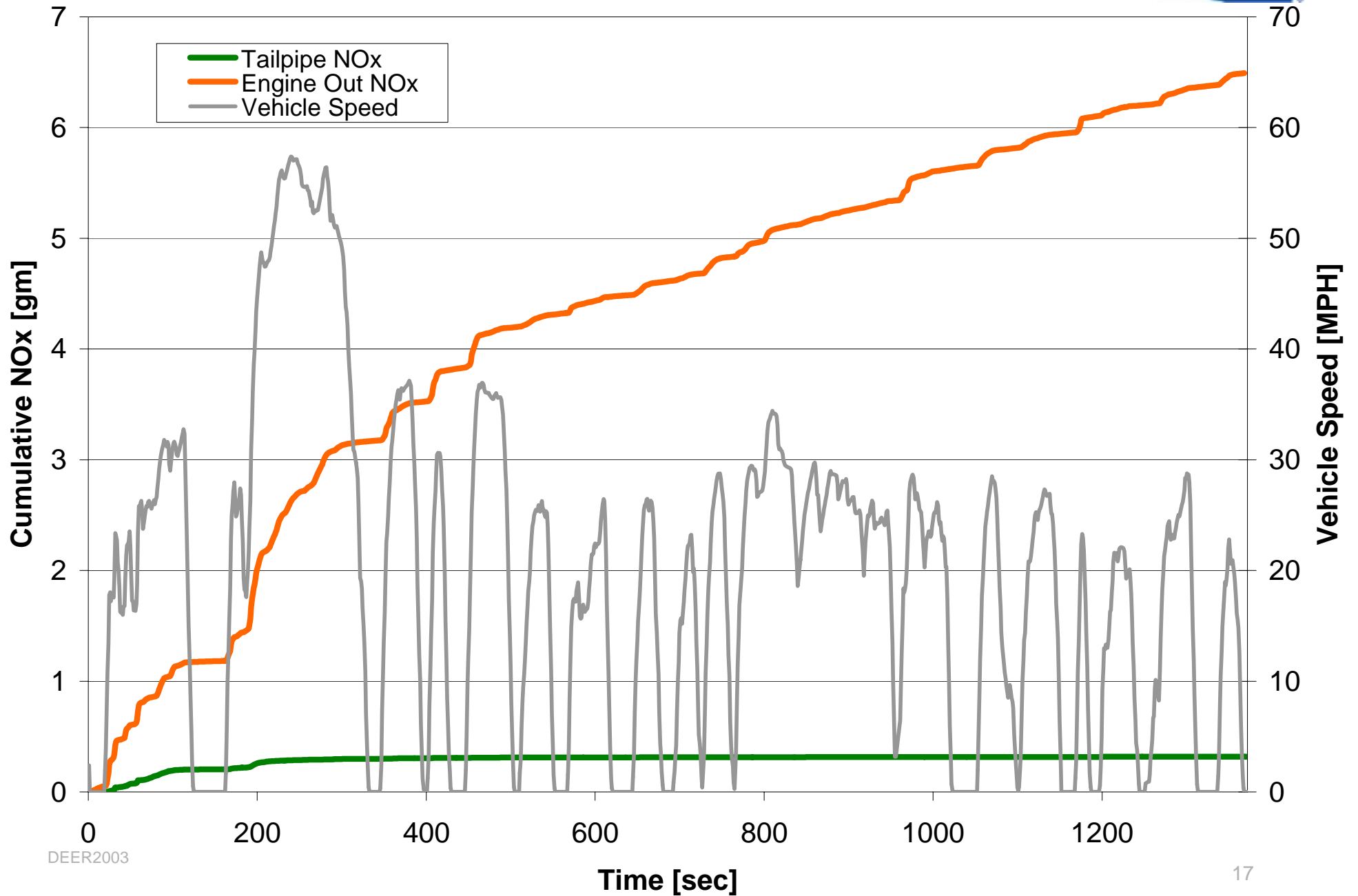


Test	CO [g/mi]	CO2 [g/mi]	NOx [g/mi]	NMHC [g/mi]	FE [mpg]	PM [g/mi]
HFET	0.122	309.94	0.005	0.000	32.8	0.006
	0.101	332.70	0.007	0.015	30.1	-
SC03	0.229	479.49	0.009	0.000	21.16	0.013
	0.200	484.82	0.015	0.000	20.93	-
US06	0.138	451.28	0.158	0.011	22.53	0.023
	0.120	496.23	0.228	0.005	20.20	-

Start
+1600 mi



Analyzer Results - Bag 1 & 2





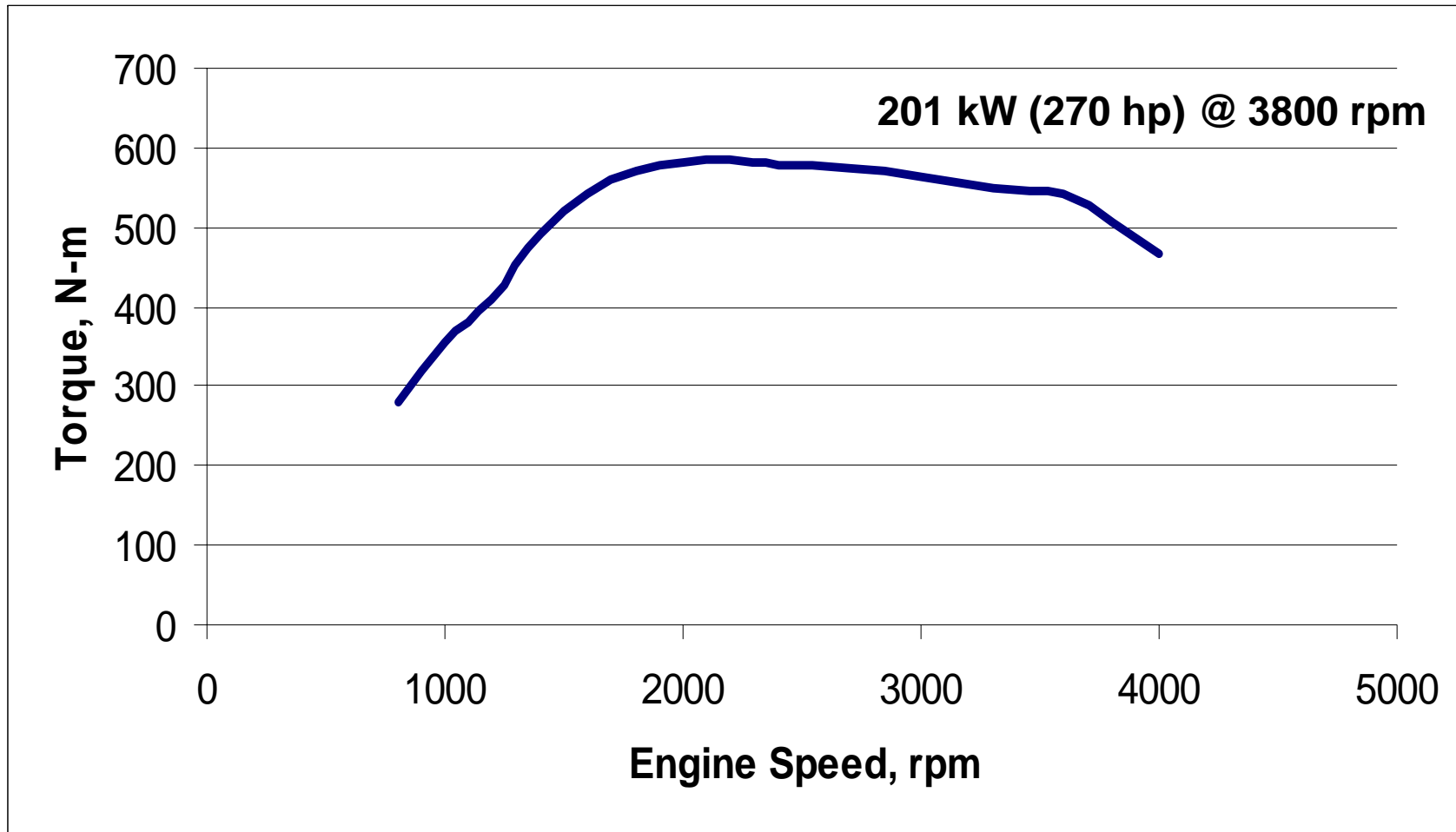
Typical Results

	<u>City,</u> <u>mpg*</u>	<u>Highway,</u> <u>mpg*</u>	<u>Combined,</u> <u>mpg*</u>	<u>Combined</u> <u>gal/mi</u>	<u>CO₂</u>
<u>Dodge Durango</u>					
- Gasoline	12	17	13.8	0.072	
- Diesel	20.3	25.0	22.1	0.045	
			+60% Improve	37% Reduction	27% Reduction
<u>Dodge Ram 1500</u>					
- Gasoline	12	16	13.5	0.074	
- Diesel	19.8	24.6	21.7	0.046	
			+61% Improve	38% Reduction	

*Adjusted values for vehicle labeling

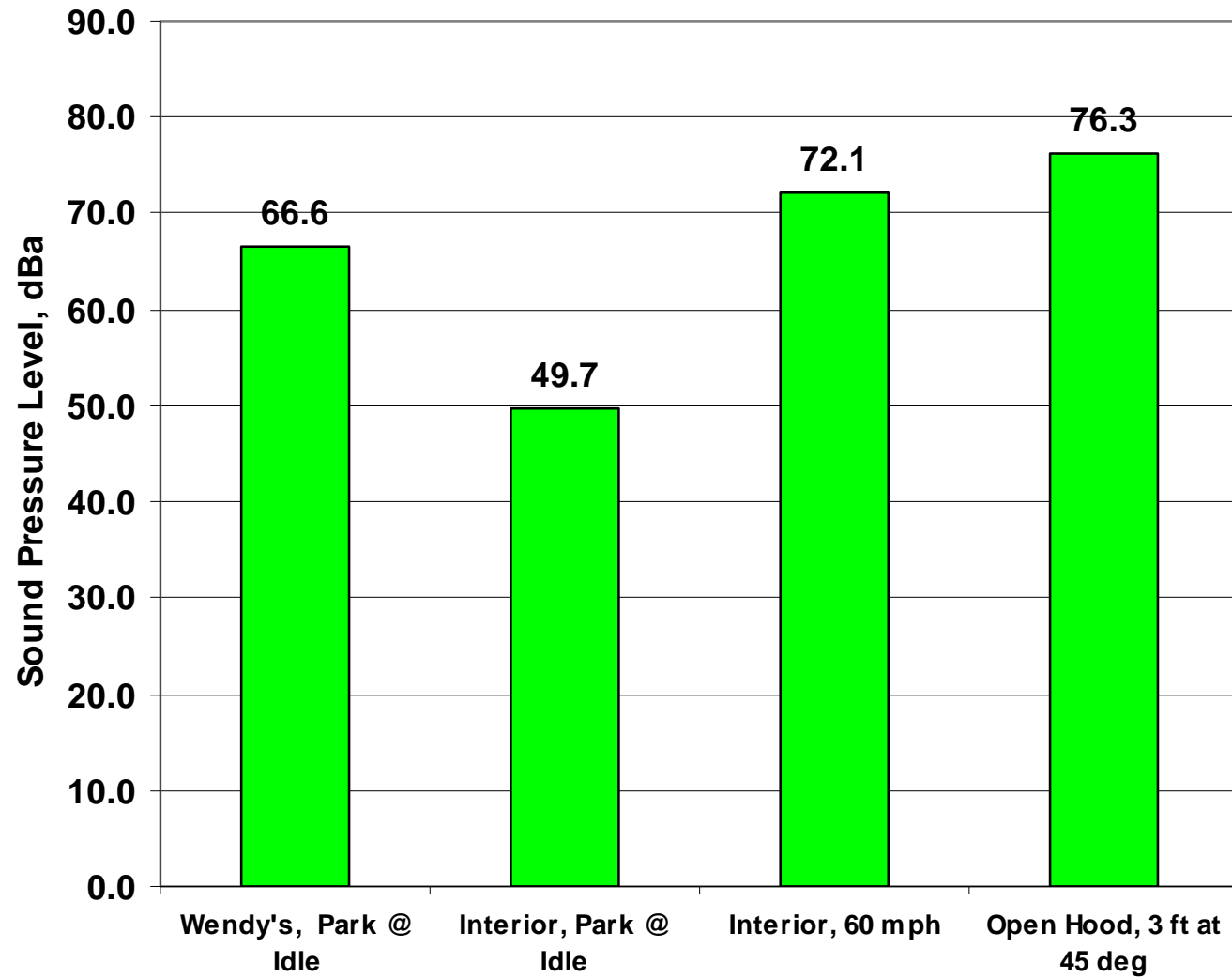


V6 Performance Results



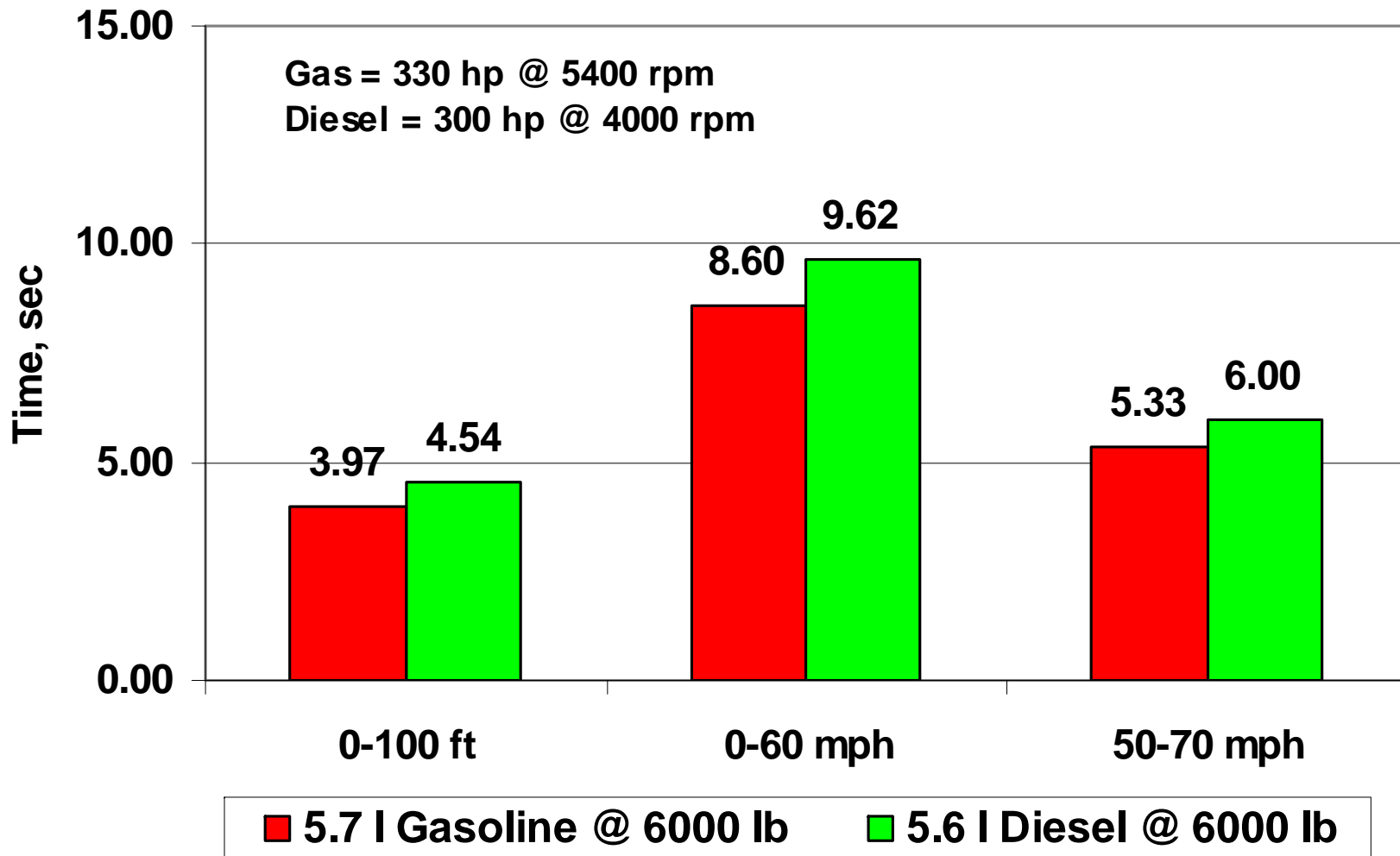
Noise Test Results

V8 in Ram 1500



Acceleration Test Results

V8 in Ram 1500





Conclusions

- Light Truck Diesel Family continues to show promise
- Fuel economy advantage is clear, approaching 60 percent
- Performance and sociability are becoming gasoline-like
- Interim Tier 2 emissions, met using known technology
- Final Tier 2 emissions, met in a complete vehicle system using advanced aftertreatment devices
- There is a path to market for the Light Truck Diesel
 - Cost/Robustness issues are the ongoing challenge