

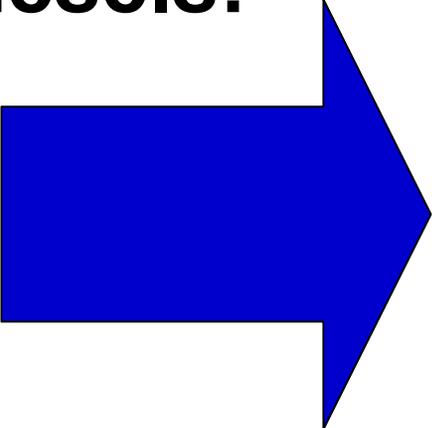
**Westport**  
INNOVATIONS INC.

# Heavy Duty Product Roll Out

How do you see the future?



# Emissions Laws Will Get Tougher

- **This is a big deal for diesels!**
    - More expensive
    - More complex
    - Reduced fuel economy
    - Reduced performance
  - Hard to see a technology road map beyond 2010
- 
- Starting  
10/02**

# US HD Truck Standards



# No easy solutions..Sooner or later

<b>In-cylinder – Exhaust Gas Recirculation (EGR)</b>	<b>Introduced on Light-Duty, coming on Heavy-Duty for EPA 2002, improves NOx, worsens PM</b>
<b>In-cylinder – Change the fuel</b>	<b>Synthetic fuels; biofuels; water blends; expensive, limited emissions reduction</b>
<b>In-cylinder - Change the operating cycle to spark ignition or dual fuel</b>	<b>Highly effective in many applications but do not match diesel performance and efficiency.</b>
<b>External - Clean up the exhaust</b>	<b>No good solution for NOx today. Affects durability and efficiency. Will be needed by end of decade.</b>
<b>Change to new technologies – fuel cells, hybrids</b>	<b>If all technical and infrastructure issues resolved, high costs remains a problem, especially in commercial applications</b>

# Cummins Westport Inc

- **50 / 50 Joint Venture formed  
March, 2001**
- **Cummins**
  - World's largest builder of commercial diesels
  - +26,000 employees
- **Westport**
  - Small incubation technology company focused on natural gas
  - 200 employees



# The JV's Mission

## Big in Clean Power

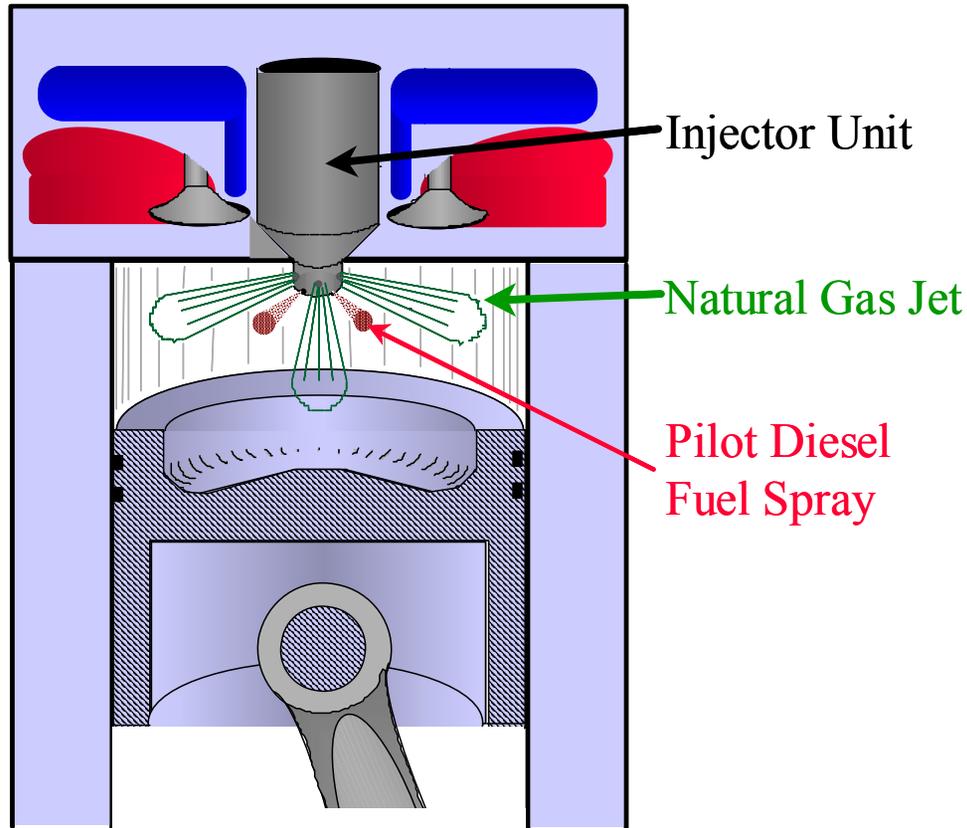
- A. Make the existing spark-ignited natural gas business work today
  
- B. Develop the new Westport HPDI Technology for the future**

# Westport's HPDI Approach

**Keep the diesel engine - - -**

**Change the fuel with HPDI  
“plug-in” natural gas injection.**

# Direct Injection Technology



## High-Pressure Direct Injection

- Natural gas injected at hi pressure
- Pilot diesel injected for ignition
- Engine remains the same:
  - Same power and torque
  - Same high efficiency
  - Diesel cycle, not Otto cycle
    - not knock limited
    - not sensitive to natural gas
- 40% less NO<sub>x</sub>
- 60% less PM
- 20% less CO<sub>2</sub>

**Average 95% Natural Gas**

# HPDI Technology Proposition

**HEAVY DUTY: YOU CAN HAVE IT ALL!**

**– Low Emissions**

**Natural Gas**

**– High Performance/BMEP**

**Like a Diesel**

**package & performance**

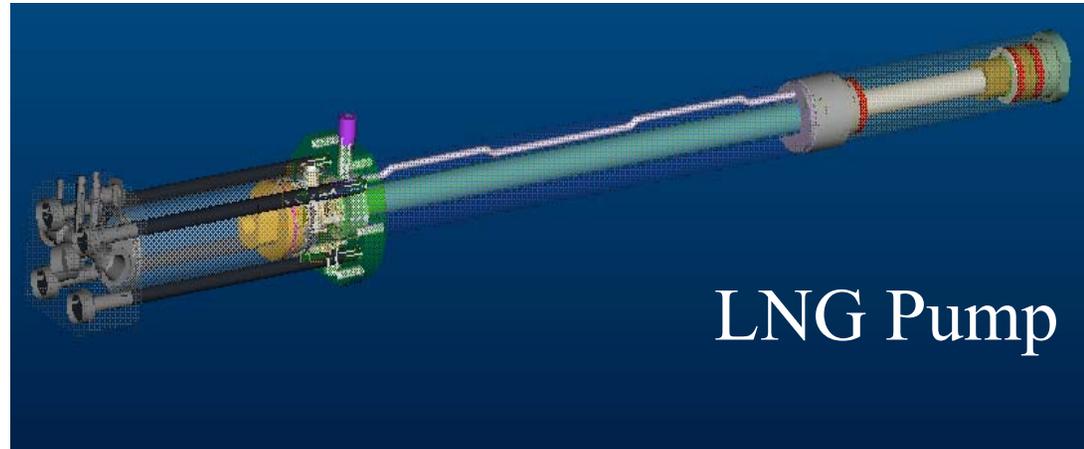
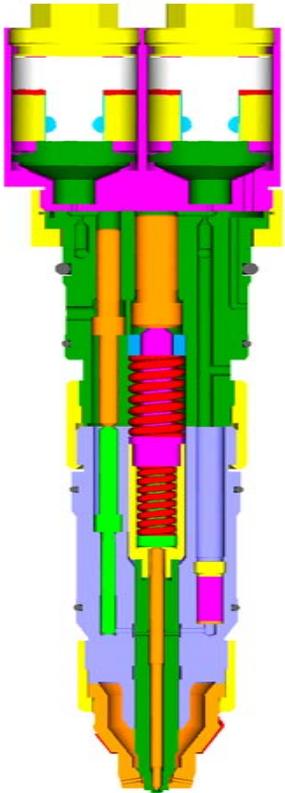
**– High Efficiency**

**Same as diesel, better than Spark Ignited, better than “Dual Fuel”**

**– Economic Payback**

**Fuel Saving**

# Key HPDI Components

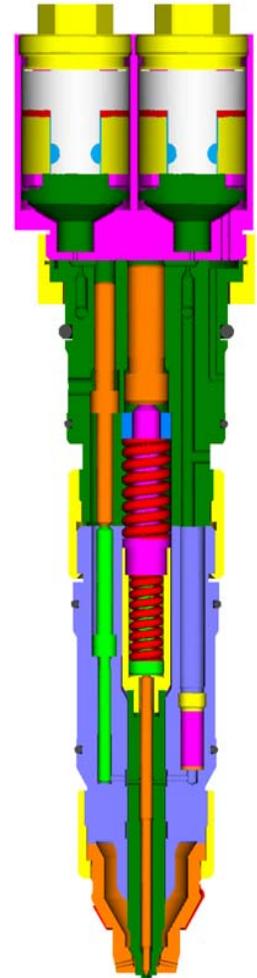


Electronic  
Control Module

- HPDI Injector similar in design to diesel injector

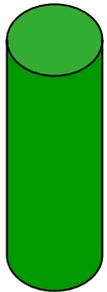
# Injector

- **Dual HPCR concept**
- **Uses 2 actuators per injector to control 2 independent HPCR circuits**
- **Fits same hole as diesel injector without modifications to head**
- **Diesel fuel used for actuation, pilot injection, sealing, and cooling**
- **Uses diesel injector-like materials, fits and finishes**

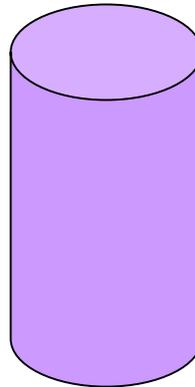


# Properties

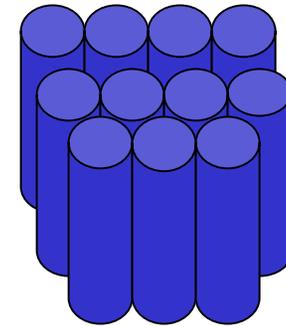
**55 Gallon Diesel Tank**  
20" Diameter, 50" Long  
551 pounds



**55 Equivalent Gallons LNG**  
25" diameter, 63" long  
639 pounds

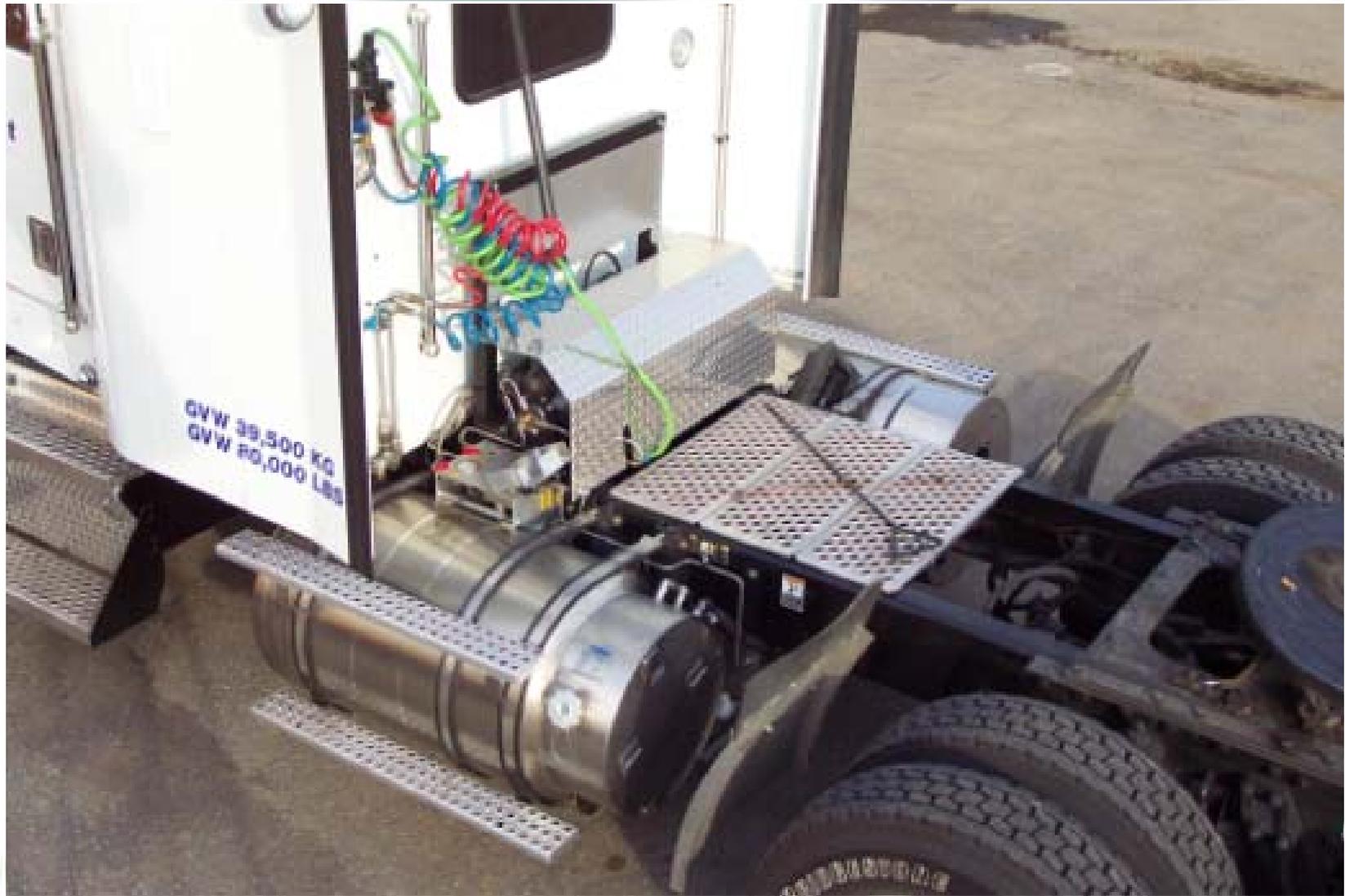


**55 Equivalent Gallons CNG**  
13 1/2" Diameter, 72" Long  
11 Cylinders, 2535 pounds



**Properties: Density Vehicle Economies**

# Vehicle Installation





# LNG Fueling

- LNG is the only feasible storage medium for natural gas storage on vehicles with space constraints and requirements for fast re-fuel rates
- LNG is a cryogenic liquid stored at  $-160^{\circ}\text{C}$ . Storage tanks are double walled, vacuum jacketed, stainless steel fuel tanks.
- LNG has about 60% of the energy density of diesel.
- LNG weighs about half as much as diesel (3.5 lbs/gal) so overall weight of fuel is similar
- LNG is safe, but handling does require special precautions and training.



# Overall HPDI Product Plan

**Introduce HPDI**

***The “Westport Cycle”***

**ISX Gas 400 - 500 HP 1450 lb ft**

**2004**

# HPDI Technology is Real

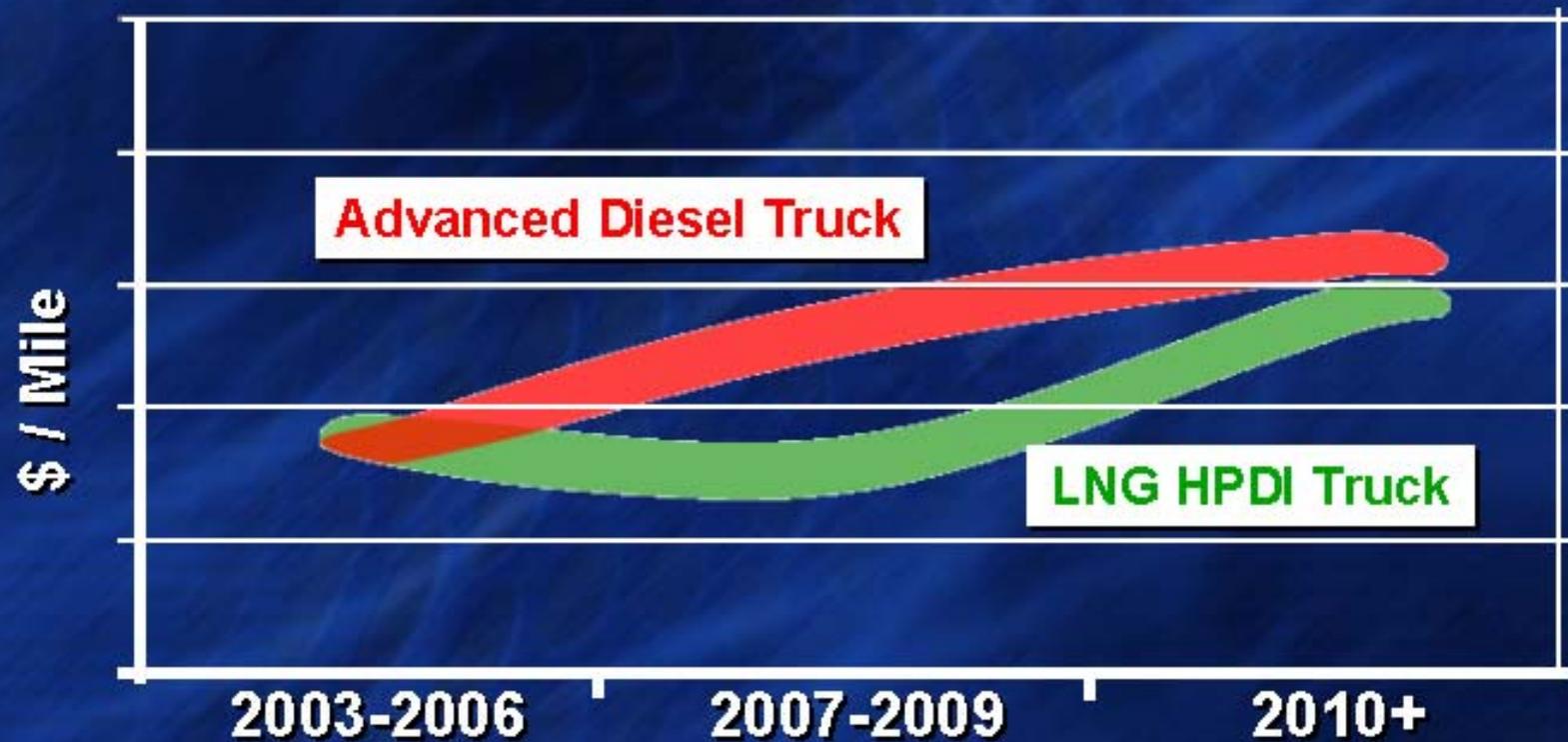


## HPDI version of ISX-400 (1450 ft-lbs)

- 2000 - Engineering Truck
- Jan 01 - Delivered Raley's Truck (KW T-800)
- Feb 01 - Certified to CARB Optional low NOx (2.5g) emissions standard
- Mar 01 - Delivered Bobell Truck (KW T-800)
- 3Q01 - 14 trucks to Norcal Waste Systems in San Francisco (Peterbilt 378)



# HD Cost/Mile Trends

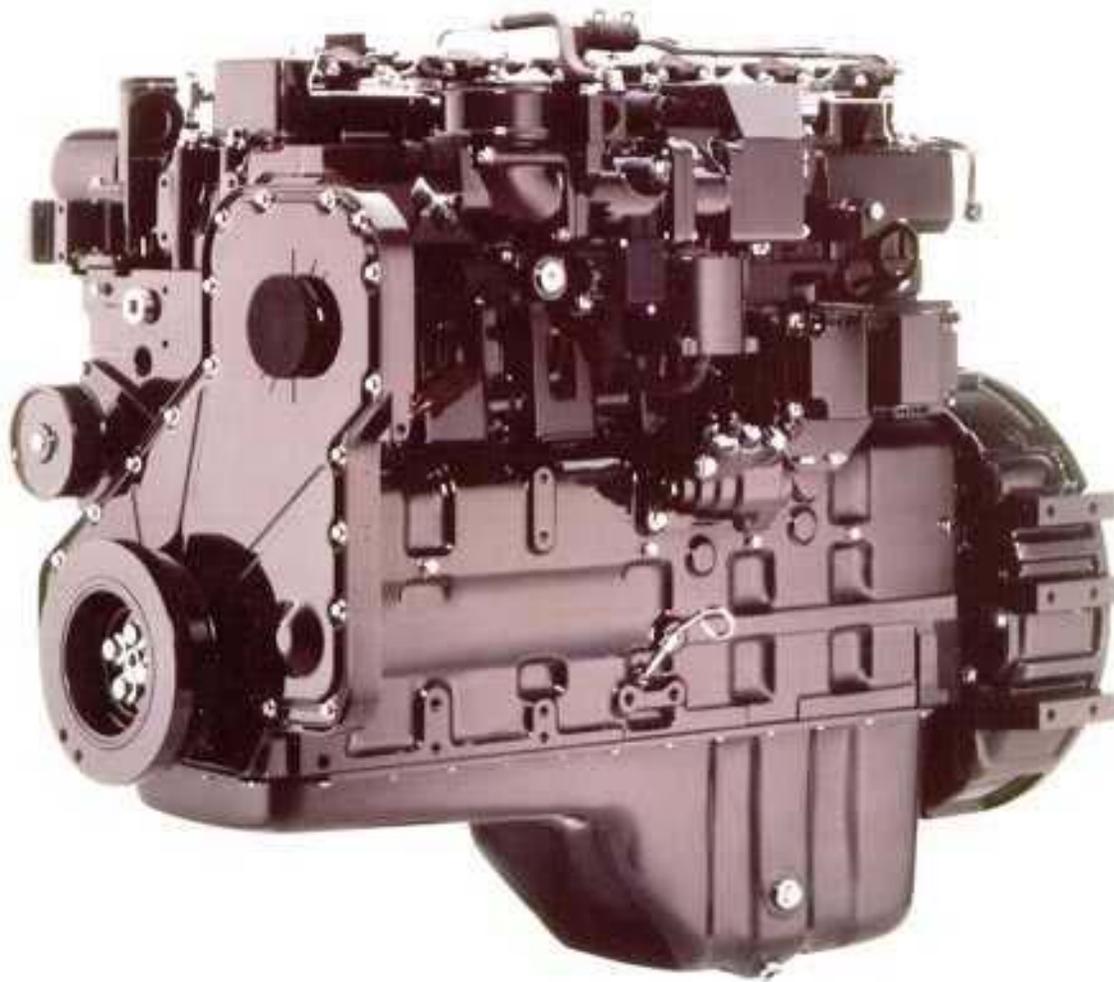


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# C Gas Plus



*Powering the Planet - Protecting the Dream*



# Cummins B Gas Plus B LPG Plus



*Powering the Planet - Protecting the Dream*



# L Gas Plus Development

- **Cummins 8.9 litre ISL engine will be launched using “C Plus” engineering**
- **320 horsepower rating**
- **Available 2004**
- **Aimed at urban transit and trucks needing more power than the C Gas Plus**



# Plus Engine Diagnostics

## Insite



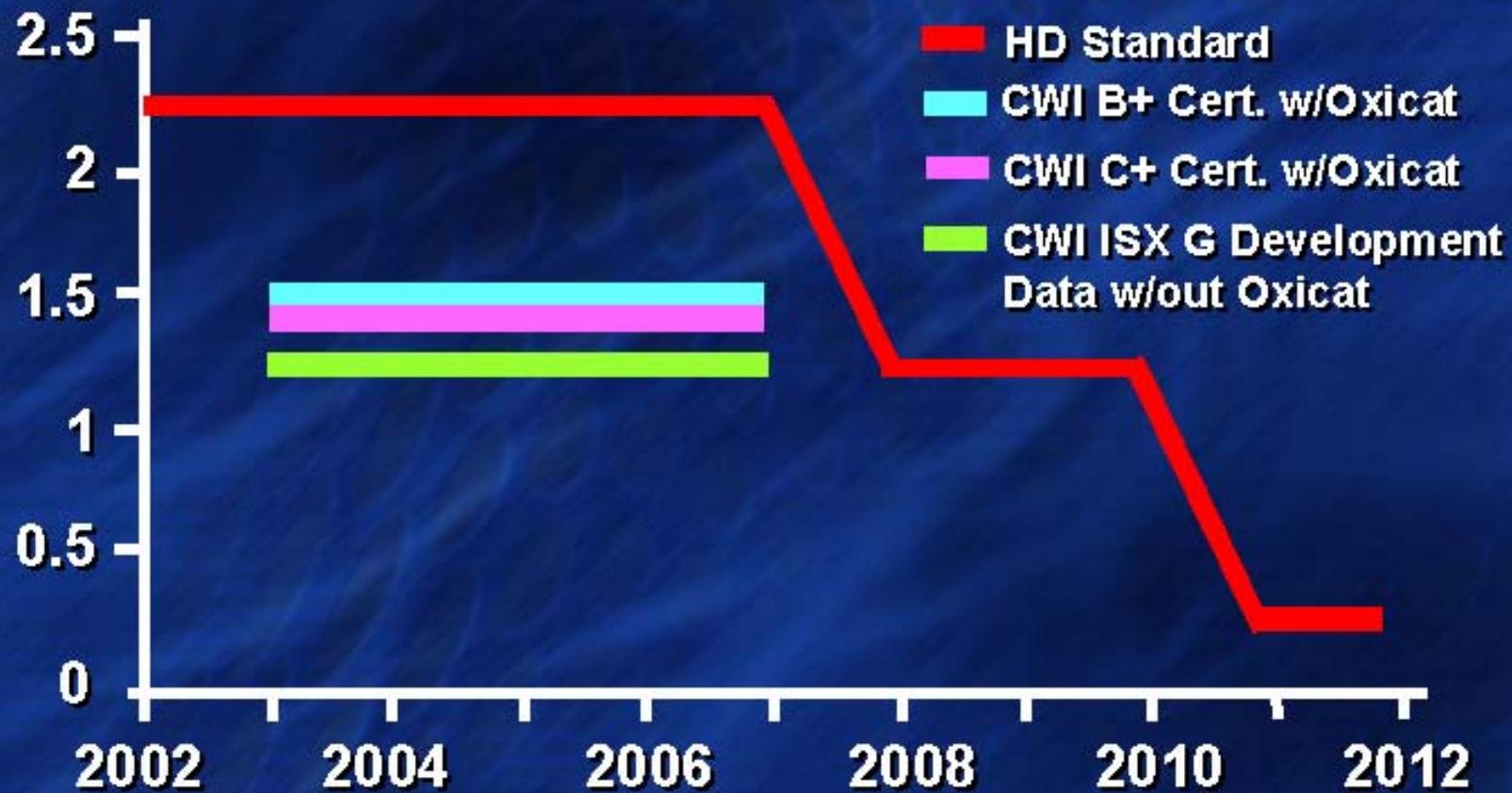
**Assists mechanics to quickly program engine, analyze faults & troubleshoot engines**

## Cummins QuickCheck

- **PalmPilot handheld device to:**
  - **Displays SAE fault code information**
  - **View sensor output data**

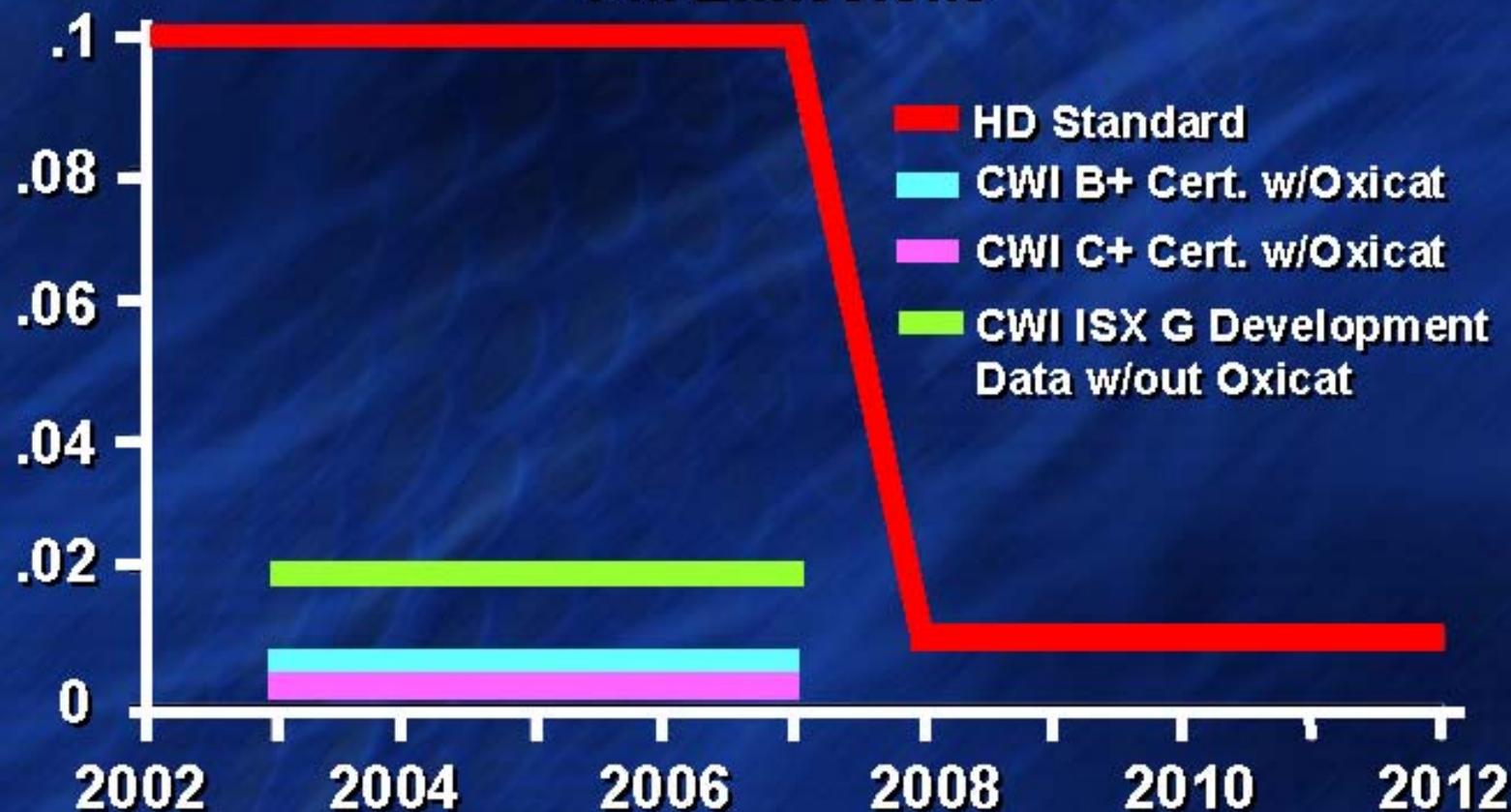


# 40% Lower NOx

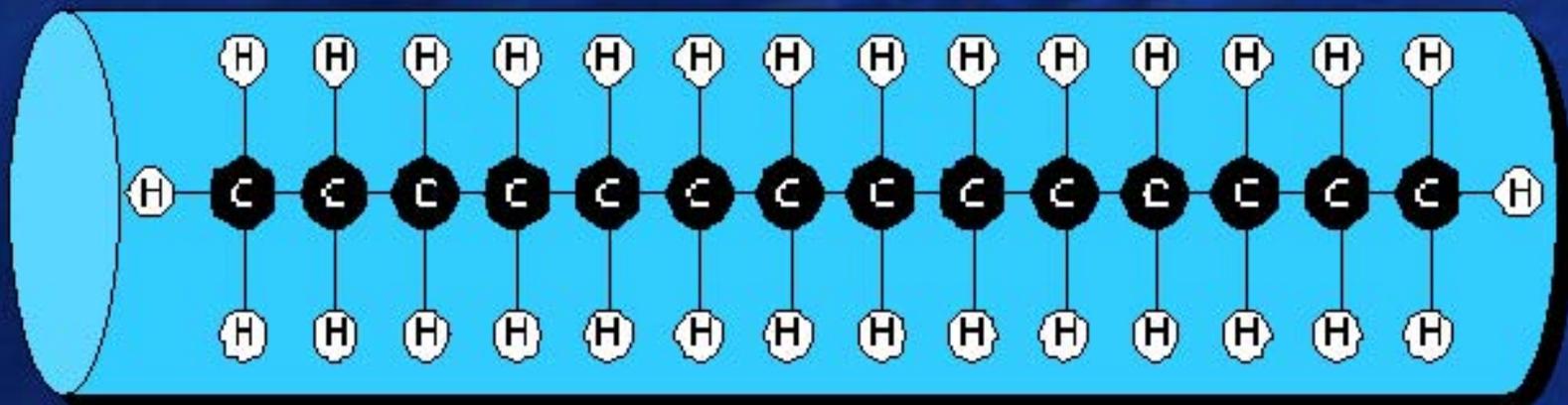


# 95% Lower Particulate

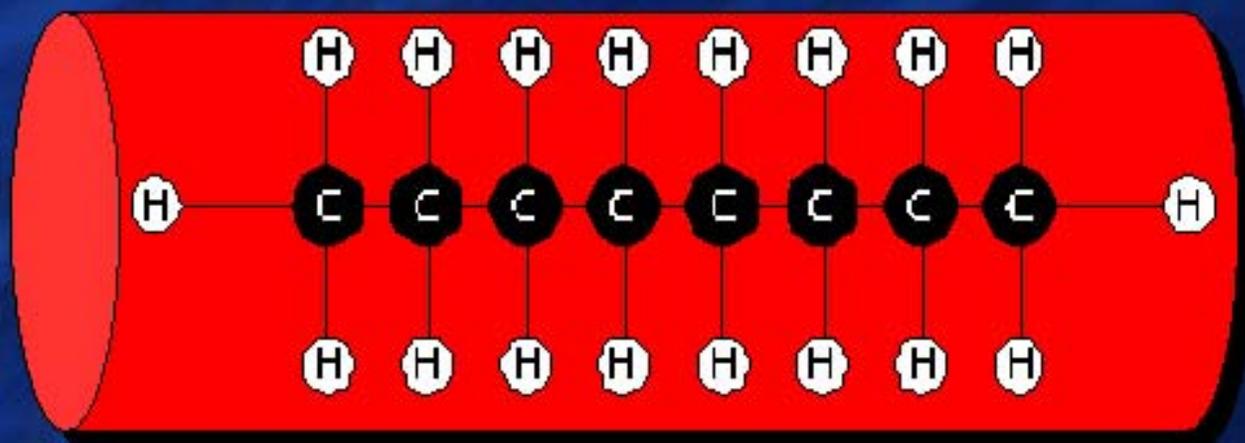
## PM Emissions



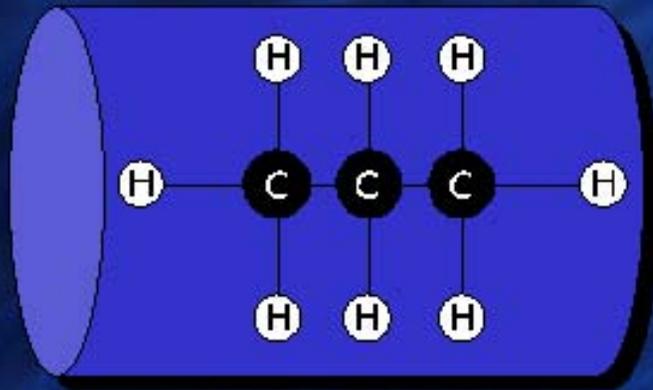
# Diesel $C_{14}H_{30}$



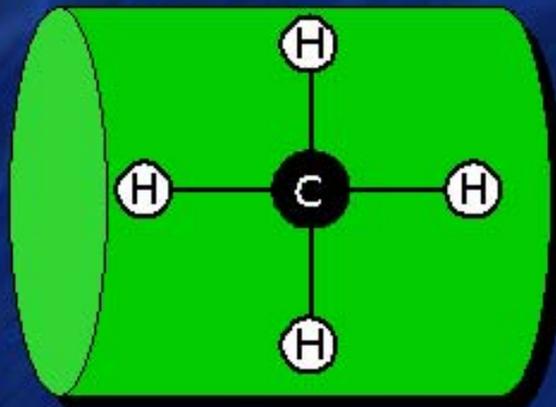
# Gasoline $C_8H_{18}$



# Propane (LPG) $C_3H_8$



# Methane $CH_4$



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