GM’s Diesel Portfolio

Market Perspective

- GM is committed to developing global diesel solutions
- Diesel powertrains satisfy unique vehicle requirements
  - Utility & large vehicles
  - Diminishing returns when applied to smaller U.S. vehicles
- Significant technological challenges exist for long term light duty North American presence
  - \( \text{NO}_x \) aftertreatment & fuel limitations
- GM is developing technologies to address these challenges
Advanced Propulsion Technology Strategy

- Improved Vehicle Fuel Economy and Emissions
- Reduced Petroleum Consumption

- Near-Term: Incremental Internal Combustion Engine and Transmission Improvements
- Mid-Term: Hybrid Electric Vehicles
- Long-Term: Hydrogen Fuel Cell

Fuel Infrastructure:
- Petroleum (Conventional and Alternative Sources)
- Biofuels (Ethanol, Biodiesel, etc.)
- Hydrogen
Diesels experienced explosive growth in the early 1980’s driven by fuel economics and availability, and new diesel entries.

Passenger car and Class 1 truck diesel sales fall off quickly as diesel fuel price advantage disappears, overall fuel costs drop, and fuel rationing ceases.

Class 2 truck diesel sales continue even as diesel and gas prices equalize.
Tier 2 Bin 5 and Production Dispersion

Lower Emission Standards Require Less Variation

![Graph showing emissions levels for Tier 2 Bin 5 and Production Dispersion. The graph plots NOx and Particulate Matter emissions, with Base Engine & Aftertreatment and Production Dispersion indicated by different colors and symbols. The data suggests that lower emission standards lead to less variation in emissions.](image-url)
Diesel Particulate Filter (DPF) Function

Trapped Diesel Particulate Matter

Porous Cell Wall

Alternate Cell Plugging Pattern
2007 Duramax 6.6L V8 LMM Engine

Base Engine Modifications for Emissions

Major changes include:

- Structural improvements
- High pressure fuel system updates
- Intake throttle
- Higher capacity EGR cooler
- Revised cooler circuitry
- Extensive engine software and calibration changes
- Diesel Particulate Filter (DPF)
- Post injection to support DPF regeneration
- Updated internal turbocharger upgrades
2007 Exhaust Aftertreatment System

- Oxidizing Catalyst
- Diesel Particulate Filter (DPF)
- Differential Pressure Sensor
Engine-out Emissions Technologies
Closed Loop Diesel Combustion Control

ECU
EGR
Turbo
Cylinder Pressure Sensor
Fuel Injectors

6.6L V-8
NO\textsubscript{x} Aftertreatment Systems

Balancing the requirements of FTP with US-06

Typical Thermal Operating “Windows”

Light Duty Diesel FTP Catalyst Temps

Light Duty Diesel US-06 Catalyst Temps

SCR Effective Range

LNT Effective Range

NO\textsubscript{x} Conversion Efficiency (%)

Catalyst Operating Temperature (degrees C)
Other Challenges – Fuel Properties

North America versus European Cetane

**North American Cetane**
2005 AAM Winter & Summer Diesel Fuel Surveys

**European Cetane**
2005 SGS Summer Diesel Fuel Survey
Engine Weight

- 2004 Diesel turbocharged
- 2004 Gasoline naturally aspirated
- 2004+ Gasoline turbo

Engine weight (DIN70020A) per displacement (kg/L)

Maximum specific performance (kW/L)
**Internal Combustion Engines**

**Diesel versus Gasoline & U.S. Emissions Challenge**

- Potential diesel fuel economy penalty for emissions reduction
- May be offset with appropriate aftertreatment technologies

The gap narrows as gasoline fuel economy improves.
**CO₂ Emissions Reduction Technologies**

- **CO₂ emission**
  - 100 %
  - 80 %

**Assumptions:**
- C -segment vehicle; Constant Performance Index (PI)
- (PI = Time 0-100 km/h + Time 60-100 km/h + Time 80-120 km/h + Time for 1 km at Vmax)
Why Use Diesels?

- Improve vehicle performance with lower displacement engine
  - “Fun-to-drive” high torque powertrain solution
- Achieve benefit of tax incentives in European markets
- Satisfy fuel economy improvement objectives
  - Positive influence on CO₂ & CAFE
  - Real world fuel economy improvement – a robust solution
  - Fuel economy advantage is greater under high load
- Heavy duty towing & hauling
  - Improved utility & towing capabilities
  - Increased durability
Where to Use Diesels?

- European light duty vehicles (near 50%)
- Asia-Pacific
  - Korea, India and potentially China are growing markets
  - Strong diesel bias in Korean SUV market (over 90% diesel)
- U.S. market, with its larger vehicles, could benefit from new diesel technologies
- Growing large truck diesel market share demonstrates U.S. consumer acceptance of diesel engines
- North American light vehicles
  - First introduced diesel engines in larger vehicles
  - Consumer recovery of additional financial investment
  - Utility applications (towing & hauling)
Technology Options

Advanced Propulsion Solutions

- Portfolio approach is required for advanced powertrain strategies
  - Market, vehicle, & customer requirements influence powertrain usage
- Diesel engines are critical to GM’s global product portfolio
- Emission regulations, fuel price, fuel taxation, taxation based on engine displacement, and fuel consumption largely dictate markets where diesels are popular today
Diesel technological advancements over the past 15 years have radically changed public perception of diesels. Diesel must overcome cost disadvantages while retaining fuel economy advantages and meeting new emissions standards.
WESTERN EUROPE
Ricardo Forecast Diesel Passenger Car Sales & Market Penetration to 2006

Introduction of true high performance diesel engines

Japanese OEM's increase diesel product range

Introduction of Common Rail and VGT

North American

North American

World/Euro Recessions

Class 2 Truck Market Share

Introduction of DI technology

Crude Oil Price (1995$/barrel)