Cummins Work Toward Successful Introduction of Light-Duty Clean Diesel Engines in US

August 2005

Technical Program Overview

- **Partnership, Cummins and U.S. Department of Energy**
  - **Seven Years, 1998-2004**
- **Focus and Goals**
  - **Development of technologies that would 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**

V Family Goals and Status

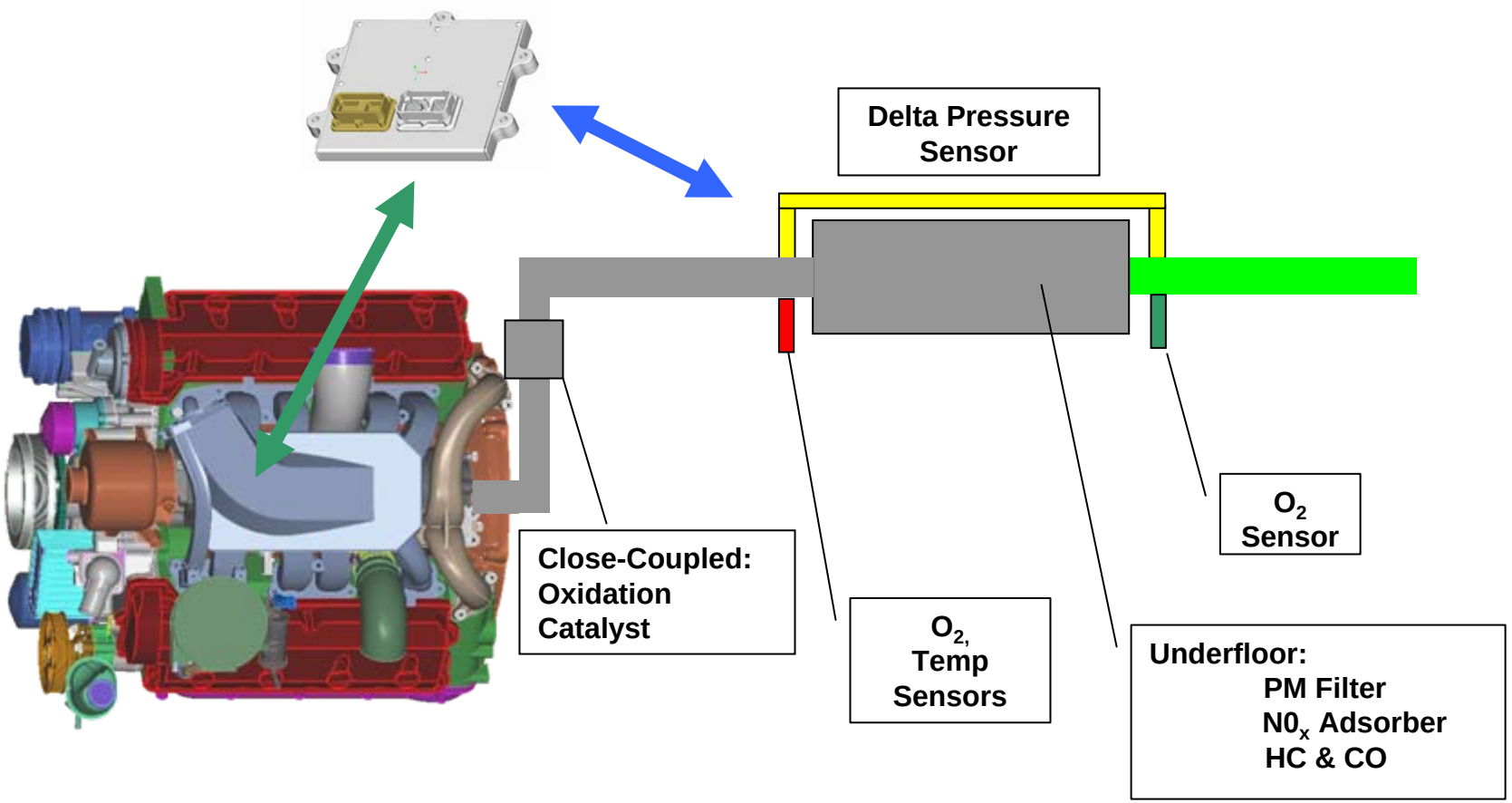
Description	Customer Target		Actual (Status) Family of Engines	
	V6	V8	V6	V8
Emissions	EPA Tier 2 & CA LEV II		NOx=0.07, PM=0.01 g/mi 5400 ft altitude 150,000 mi aged system	Simulated FTP Cycle Engine-Out Development
Noise, dBa	69 Hood Open, Equal to Gas		72.7, Bare Engine in Test Cell	65.0, Interior, Cruise @ 65 mph, 1500 Pickup
Fuel Economy, MPG	50 % Better than '97 Gas		22.1 Combined, Durango (+60%)	21.7 Combined, BR1500 (+60%)
Rated Speed	4000 rpm (5000 max.)		4000 rpm (5000 max.)	
Performance	Gasoline-Like (9-10 sec 0-60 mph)		9.6 sec, 0-60 mph, 5940 lb PTW	8.8 sec, 0-60 mph, 6200 lb PTW
Displacement, Liter	4.2	5.6	4.2	5.6
Power, kW(hp) @ rpm	190 (250) @ 4000	260 (350) @ 4000	201(270) @ 3800 VNT	224 (300) @ 4000, Interim Target Met
Torque Peak, Nm(ft-lb)	569(420) max.	760(560) max.	569 (420)	623 (460)
Weight, kg(lb)	295 (650)	340 (750)	301 (663)	357 (788)

Meets Goal

Partially Meets Goal; Plan in Place

Prime-Path-System

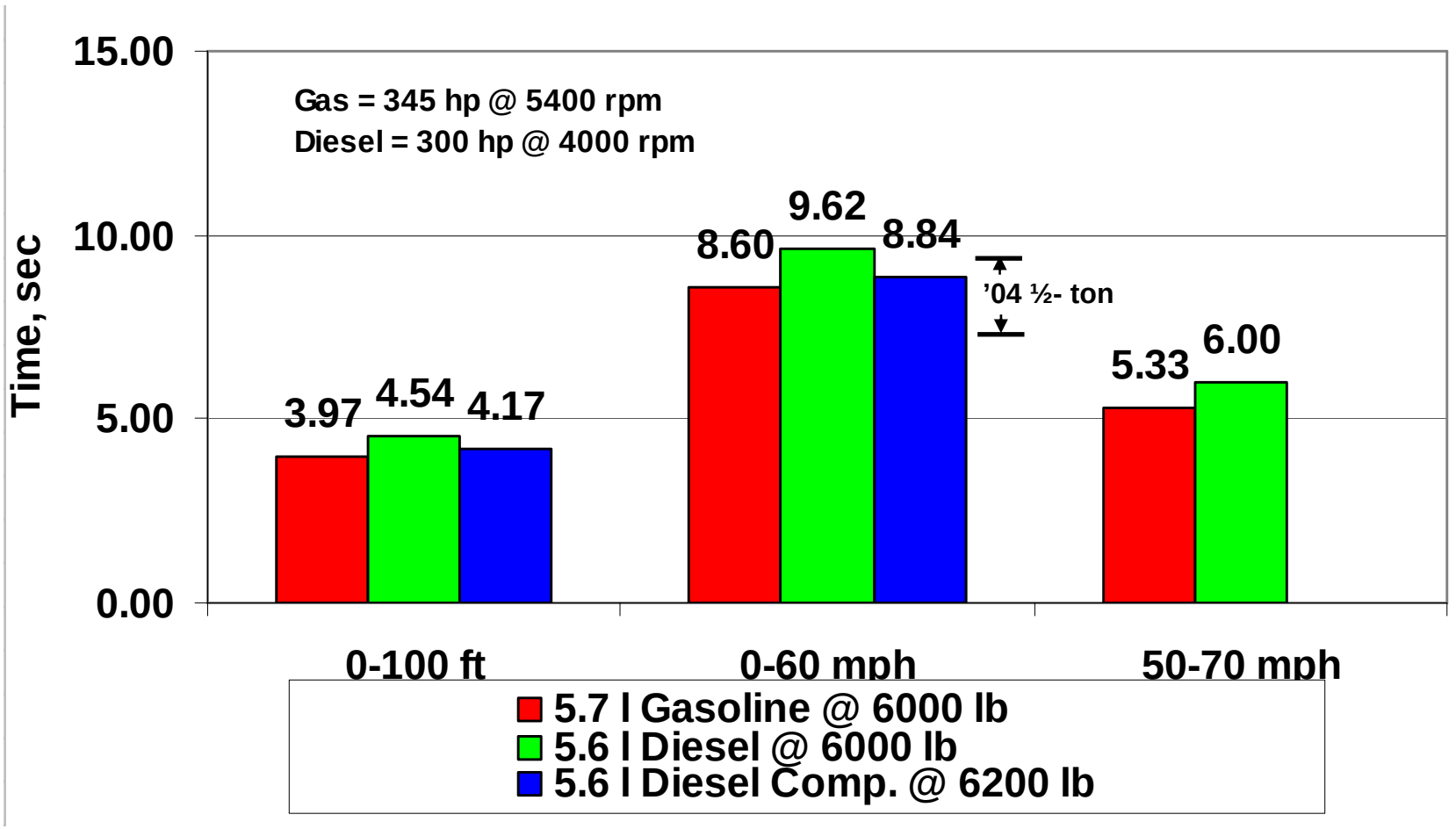
with 4-Way Catalyst System



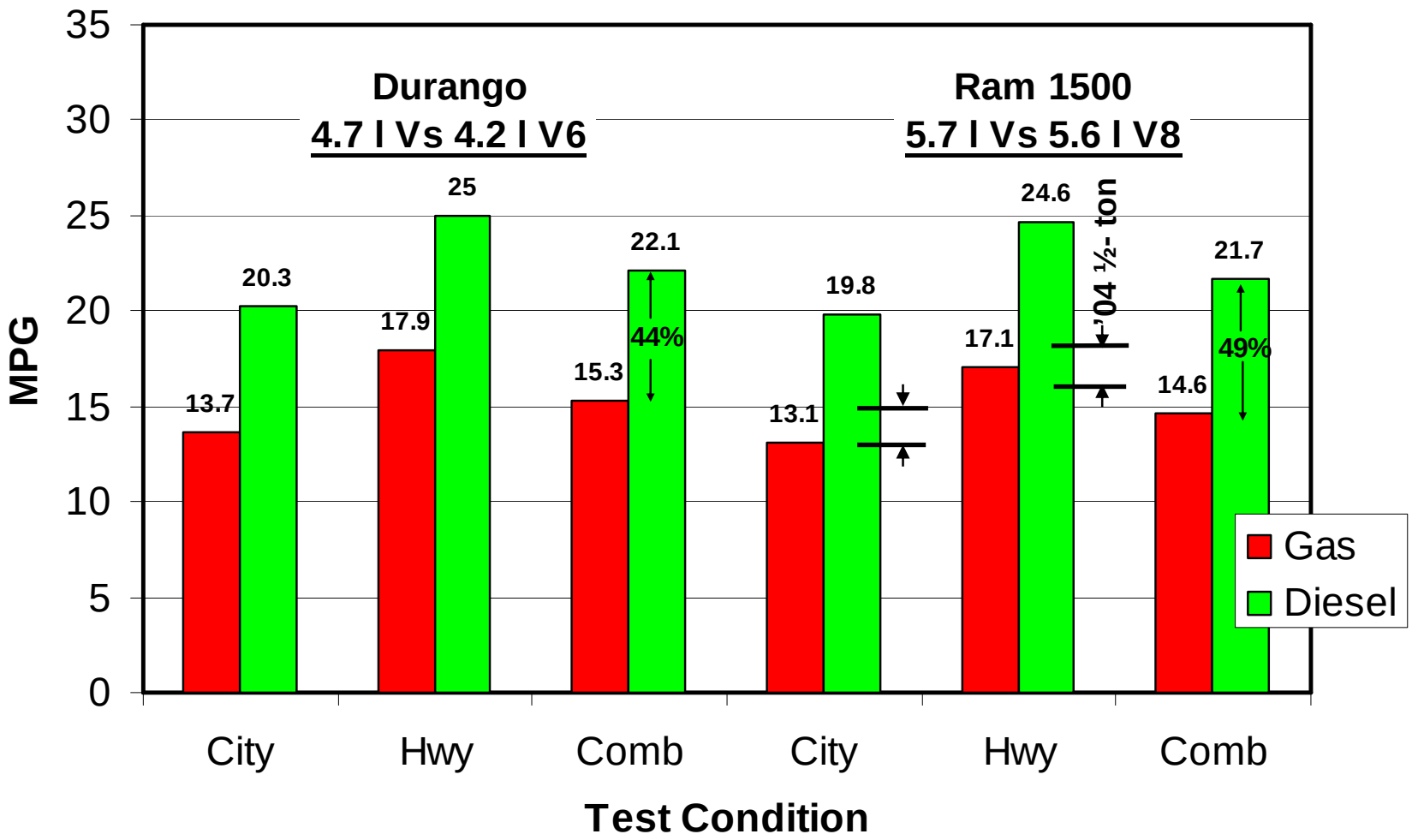
Chassis Test Results - Bag Results
V6 - 5000 lb - 12.7 hp@50 mph

Test Condition FTP-75	CO g/mi	CO_2 g/mi	NO_x g/mi	NMHC g/mi	Fuel Economy mpg	PM g/mi
FUL limits	4.2	-	0.07	0.09	-	0.01
degreened	0.399	480.27	0.033	0.089	21.12	0.006
1600 mi vehicle test	0.367	491.67	0.038	0.056	20.32	-
Aged ~150,000 mi Altitude 5400 ft	0.241	519.18	0.074	0.043	19.16	-

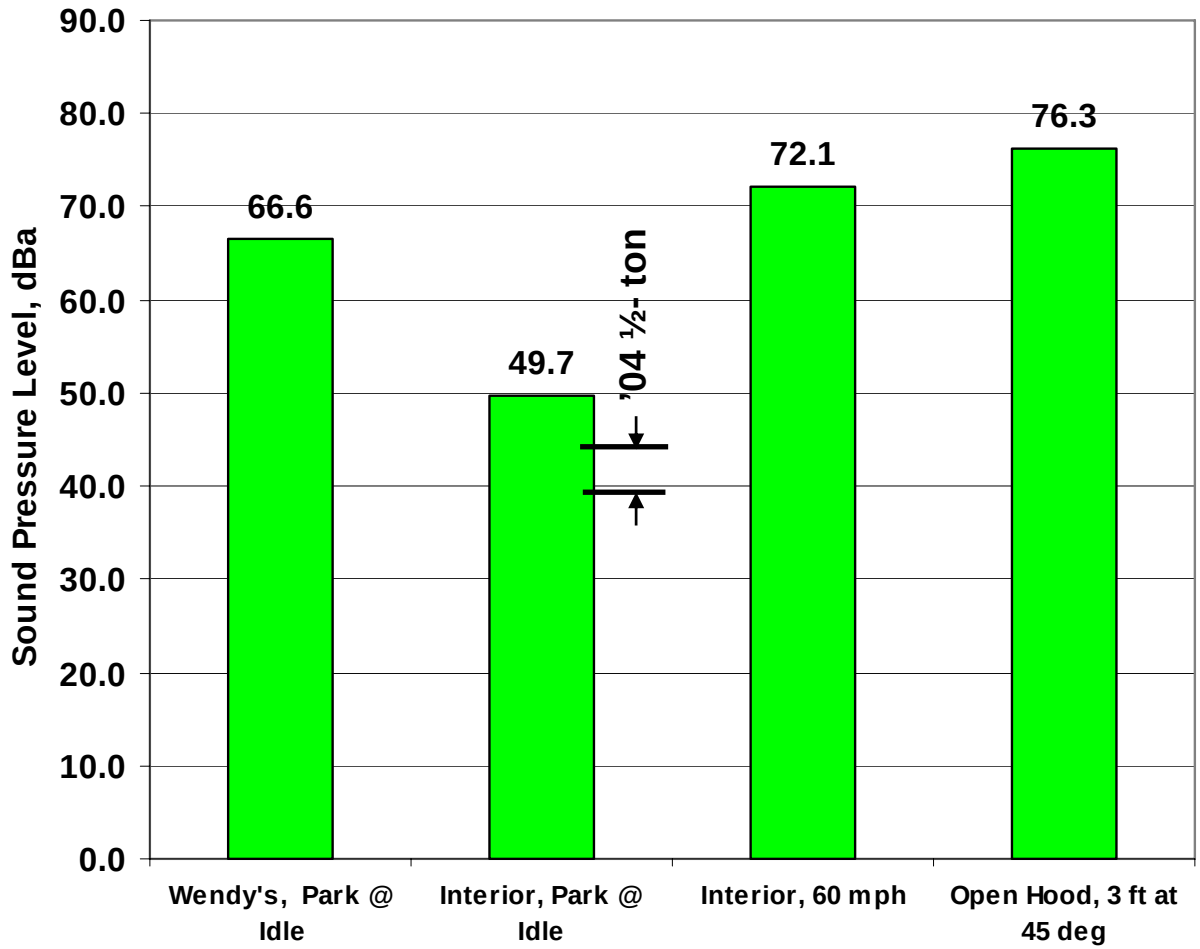
Acceleration Test Results



Fuel Economy Results



Noise Test Results V8 in Ram 1500

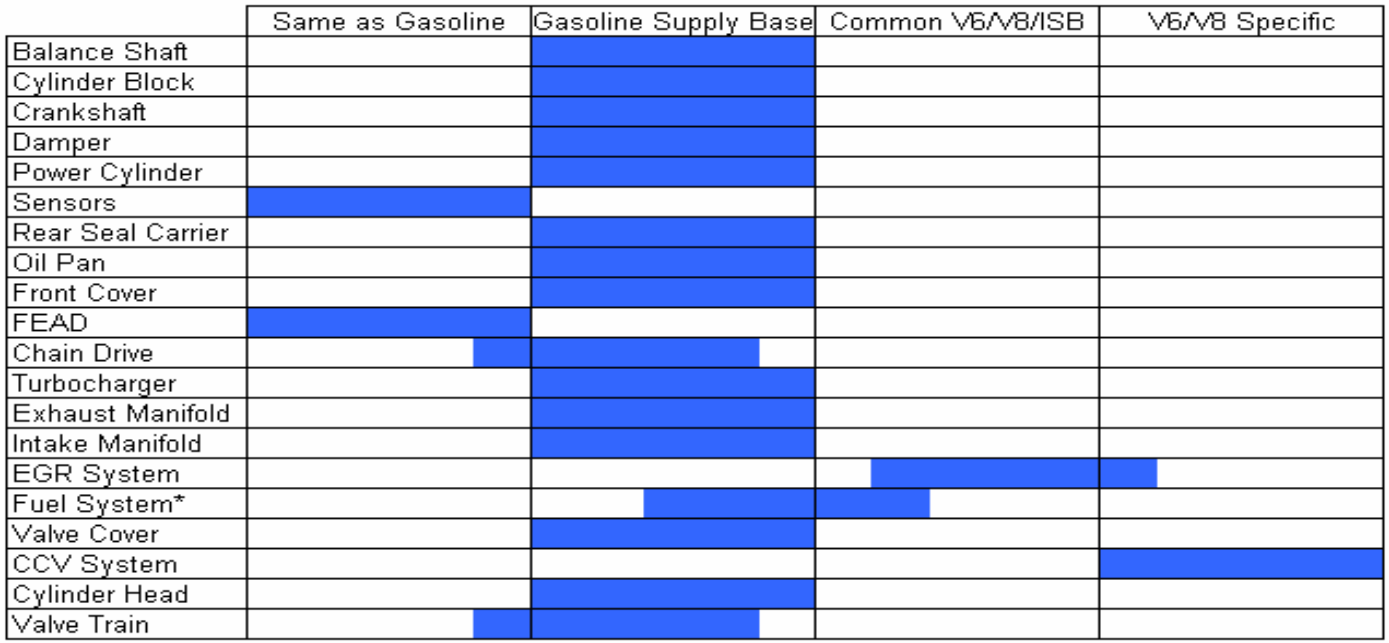


Barriers to Selling Light-Duty Diesels in US

1. **Cost for business case borderline**
   - **Simplified engine structure**
   - **Reduced engine-out emissions**
2. **Technology new-unique-difficult**
   - **Reduced aftertreatment**
   - **Simpler Particulate filter**
3. **Market readiness**
   - **Focus-customer demo's & Awareness**
   - **Fuel prices & Operating cost**
   - **World economies**

Cost Effectiveness

- **Cost Focused Areas**



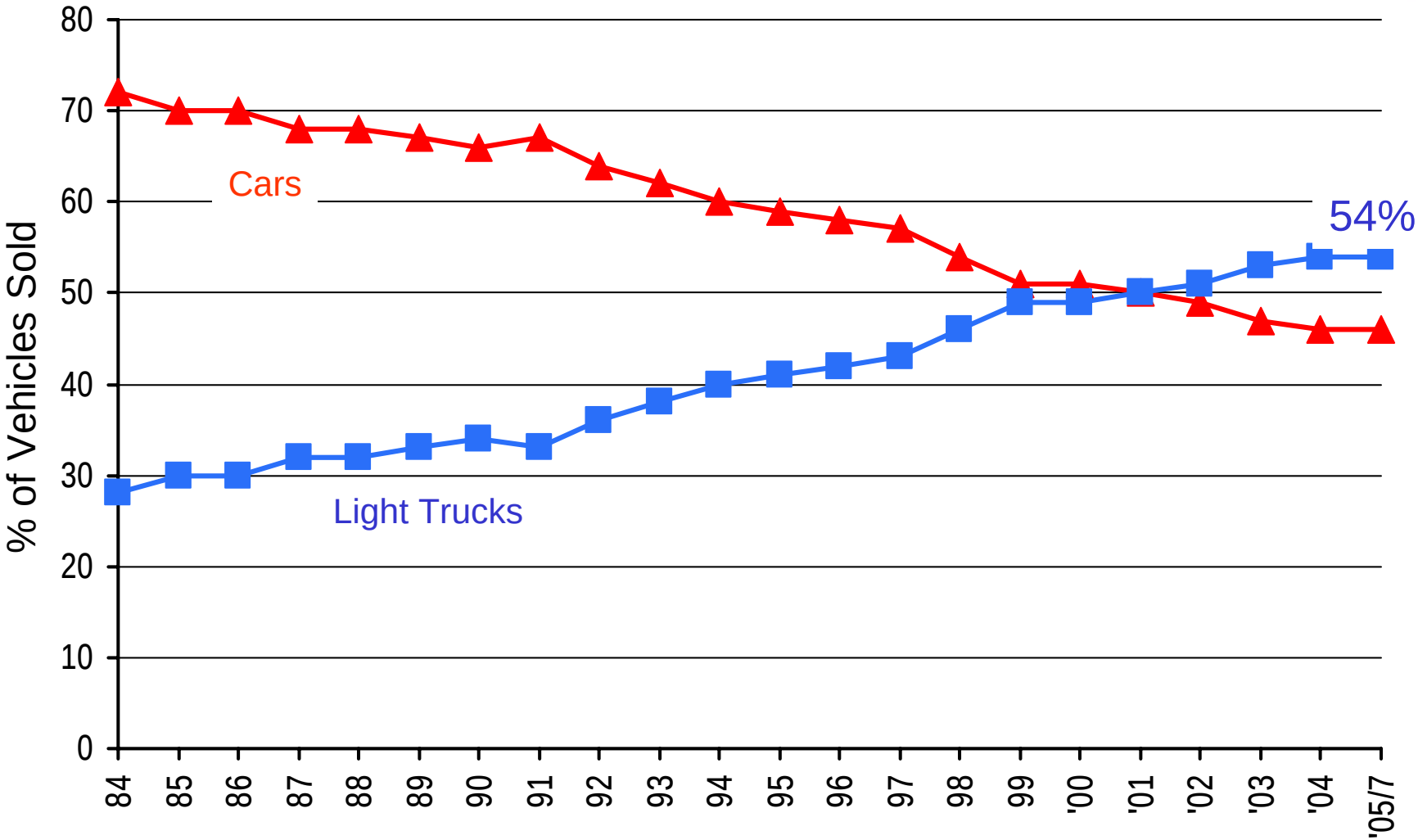
	Same as Gasoline	Gasoline Supply Base	Common V6/V8/ISB	V6/V8 Specific
Balance Shaft		■		
Cylinder Block		■		
Crankshaft		■		
Damper		■		
Power Cylinder		■		
Sensors	■			
Rear Seal Carrier		■		
Oil Pan		■		
Front Cover		■		
FEAD	■			
Chain Drive	■	■		
Turbocharger		■		
Exhaust Manifold		■		
Intake Manifold		■		
EGR System			■	■
Fuel System*		■	■	
Valve Cover		■		
CCV System				■
Cylinder Head		■		
Valve Train	■	■		

- **Results compare favorably with V8-gasoline-like components**
  - **Exceptions Fuel System, Turbocharger, EGR System**

Technology

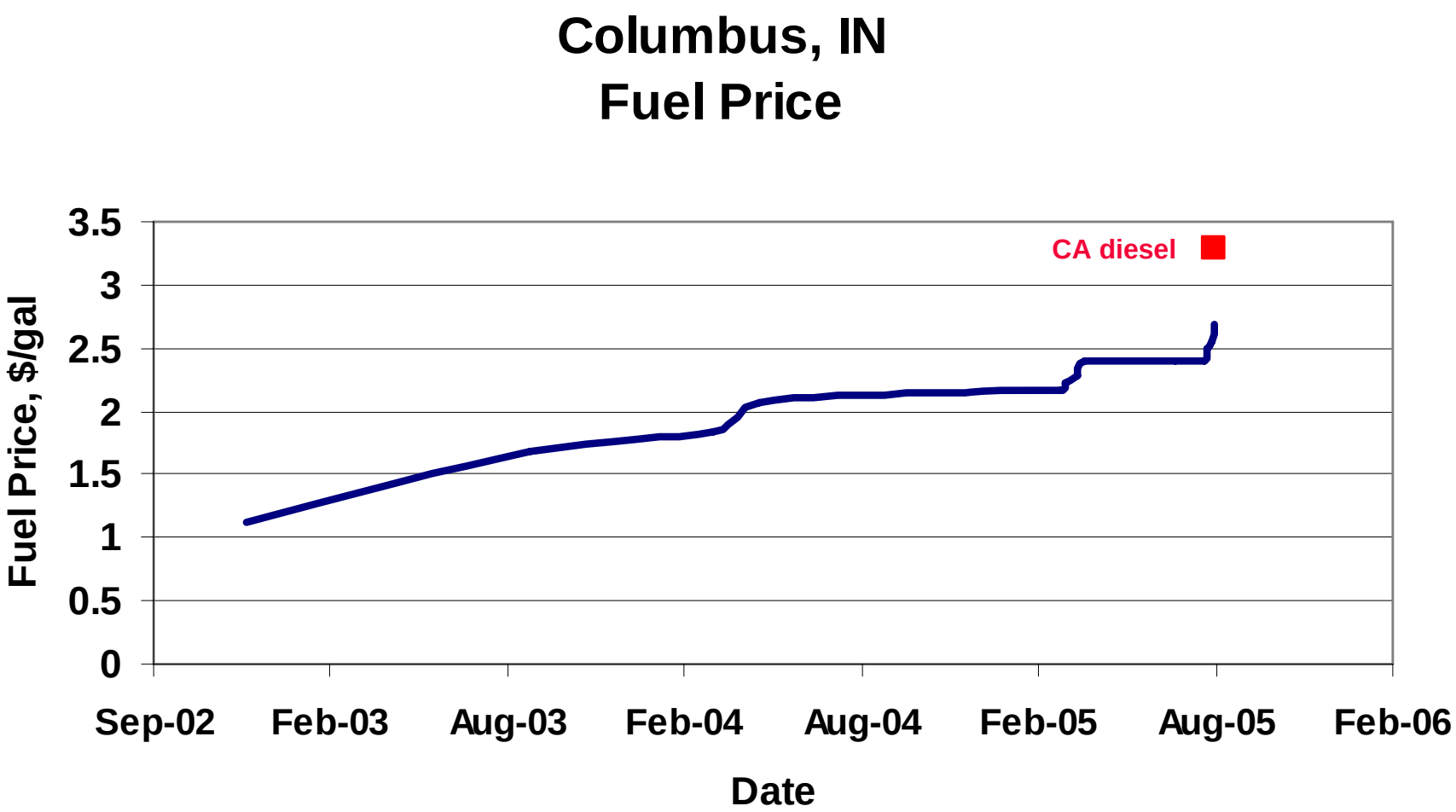
- **Technology New-Unique-Difficult**
  - **Low Emissions Combustion Development**
    - **Approach Standards with Low Engine-Out**
    - **Precise Control of Combustion Event(s)**
    - **Precise Control of Airhandling System**
  - **Aftertreatment - NO_x Adsorber**
    - **3-4 yr since emissions std announcement**
    - **No commercial experience in US**
    - **Durability Development**
  - **Aftertreatment - Particulate Filter**
    - **Low-NO_x feedgas**
    - **Low-NO_x combustion**

Automotive Market



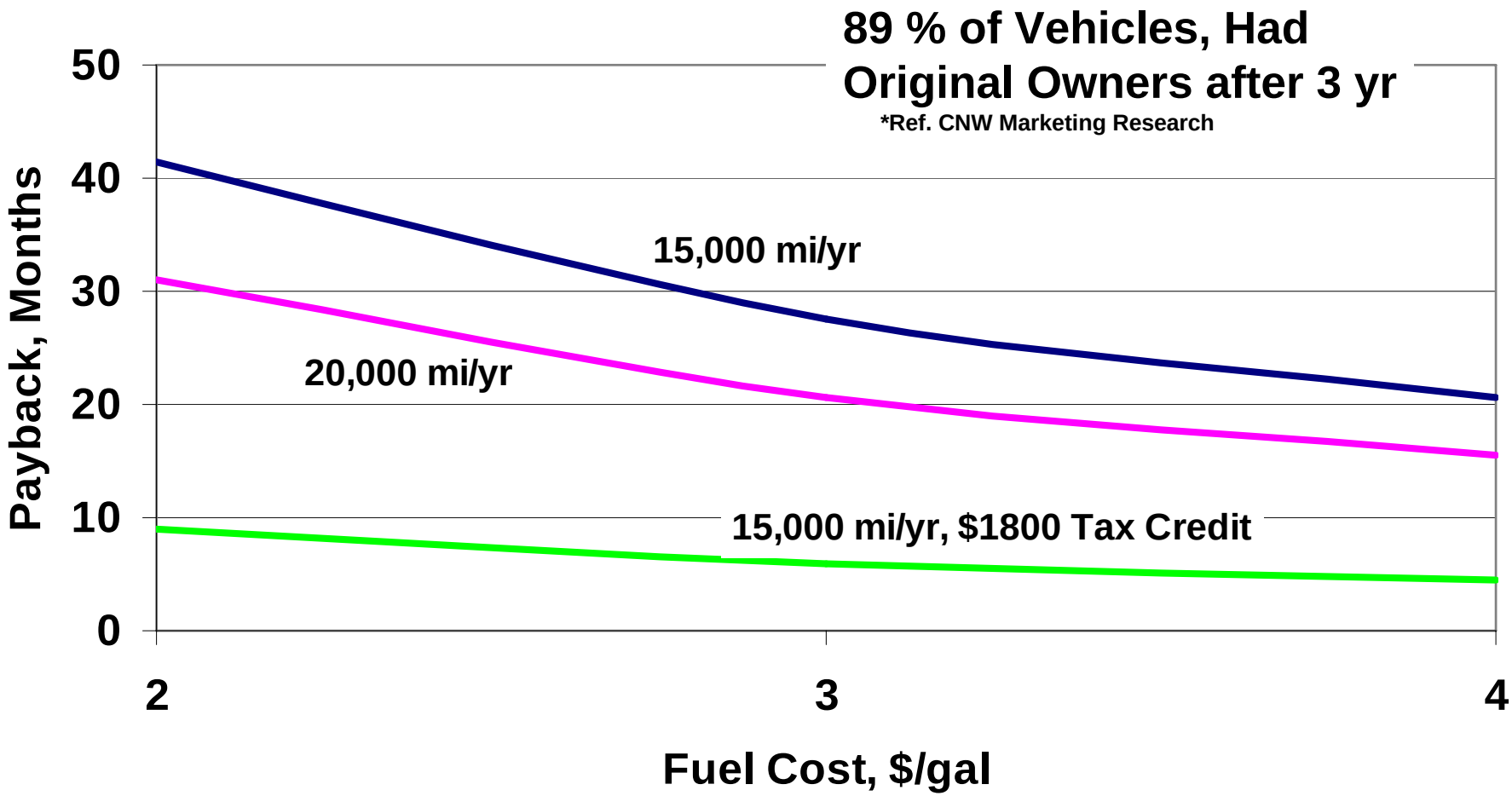
Source - Automotive News

Fuel Market


Columbus, IN
Fuel Price
Fuel Price, $/gal
3.5
3
2.5
2
1.5
1
0.5
0
CA diesel
Sep-02
Feb-03
Aug-03
Feb-04
Aug-04
Feb-05
Aug-05
Feb-06
Date

First Purchase Payback Times

w/o Trade-In Premium, Simplified



Conclusions

- **Light Truck Diesel Family has met all DOE contract and most customer targets**
- **Tier 2 Bin 5/ULEV II emissions, met in a complete vehicle system**
- **Customer features:**
  - **Performance, comparable to Top Rated gasoline**
  - **Fuel economy, advantage 44-49% (improves CAFE)**
  - **Noise, approaching gasoline**
  - **Smoke and odor, eliminated**
- **Cost approached on a fundamental basis**
  - **Lower Engine-Out Emissions**
  - **High-Volume Gasoline Supply Base**

Conclusions

- **Critical time for Light Truck Clean Diesel**
  - **Market acceptance should be greatly increased**
  - **Payback time reduced by 5:1**
  - **Recognize that NO_x Adsorber is Feasible**
    - **Benefit from further development**
  - **Improved In-Cylinder Combustion**
    - **Ease the Adsorber burden**
    - **Lower system cost**