Diesel Engine Strategy & North American Market

Challenges, Technology and Growth

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GM Powertrain

Overview

- GM's Energy & Propulsion Strategy
- The Diesel Engine's Role in Propulsion Strategy
  - Regional Contrast between Europe & United States
- Diesel Challenges & Technologies

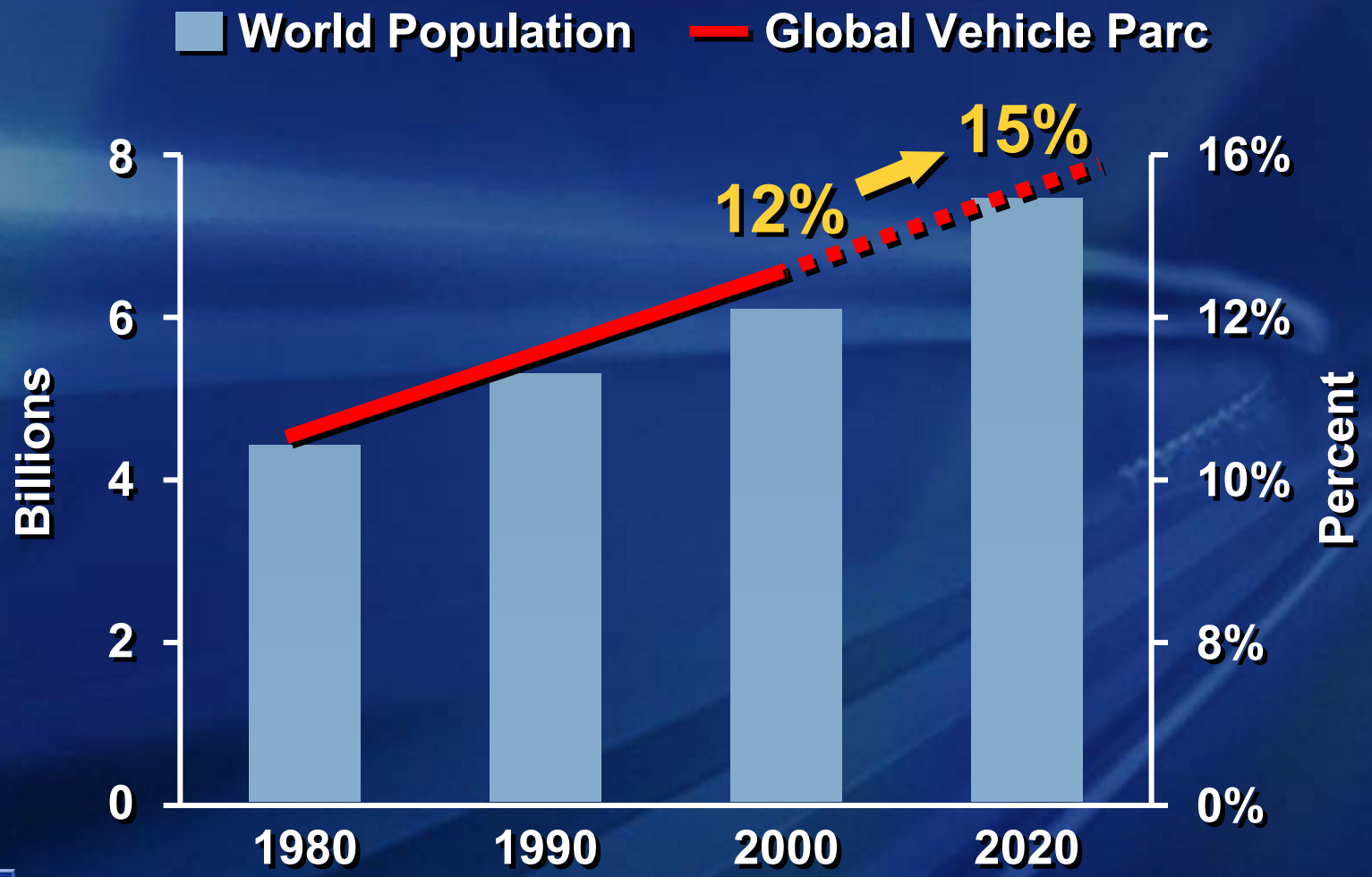
Answer Question:

Why not put a diesel engine into every vehicle?

GM's Long Term Vision

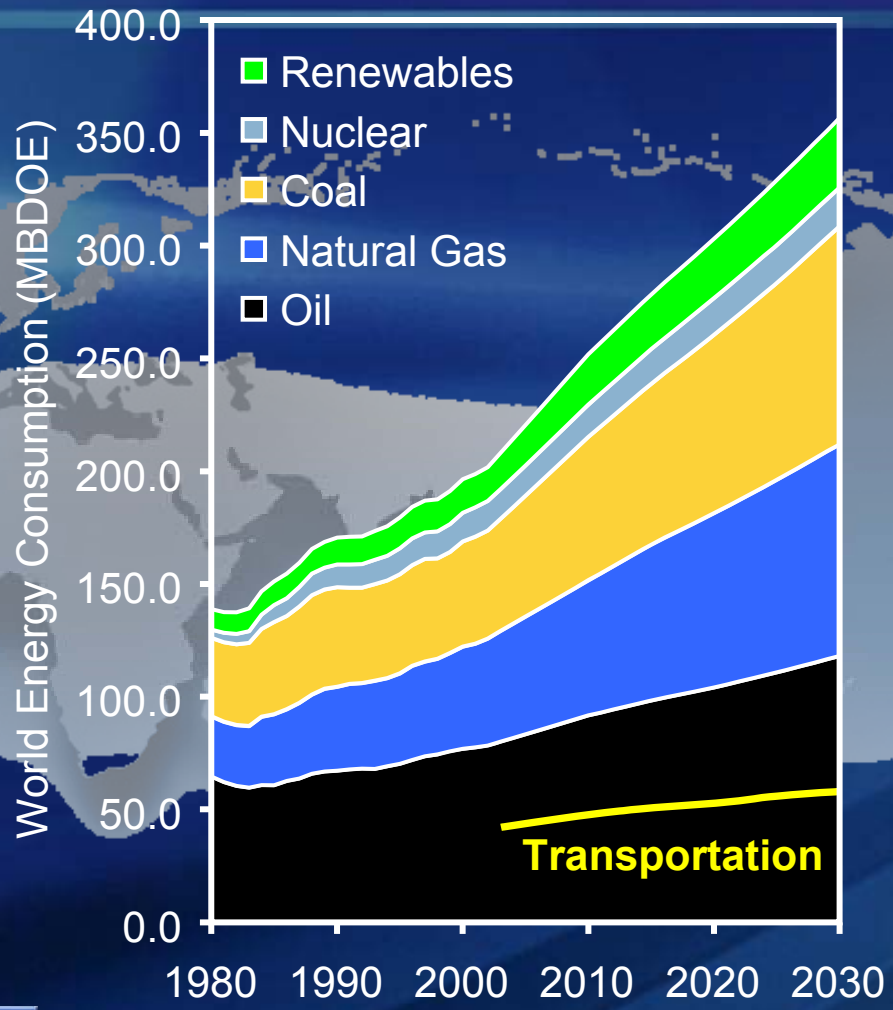
Remove the automobile from the energy & environmental equation

Transportation is a growth industry!



Sources: U.S. Census Bureau International Population Database, GM Global Market & Industry Analysis

Global Energy Consumption to 2030



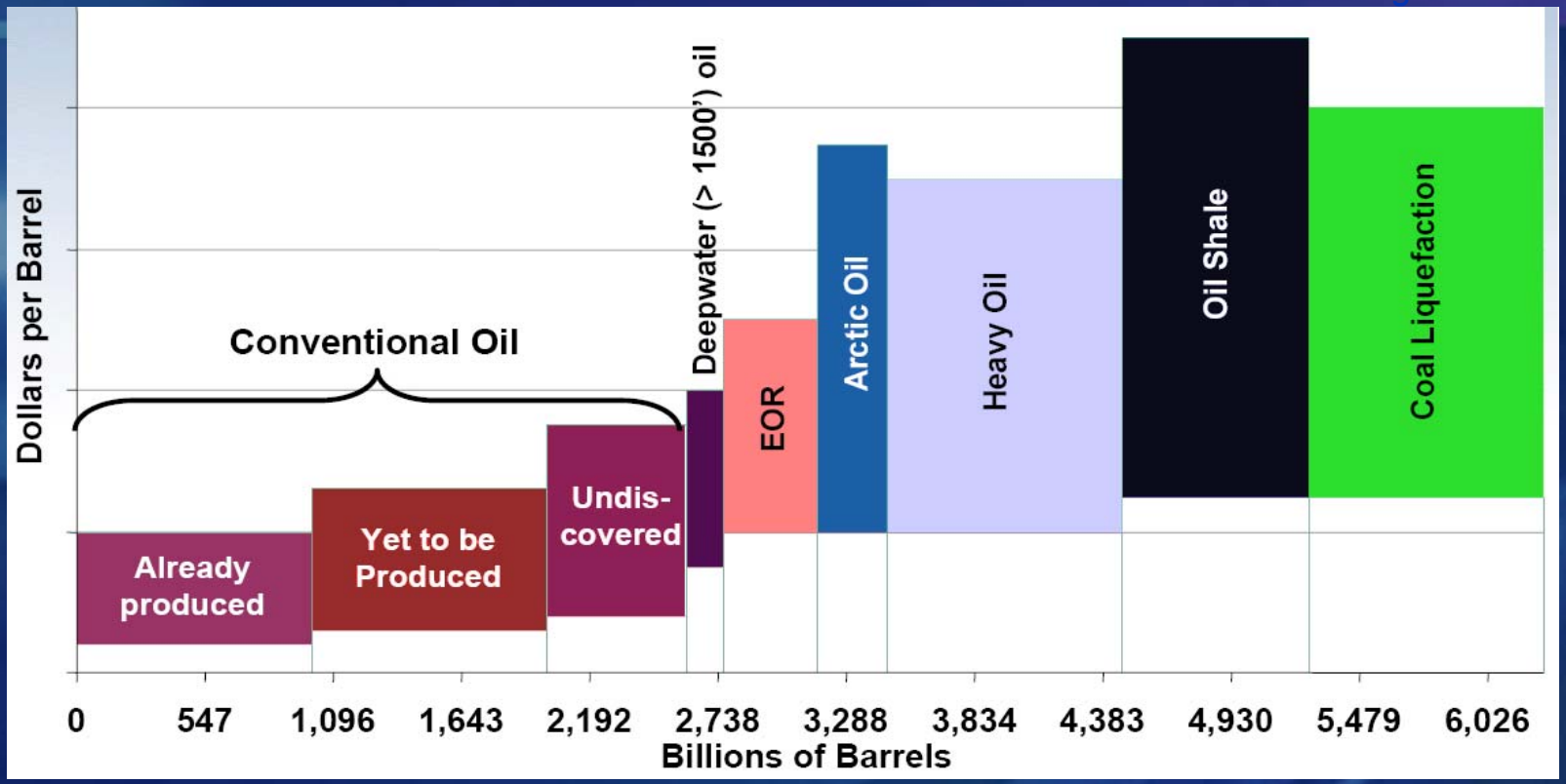
Oil

- 2006: 85MBD
  1,000 barrels/second !
- 2030: 120 MBD projected
- 50% used for transportation
- Transportation is 98% dependent on petroleum

Source: DOE-EIA 2006

Fossil Fuel Resource Alternatives

Source: Global Insight 2006



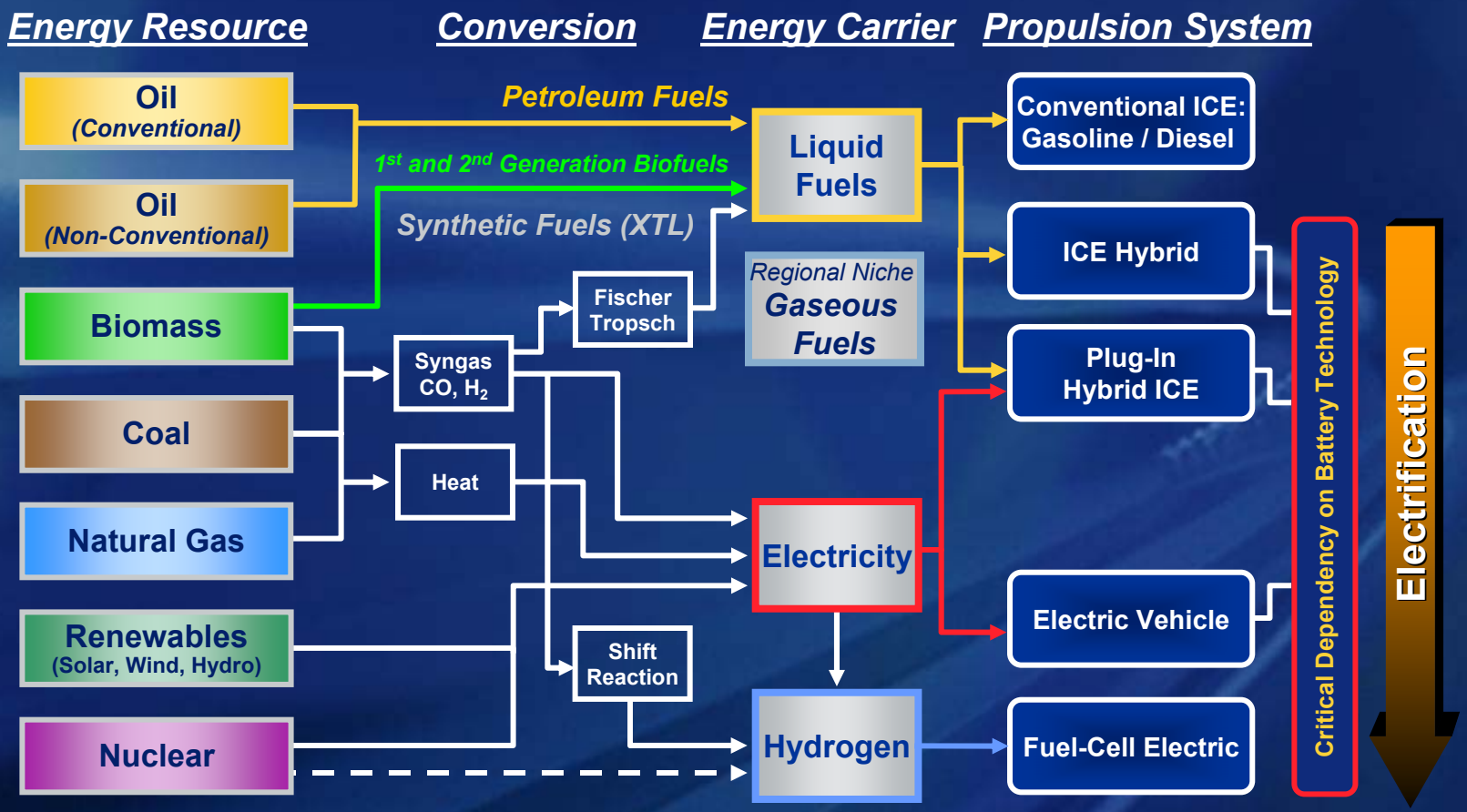
- Very large reserves from unconventional oil & coal
- Issues: Cost, CO_2 emissions & large energy required to extract

Source: Global Insight 2006

BIOFUELS

Alternate Resources – A Blending Strategy

Liquid Fuels / Electricity / Hydrogen as the In-Vehicle Energy Carriers



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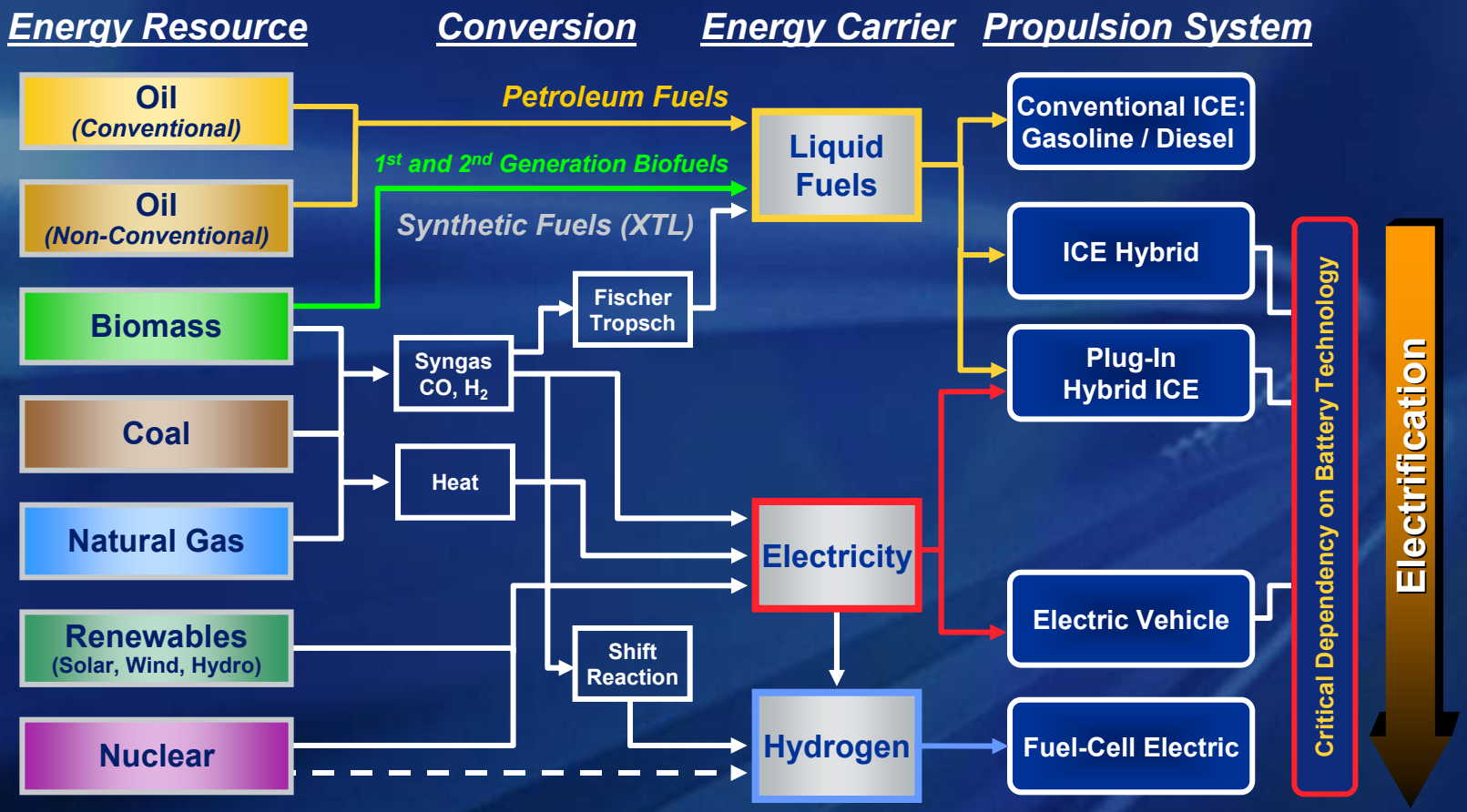
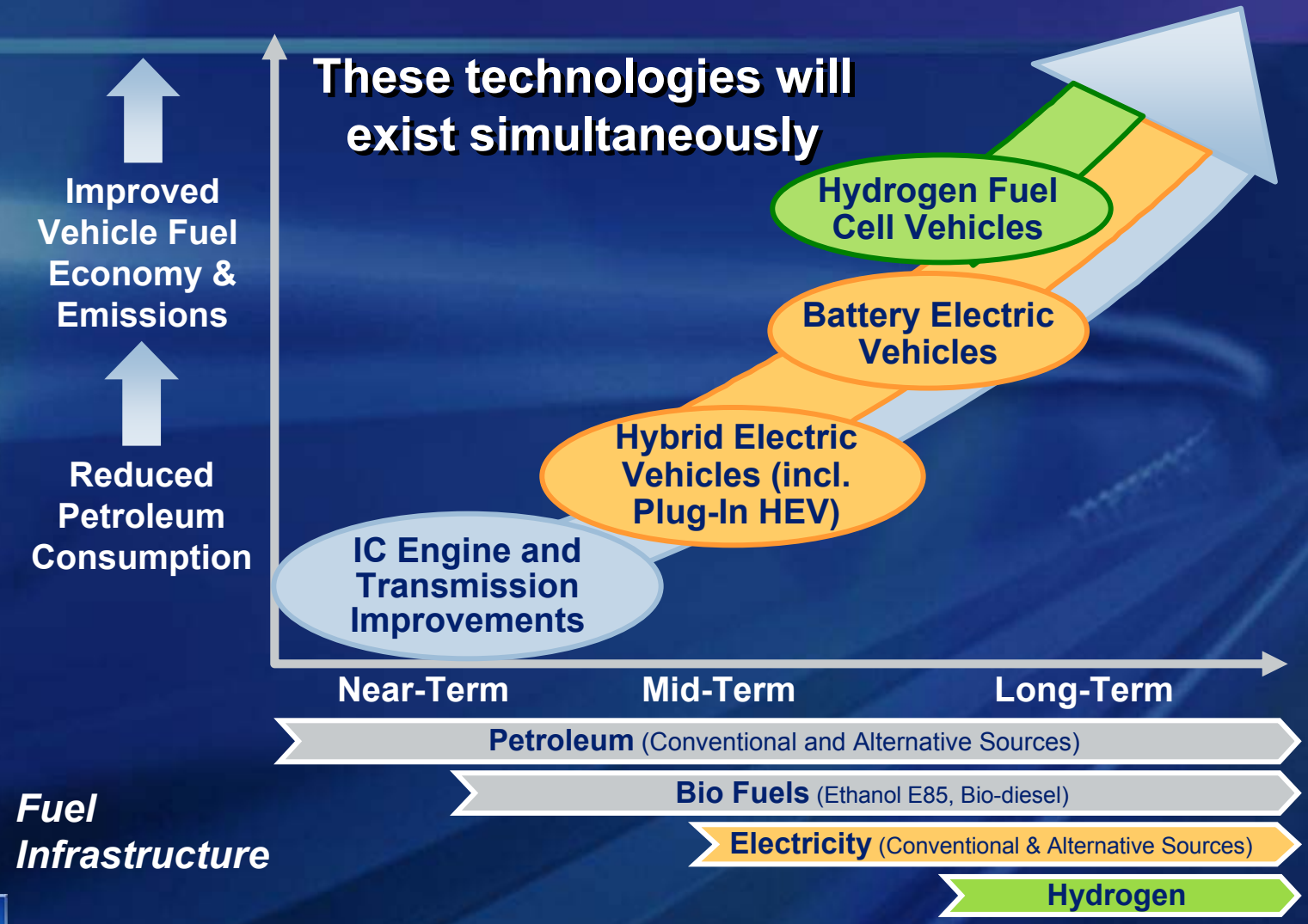
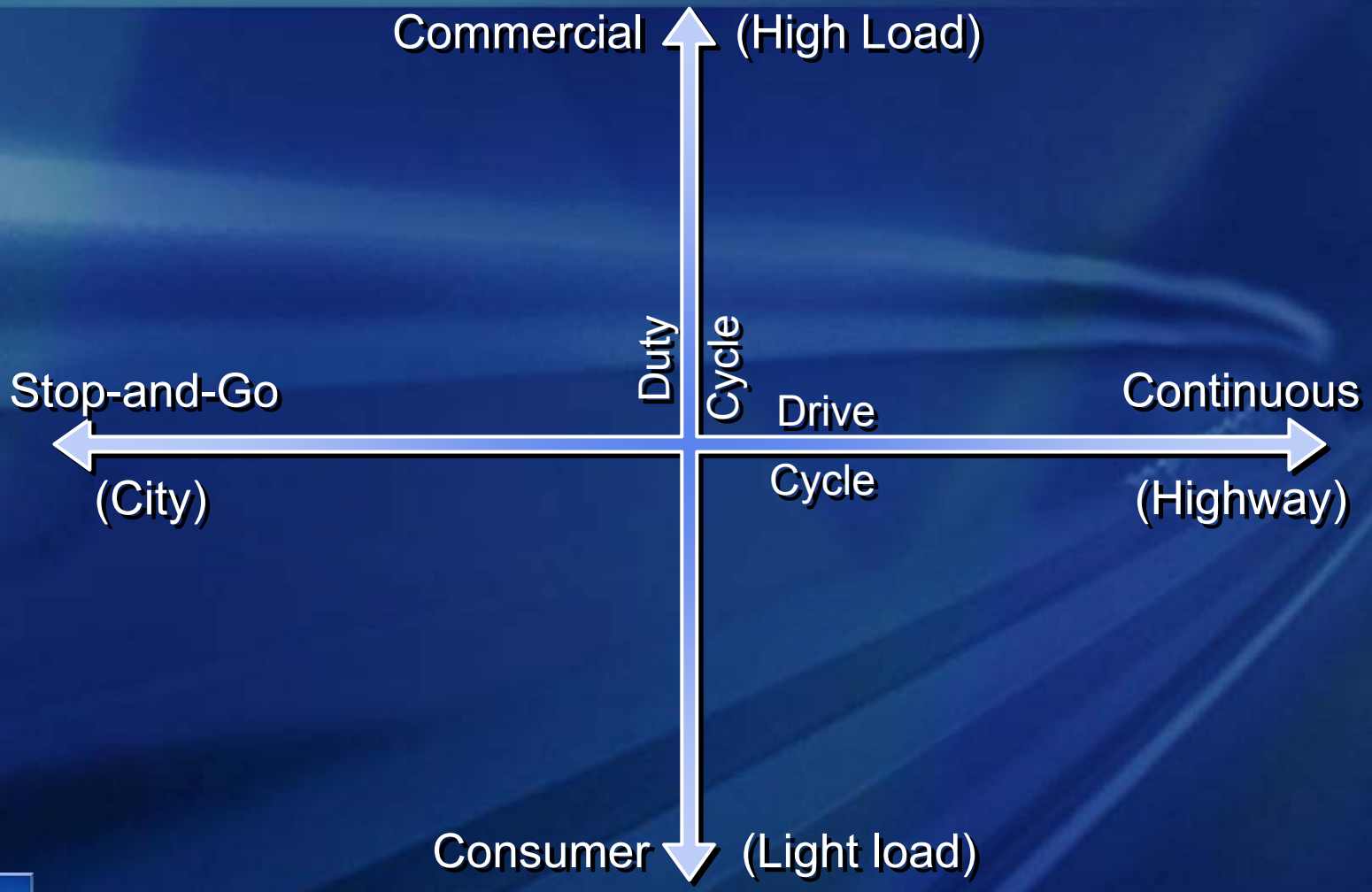


GM Advanced Propulsion Technology Strategy



Propulsion Application Map



Propulsion Application Map

Commercial (High Load)

Diesel Engine Applications

Consumer (Light load)

Stop-and-Go (City)

Drive Cycle

Continuous (Highway)

Diesel Hybrid Bus

Heavy Duty Pickup Truck

Over the Road Truck

City Car (Gas Hybrid)

Commuter Car

Non-towing Highway Gas Car & SUV


GM HYBRID TECHNOLOGY
Plug-in
Hybrid


VOLT
E FLEX
GM

GM Advanced Propulsion Technology Strategy

Improved Vehicle Fuel Economy & Emissions

Reduced Petroleum Consumption

Hydrogen Fuel Cell Vehicles

Battery Electric Vehicles

Hyb[illegible] Electric Vehicles (incl. Plug-In HEV)

IC Engine and Transmission Improvements

Near-Term | Mid-Term | Long-Term

Petroleum (Conventional and Alternative Sources)

Bio Fuels (Ethanol E85, Bio-diesel)

Electricity (Conventional & Alternative Sources)

Hydrogen

Fuel Infrastructure

Conventional Propulsion Systems

Gasoline

Improve fuel efficiency:

- Port Deactivation
- Variable Valve Timing (VVT)
- Direct Injection
- Turbocharging
- Lean Combustion: HCCI / Stratified

Diesel

Improve Emissions:

- Low-Temperature Combustion
- Advanced Air Handling
- Model-Based & Closed-Loop Control
- Efficient NO_X aftertreatment

GM's Diesel Portfolio

Market Perspective

- GM is committed to developing global diesel solutions
- Capacity for over 1.3 million diesels per year
- Support world markets with products ranging from 1.3L 4-cylinder diesel engine in Opel Astra to 6.6L V8 Duramax diesel in the U.S. Silverado/Sierra
- 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
  - NO_X aftertreatment & fuel limitations
- GM is development technologies to address challenges

GMPT Global Portfolio Diesel Engines

1.3L I-4 CDTi
90 hp / 200 Nm (148 lb-ft)

1.7L I-4 CDTi
125 hp / 280 Nm (207 lb ft)

1.9L I-4 CDTi
150 hp / 320 Nm (236 lb ft)

2.0L I-4
150 hp / 310 Nm (229 lb ft)

NEW IN 2009 – Europe

3.0L V-6 CDTi
180 hp / 420 Nm (310 lb ft)

NEW IN 2009

Duramax 6.6L V-8
365 hp / 895 Nm (660 lb ft)

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NEW IN 2009 – Europe

2.9L V-6
250 hp / 550 Nm (406 lb ft)

3.0L V-6 CDTi
180 hp / 420 Nm (310 lb ft)

NEW IN 2009

Duramax 4.5L V-8
310 hp / 704 Nm (520 lb ft)

Duramax 6.6L V-8
365 hp / 895 Nm (660 lb ft)

The All-New 2008 CTS

Cadillac

GM

Where to Use Diesels?

- European light duty vehicles (near 50%)
- Heavy duty Class 7 & 8 trucks for cargo hauling
- Heavy duty diesel hybrid buses
- Asia-Pacific
  - Korea, India and potentially China are growing markets
  - Strong diesel bias in Korean SUV market (over 90% diesel)
- North America
  - First introduced diesel engines in larger vehicles
  - Consumer recovery of additional financial investment
  - Utility applications
  - Towing & hauling

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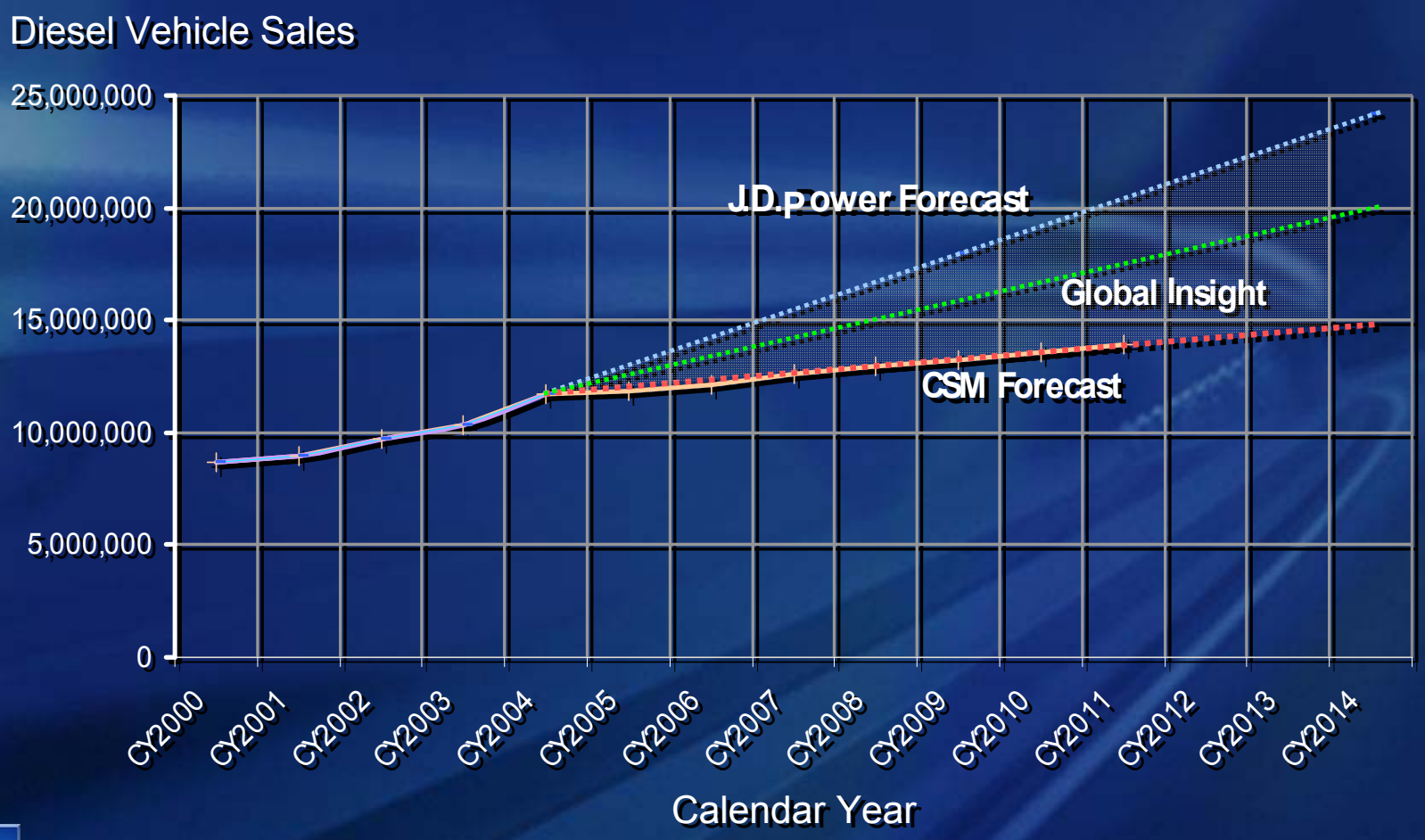
Global Diesel Sales

Growth Projections



Why Use Diesels?

- Heavy duty towing & hauling
  - Improved utility & towing capabilities
  - Increased durability
- Satisfy fuel economy improvement objectives
  - Positive influence on CO_2 & CAFE
  - Real world fuel economy improvement – a robust solution
  - Fuel economy advantage is greater under high load
- Improve vehicle performance with less displacement
  - Fun to drive
- Tax incentives in European markets

Economic Model

Comparison between U.S. & Europe – Diesel Break-Even

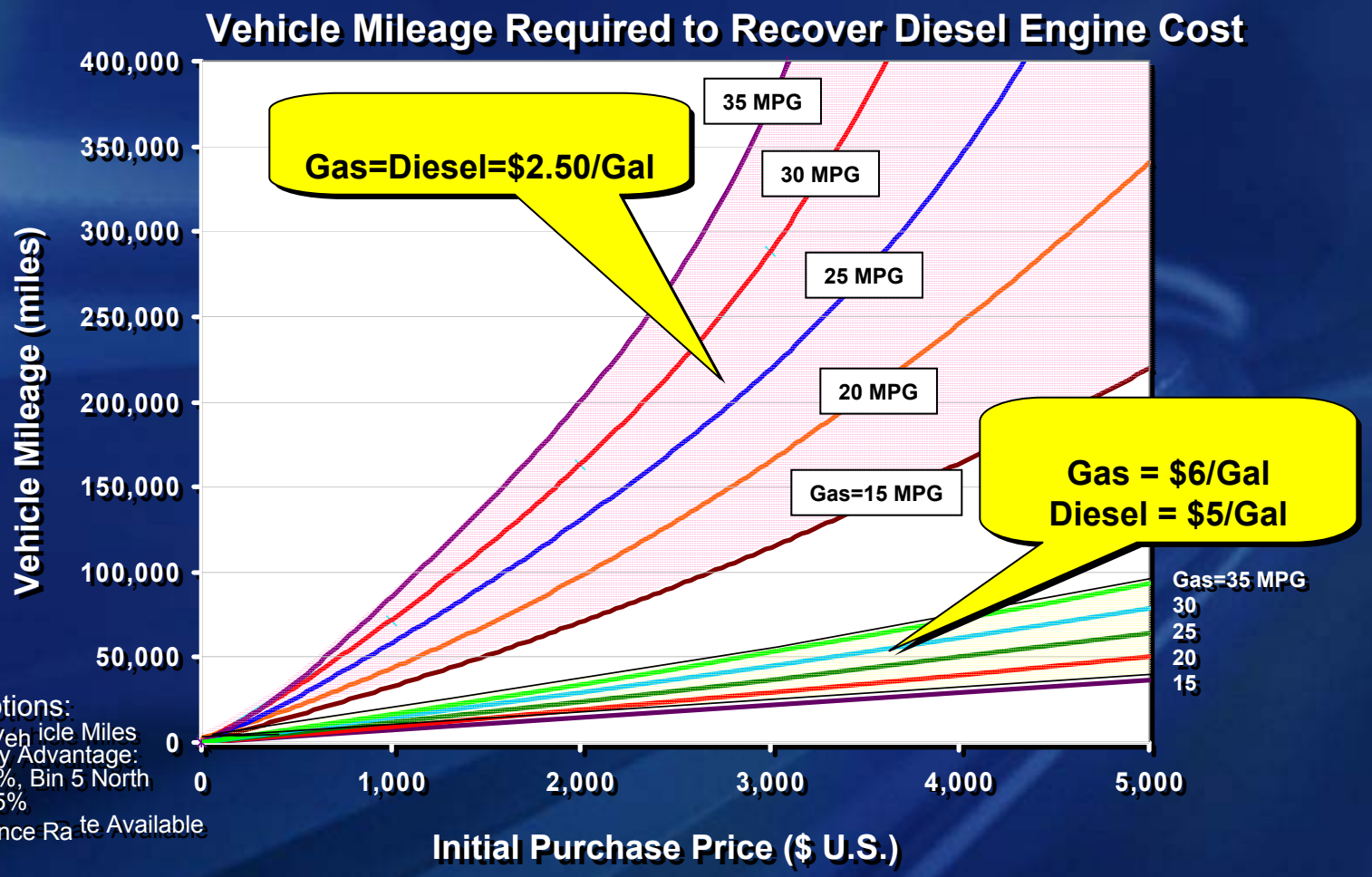


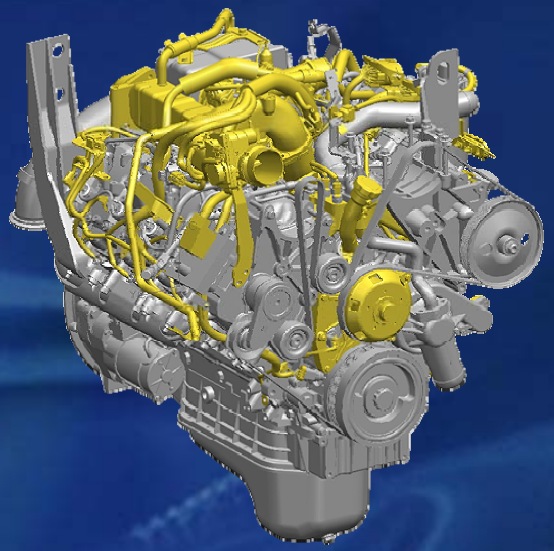
Chart Assumptions:

- 20,000 Annual Vehicle Miles
- Diesel Efficiency Advantage: Europe 30%, Bin 5 North America 25%
- 6% Annual Finance Rate Available

U.S. Heavy Duty Emissions Standards

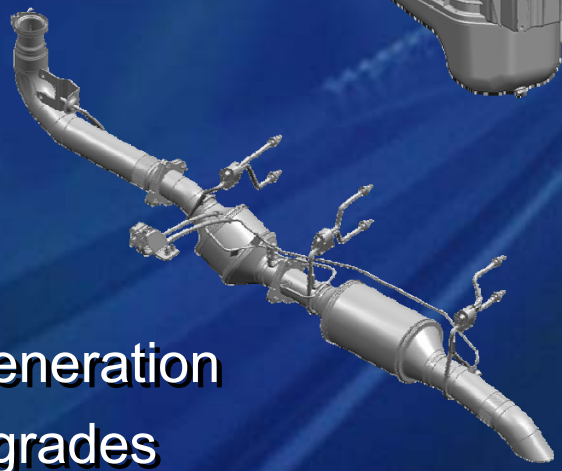
2007 Duramax 6.6L V8 LMM Engine

Base Engine Modifications for Emissions



Major emissions related changes include:

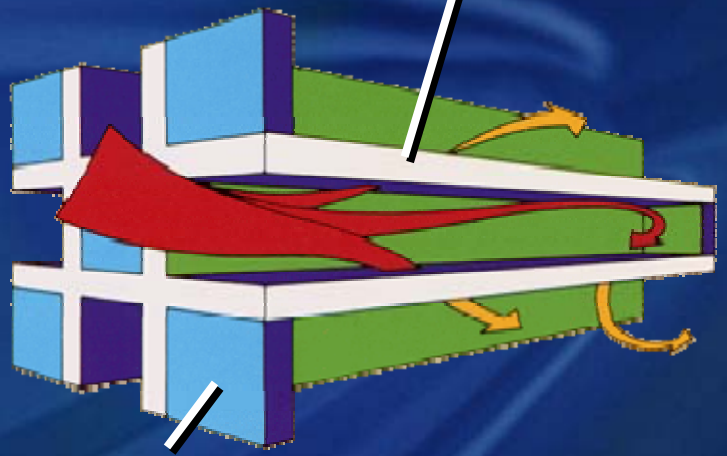
- Structural improvements
- High pressure fuel system updates
- Intake throttle
- Higher capacity EGR cooler
- Revised cooler circuitry
- Extensive engine software and calibration changes
- Diesel Particulate Filter (DPF)
- Post injection to support DPF regeneration
- Updated internal turbocharger upgrades



Diesel Particulate Filter (DPF) Function

Trapped Diesel Particulate Matter

Porous Cell Wall



Alternate Cell Plugging Pattern

Global Emissions (Europe vs. U.S. Applications)

Light Duty

1.7L I-4

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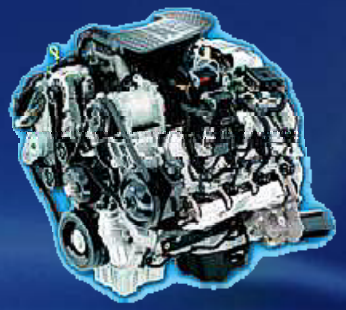


6.6L V-8

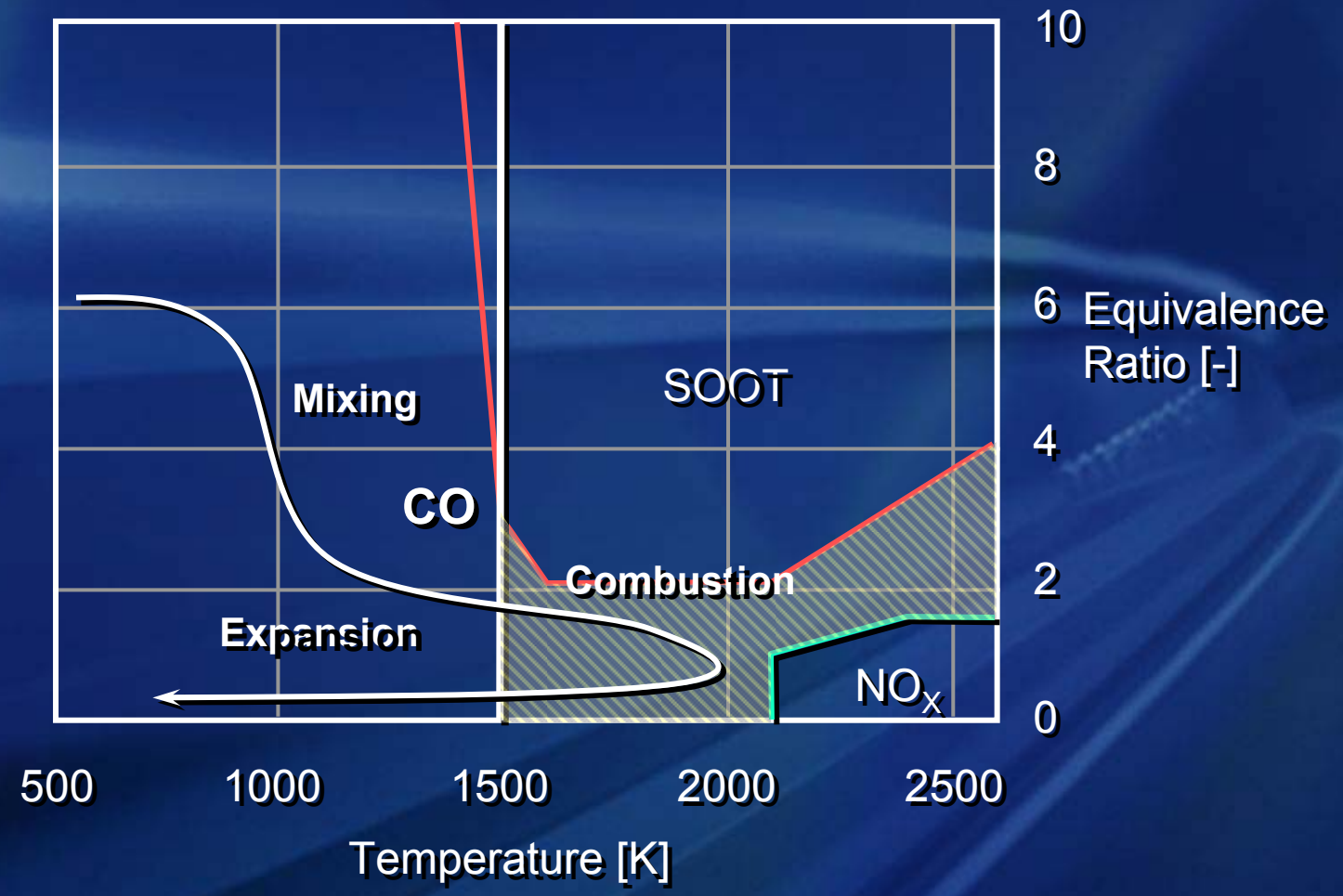
Opel Astra

Chevrolet Silverado

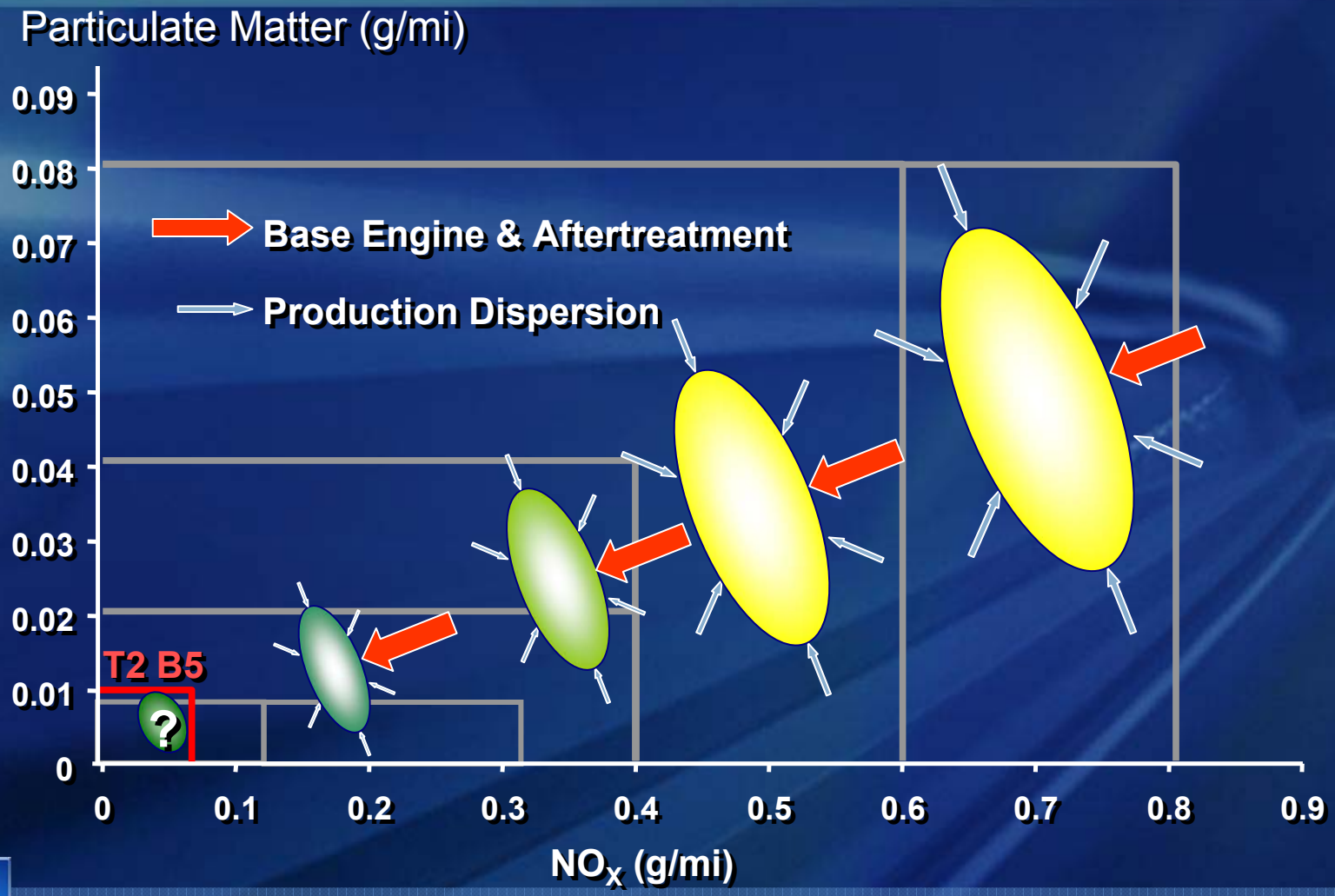
Emission (g/mile)	=	Emission Index (g/kg fuel)	X	Fuel Consumption (kg fuel/mile)

Diesel Advanced Combustion Technology

Path to Engine-Out NO_X/PM Reduction

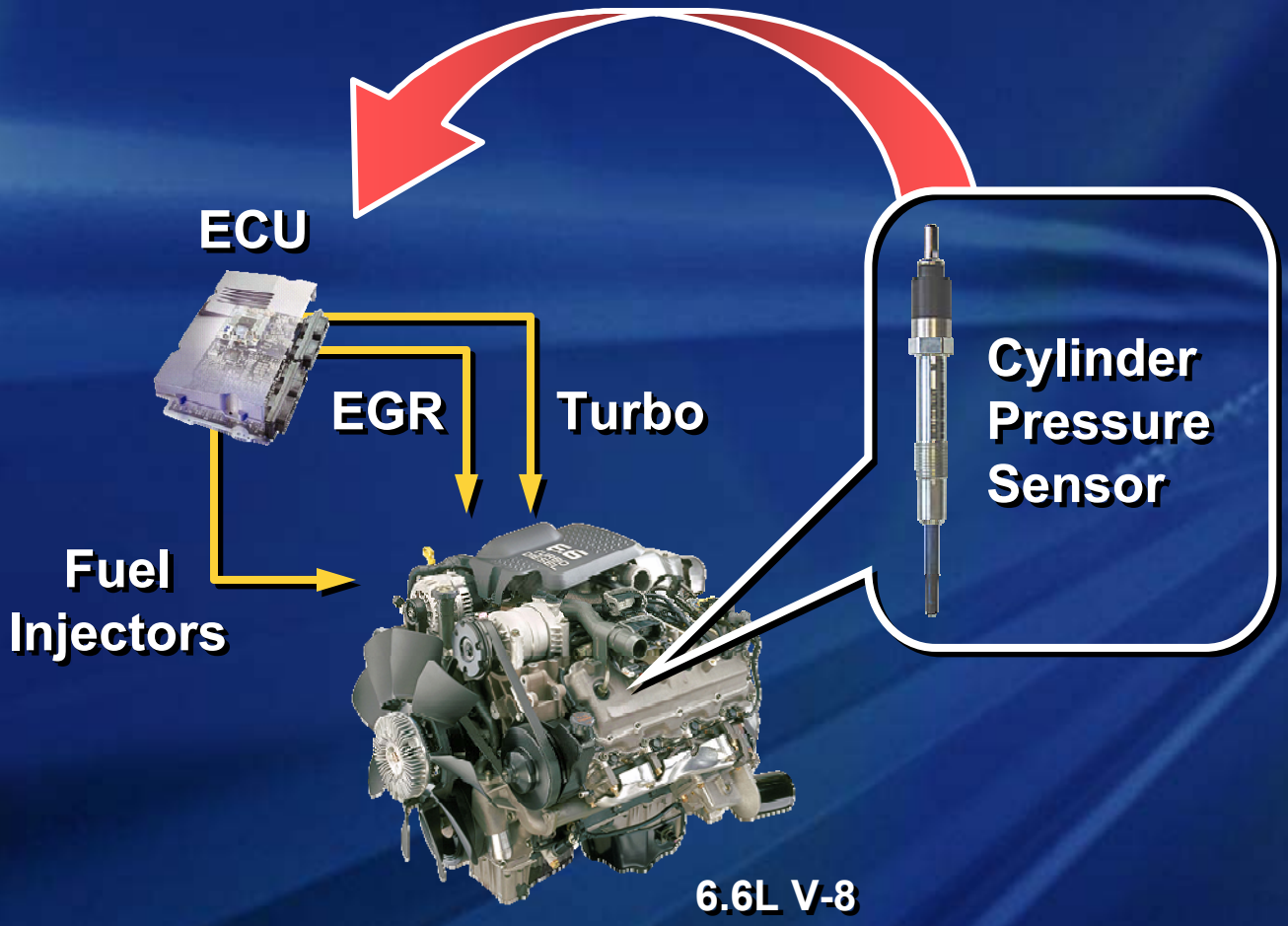


Tier 2 Bin 5 and Production Dispersion



Technologies to Reduce Engine-out Emissions

Closed Loop Diesel Combustion Control



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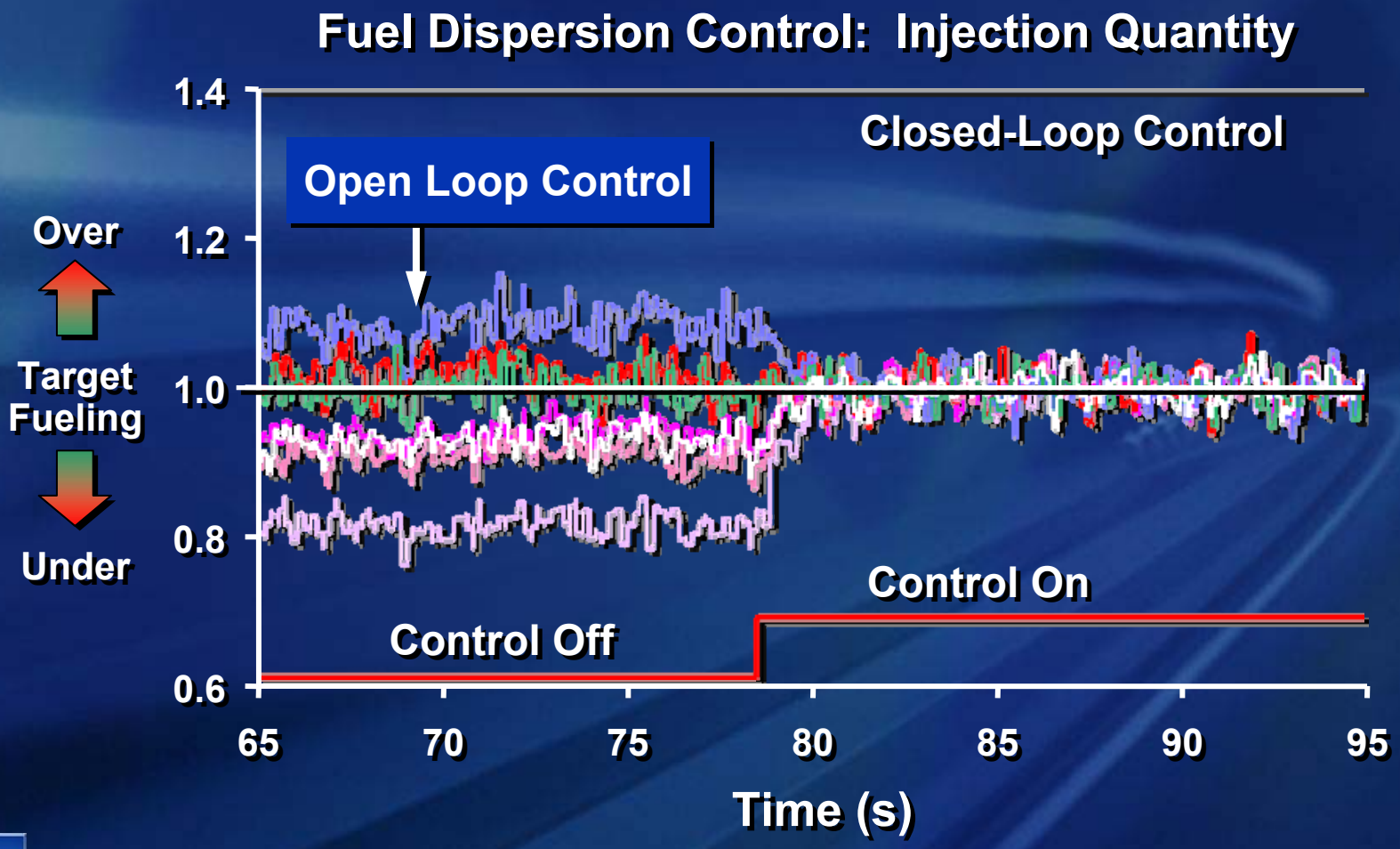
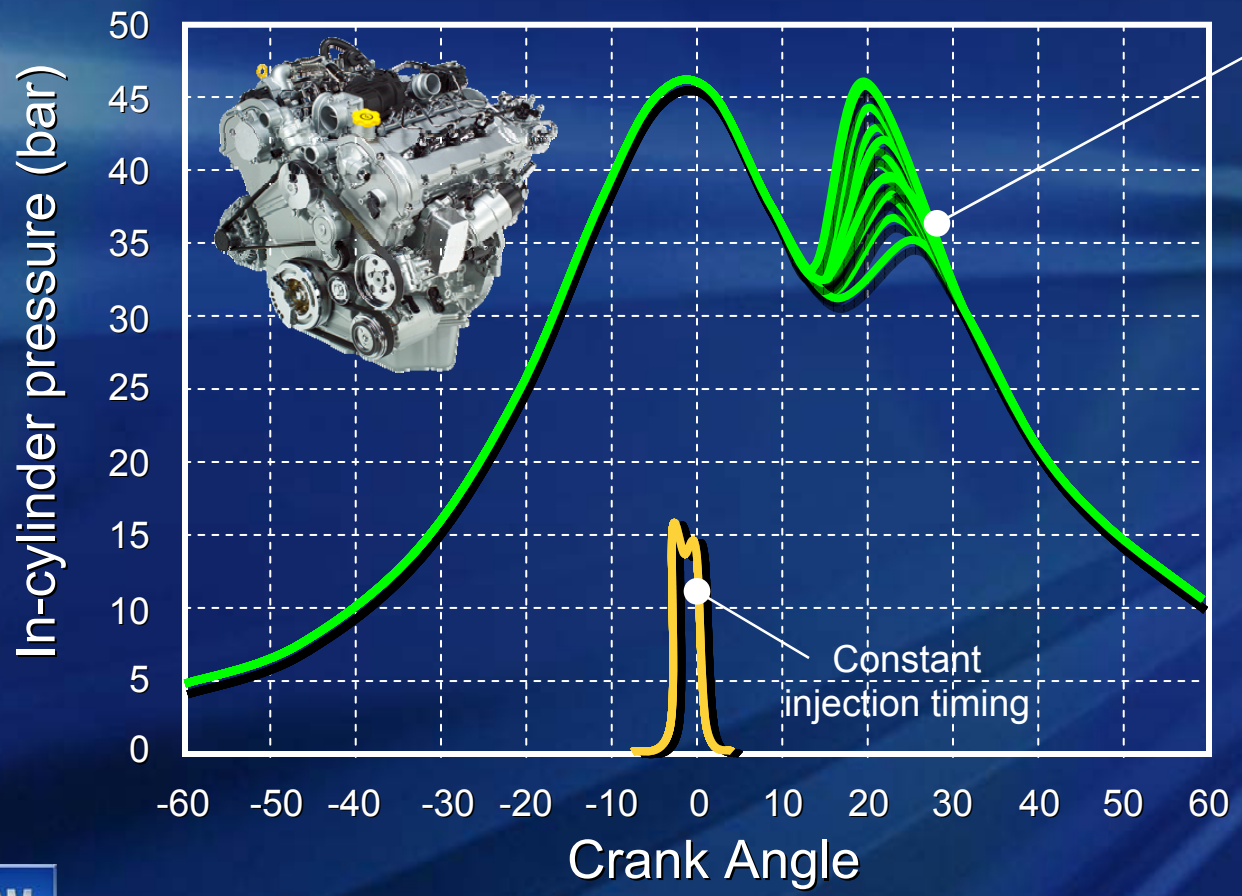


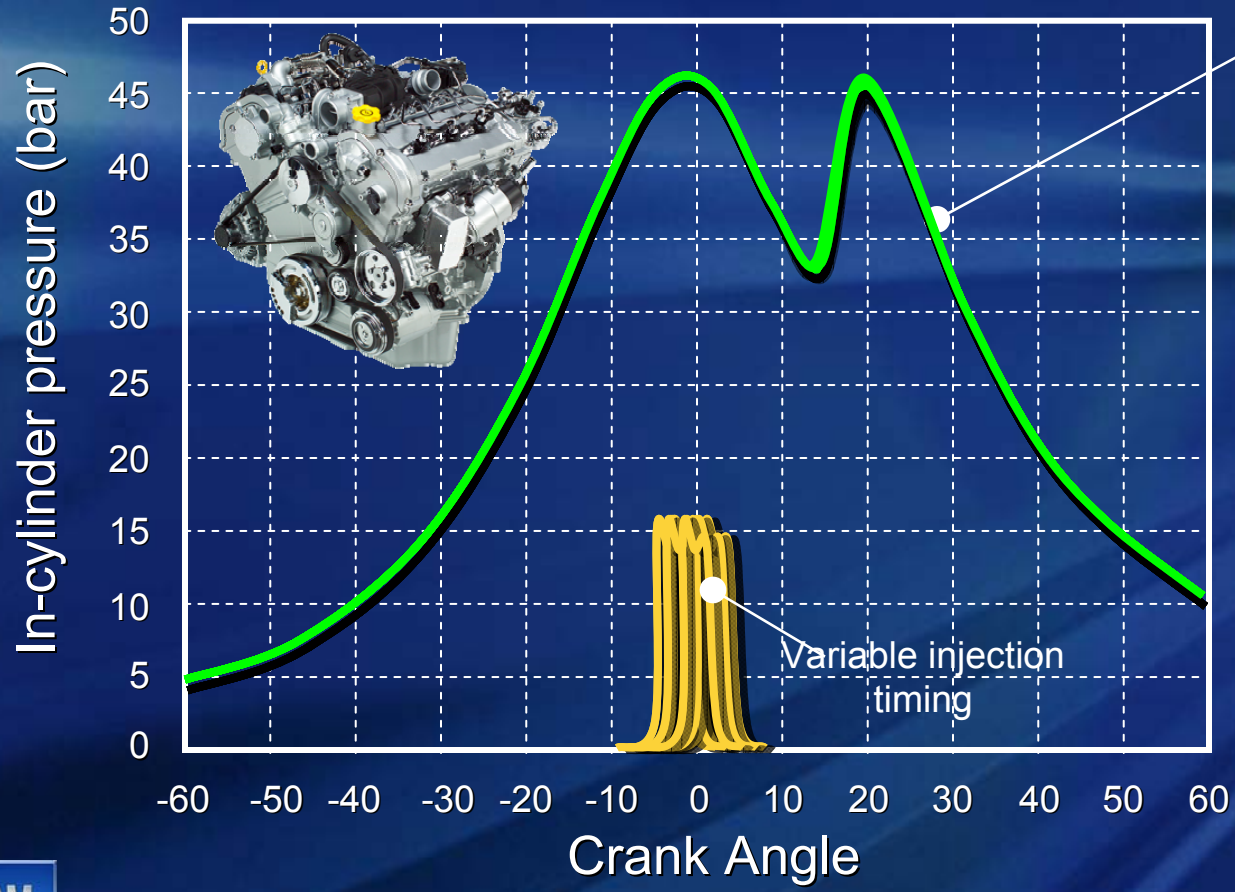
Combustion Stability



Unstable Premixed combustion (without closed loop control)

Example, measured at 1500 rpm, 4 bar BMEP

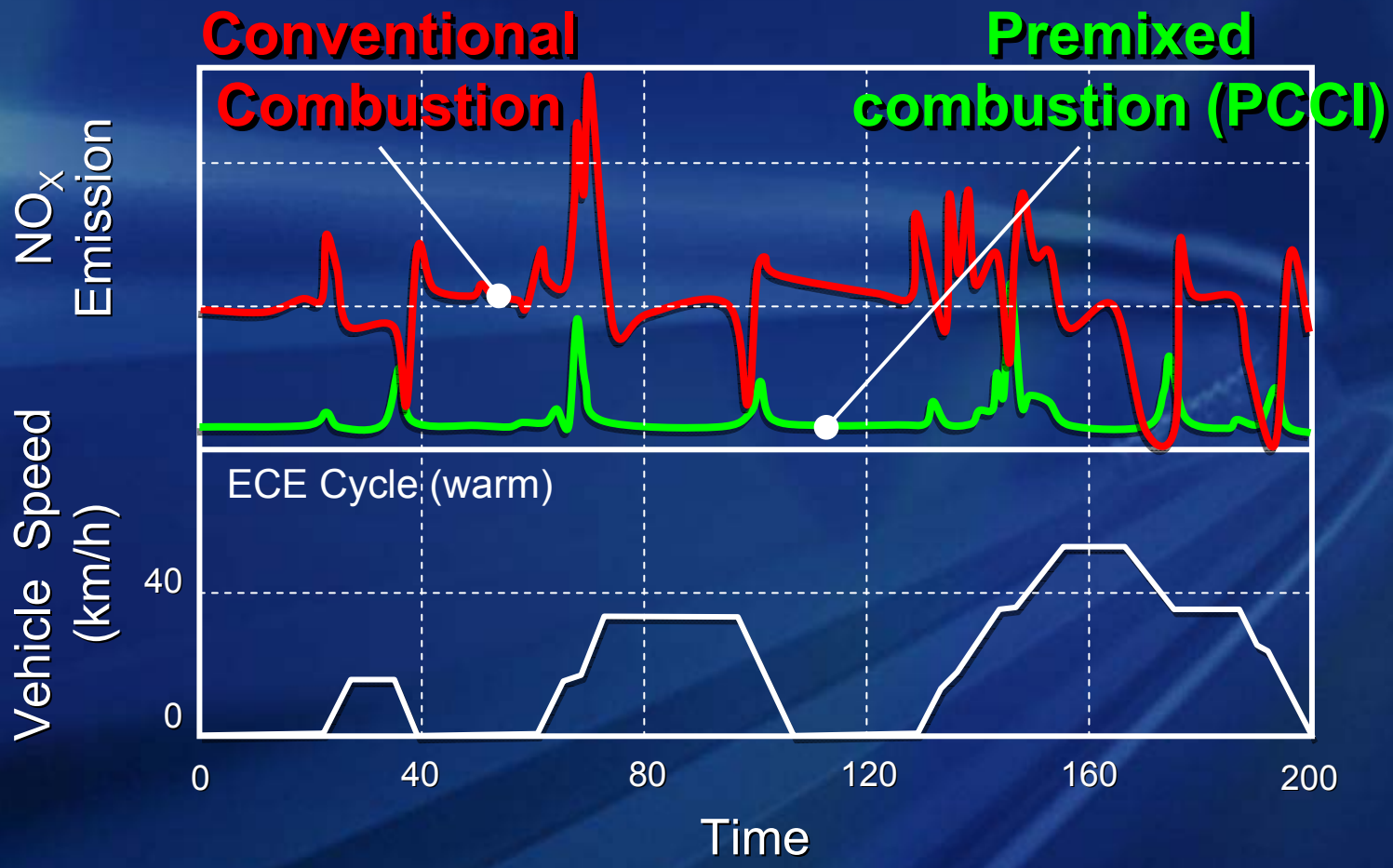
Closed Loop Combustion



Stable Premixed combustion (with closed loop control)

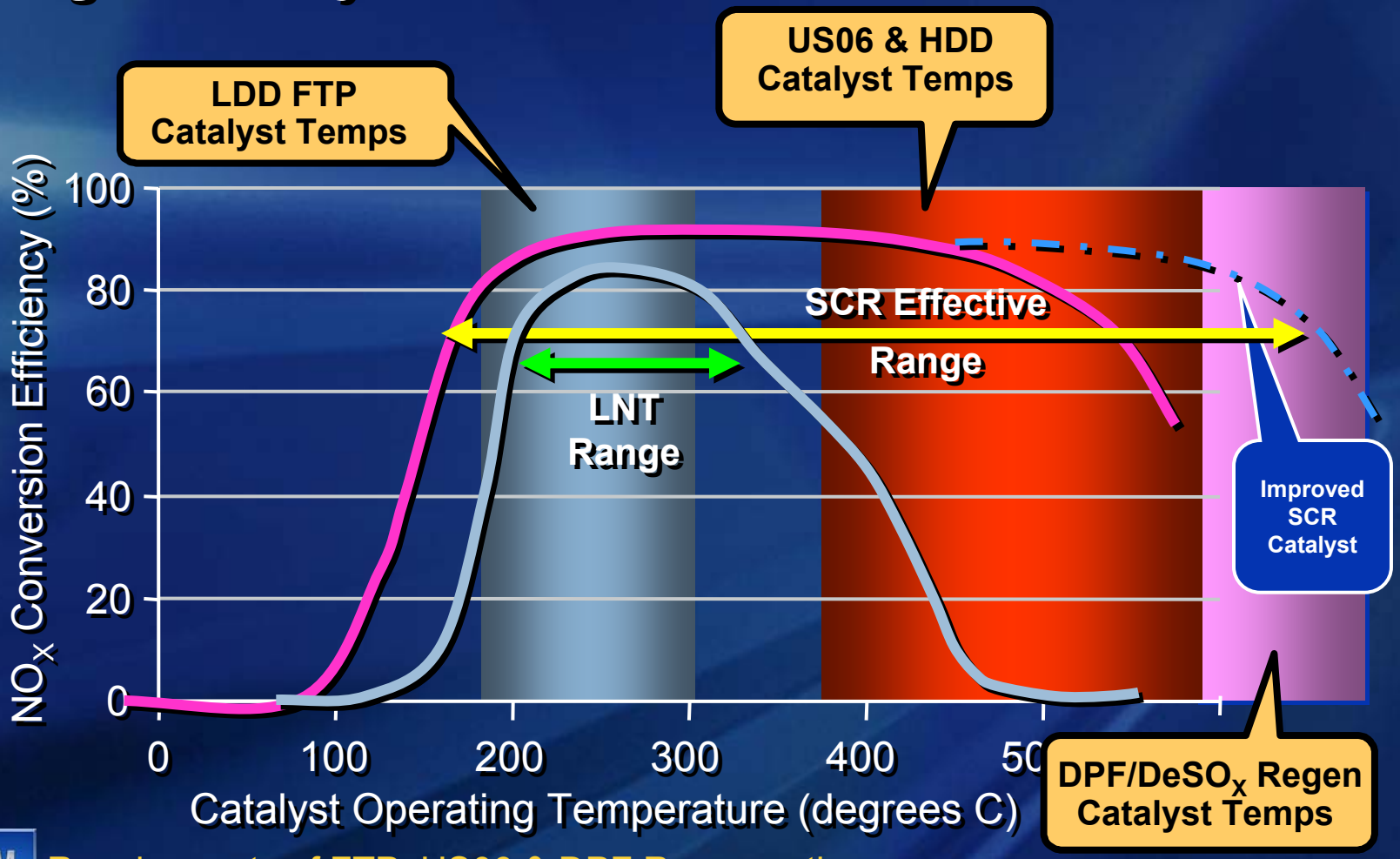
Example, measured at 1500 rpm, 4 bar BMEP

NO_X Reduction in MVEG Cycle



Typical Operating "Windows"

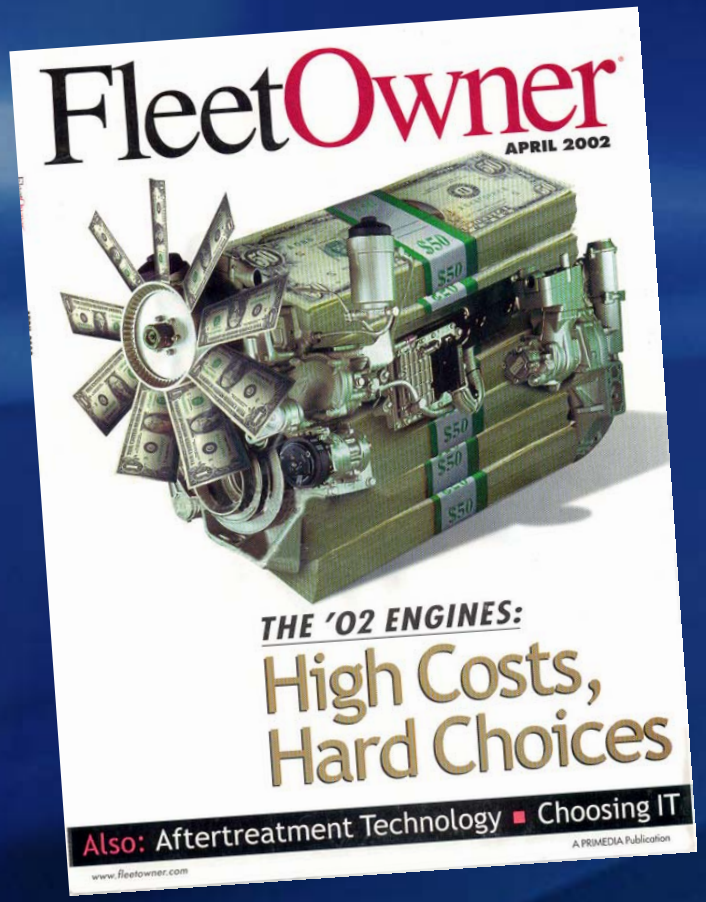
Aged Catalyst

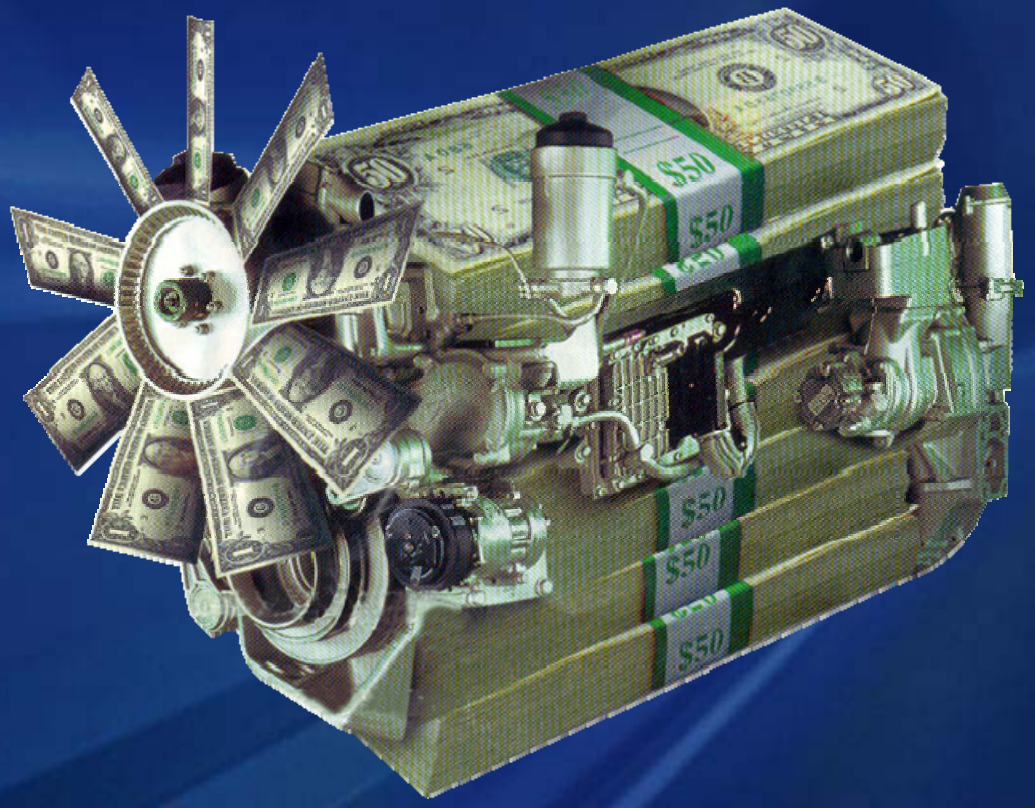


Requirements of FTP, US06 & DPF Regeneration

Then, Now & The Future…

Emissions Reduction Technologies versus Cost





GM

Summary

Fuels & Advanced Propulsion Strategy

- Transportation is a growth industry
- Vehicle production is increasing Globally
- Transportation Sector is highly dependent upon fossil fuels
- A diverse energy strategy is required for both energy security & competitive reasons
- There is no single silver bullet technology
- Successful Energy & Advanced Propulsion Strategies must be tightly integrated

Summary

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, taxation based on engine displacement and fuel consumption largely dictate markets where diesels are popular today
  - Voluntary 140 g/km CO_2 commitment is a European driver
  - Moving toward 120 g/km CO_2 requirement

Summary

Technology Driven Trends

- Diesel technological advancements over past 15 years radically changed public perception of diesels
  - High performance (torque)
  - Fun to drive
  - Refined
  - Significant penetration in European luxury vehicle segments
- Must retain fuel economy advantages while meeting new emissions standards
- Diesel must overcome cost disadvantages

Summary

Market Factors in North America

- GM continues to apply North American diesel engines where they maximize customer benefits:
  - Large vehicles
  - Towing & hauling utility applications
- U.S. market, with its larger vehicles, will benefit from diesel technology introduction
- Growing large truck diesel market share implies improved U.S. consumer acceptance of diesel engines
- Must address North American NO_X standards (one sixth that of Europe) at an acceptable cost