Clean Diesels, an Economy or Performance Option?

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Dean Harlow

President - Ricardo, Inc.
Thank You DOE

“Ricardo is Fuel Economy”

**Engine Downsizing - Cooled EGR**
- Goal: 15% Fuel Economy Improvement
- Partner: GM

**Advanced Flex-Fuel Technologies**
- Goal: Gas-like Fuel Economy with E85
- Partners: Bosch & University of Michigan
R&D - Technologies for fuel economy, emissions & vehicle electrification

Technology Portfolio

- Hybrids & Fuel Cells
- Advanced Gasoline Engines
- Clean Diesels
- Efficient Transmissions
- Controls and Electronics
- Alternative Fuels

Example Ricardo Solutions

- Pass Car T2B2 Diesel Adv Tech Demo Vehicle
- 2-Stroke/4-Stroke Engine
- Torque Vectoring - Active Steer with Safety Critical Software
- Hydrogen-Powered Vehicle Concept
- Down Sizing & Boosting "DI Boost"
- "Efficient-C" Diesel Hybrid -- world's most efficient powertrain
- Hybrid Transmission Design
- Vehicle-to-Vehicle or Infrastructure Communication
- Advanced Electronic Controllers
- WAVE-RT for Full Model Based Control in ECU
A systems approach is required to meet the Fuel Economy and CO₂ challenge

Ricardo is applying a systems approach to optimizing powertrain efficiency and Total Vehicle Fuel Economy

Diesels have a bright future in the US and Ricardo is helping to deliver the technology that is leading the way

- World’s Most Efficient Powertrain – Ricardo “Efficient-C” Diesel Hybrid
- Tier2Bin2 Breakthrough
- DIESELMAX – land speed record
Energy Security, Fuel Availability and Low Carbon Fuel
Efficient Vehicle Technologies are driving industry investments

Evidence links increased use of fossil fuels with global warming

Oil Pricing up sharply, increasing global demand will increase prices further

World-wide adoption of low carbon targets

Source: Ricardo Analysis

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In the near term, powertrain improvements will remain the most cost effective solution to the FE & CO$_2$ challenge

- Vehicle Down-sizing
- Restricting Vehicle Use
- Improved vehicle Weight, Aerodynamics and Friction
- Alternative Fuels and Energy
- Improved Powertrain Efficiency

- Each solution has its own merits, and all have a role to play
- However, improved powertrain efficiency will be a main-stay of short / medium term fuel consumption & CO$_2$ reduction

Source: Ricardo Internal data
Advanced Gasoline technologies will close the gap with Diesel with Hybrid solutions remaining expensive.
Ricardo “Efficient–C” Diesel Hybrid Demonstrator features the world’s most efficient powertrain, achieving >60 mpg

- Powertrain efficiency optimization program
- 35% improvement in cycle fuel consumption compared with 2.0l base vehicle
- 0-60 mph less than 13 seconds
- 5 km to 10 km electric only range
Further gains will be achieved by combining powertrain efficiency improvement with vehicle systems optimization.

**Conventional Vehicle**

**Improved Vehicle Energy Efficiency**

- **Reduce Carbon in Fuel**
- **Reduce Power required by vehicle**
- **Improve Efficiency of Powertrain**

**Efficient ~ Low Carbon Vehicle**

- Lower vehicle weight/size: <5%
- Reduced aerodynamic drag: 3-5% (high speed)
- Energy recovery (hybrid): 20-30% (city)
- Higher mechanical efficiency: 10-15%
- Higher combustion efficiency: 2-3%
- Optimised control: 5-10% (inc trans)
- Fuel cells/battery electric: Marginal v Hybrid

Potential benefit
Ricardo is uniquely contributing to the systems approach

- Offering OEMs…
  - “No Compromises” *Total Vehicle Fuel Economy* improvement process
  - Independent, unbiased assessment of most cost effective strategies to meet increased fuel economy standards across their product portfolios

- Assisting EPA with objective approach to reasonable and achievable future CAFE standards

- Providing Governments strategic insights on balancing CO₂ reduction strategies with regulations and industry/societal impact
T2B2 emission requirements dictate a comprehensive and integrated systems approach to Diesel engine optimization.

**System**

**Combustion**
- Reduce Combustion Temperatures
  - Low Comp. Ratio (<16:1)
  - Modulated super cooled EGR
  - High pressure FIE 2000+ bar

**Improved Fuel Mixing**
- Low Comp. Ratio (<16:1)
- Modulated super cooled EGR
- High pressure FIE 2000+ bar
- Small bore 8-10 hole Nozzles
- Advanced Conventional Combustion (PPCC & FPCC)

**Boost System**
- Performance & High EGR Capability
  - Wide flow range VGT
  - High power/weight ratio
  - Mixed HP/LP route EGR
  - Next Generation VGC & S/C

**Control**
- Transient Response & Robustness
  - Electric actuators w/ feedback
  - Model based gas path control
  - Full closed loop CPEMS
  - Closed loop MAF/EGR balance

**Aftertreatment**
- Low Cost Integrated Solution
  - SiC CDPF
  - Low Cost / Low Inertia DPF
  - Urea SCR
  - LNT
  - Pre-Turbo Cat
  - 4-Way Catalyst

Available | In Progress | High Risk
Ricardo’s “Tier 2 Bin 2” Diesel Technology Breakthrough

- Research Program with Production Intent
- Goals - Demonstrate on D-class Pass Car:
  - Tier 2 Bin 5 without NOx aftertreatment
    - Bin 5 “Engine-Out” emissions
    - August 2007 Demo
  - SULEV with simplified LNT NOx aftertreatment
    - Bin 2 “Tailpipe” emissions
    - December 2007 Demo

- Results:
  - Achieved Bin 5 “Engine-Out” emissions
  - Targets demonstrated with acceptable smoke and fuel economy
  - Further refinement continues

Details at 2:20 pm Today
Mark Kuhn - Ricardo
Diesels are an important part of the solution – penetration will nearly triple to 9% by 2013

Projected US Diesel Passenger Vehicle Sales and Market Penetration

Other forecasters are even more optimistic:
- Bosch forecasts 6% Diesel penetration in the U.S.A by 2010 and 15% by 2015 (over 2.5 mm)
- J.D.Power forecast a rise to 10-15+% penetration in North America by 2015 (up to 2.5 mm)
- Martec Group forecast 10-12% in North America by 2013 depending on Diesel price vs. Gasoline
DIESELMAX - 350.092 mph FIA Land Speed Record – high performance while fuel efficient!

- DIESELMAX • 4.5 mpg @ 350 mph
- Bugatti Veyron • 2.8 mpg @ 250 mph
- Mini Cooper S • 5 mpg @ 120 mph