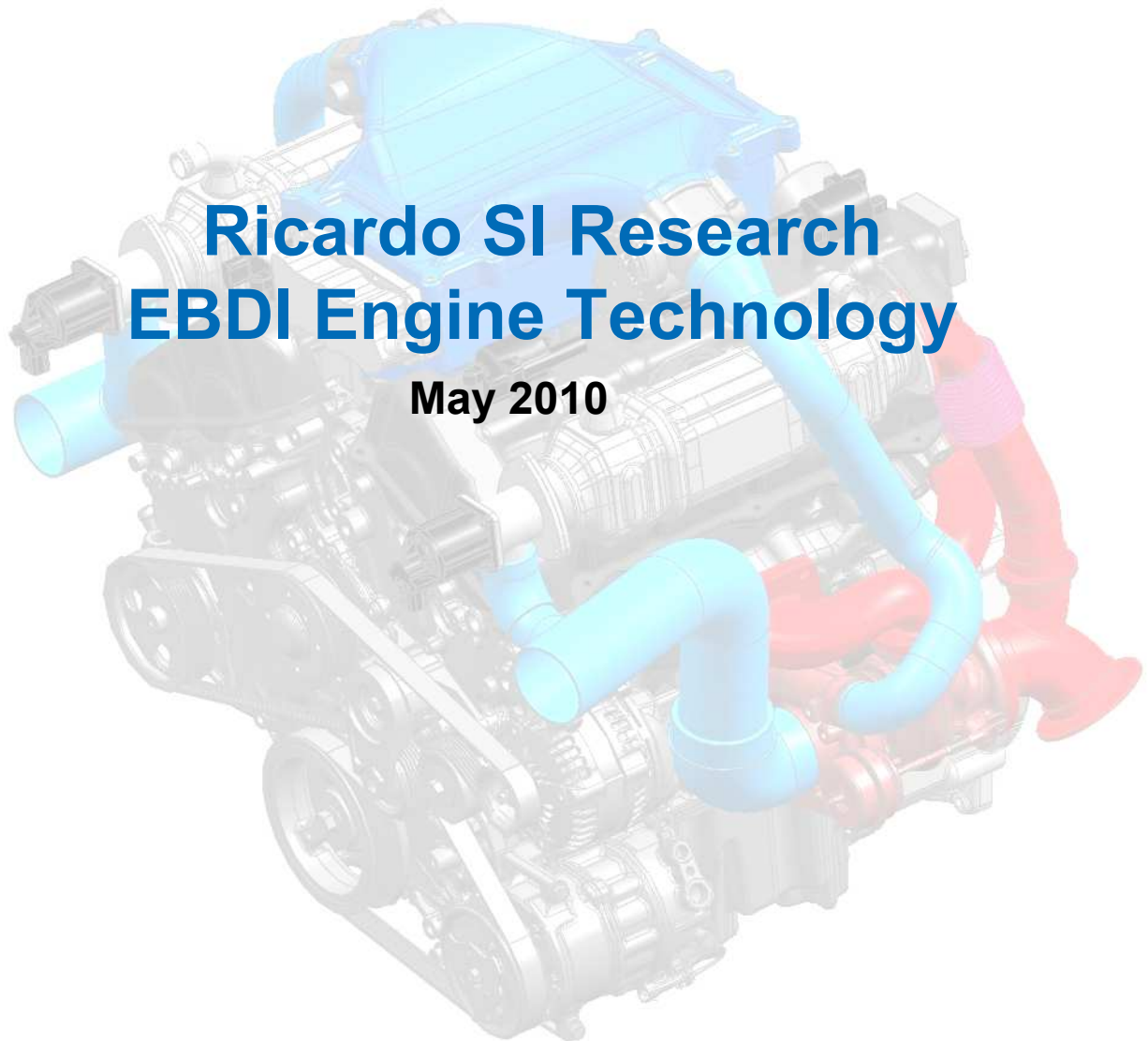


A detailed 3D CAD model of an internal combustion engine. The intake manifold is highlighted in light blue, and the exhaust manifold is highlighted in red. The rest of the engine components are in a light grey/white color.

Ricardo SI Research EBDI Engine Technology

May 2010

Downsizing = "Doing More With Less"

Ethanol Boosted Direct Injection (EBDI)



**EBDI =
EXTREME
Downsizing**



Fuel economy improvement solutions for multiple applications:

Passenger cars

Truck and medium duty vehicles

Off road applications: Agricultural and Construction

A scaleable SI engine technology package

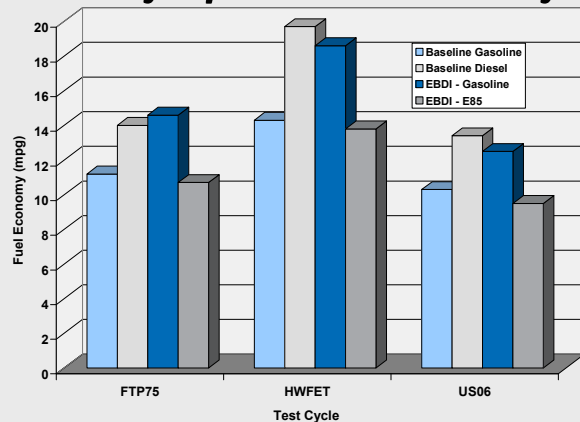


3.2L Spark Ignited engine running on E85 ethanol with performance of 6-7L Diesel engine

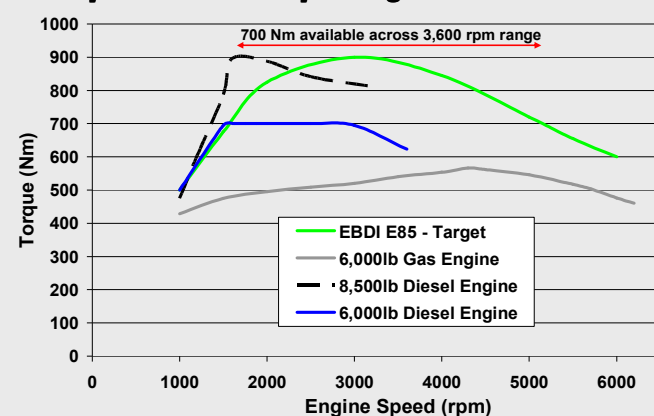
Fully flexible powertrain optimized for operation on standard pump gasoline to E85



Vastly Improved SI Fuel Economy



Unprecedented Spark-Ignited Performance



BEHR



BOSCH

DELPHI

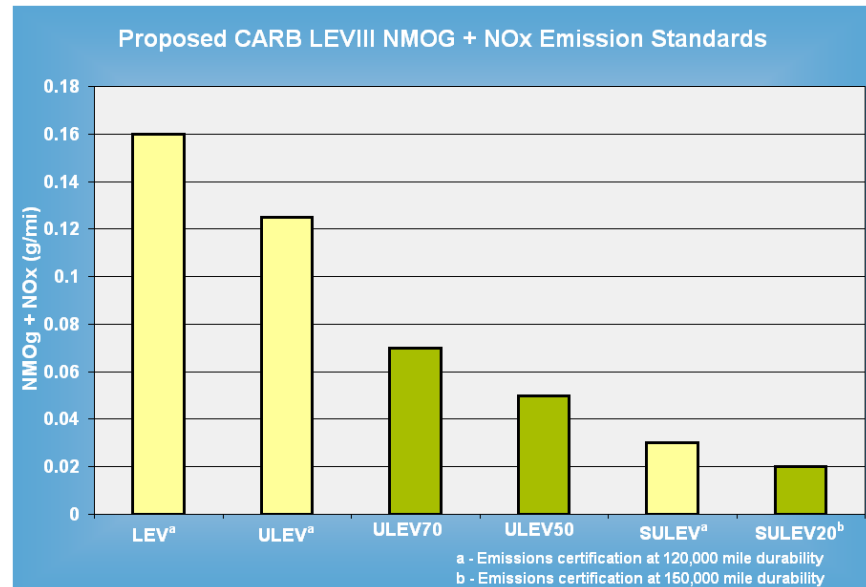
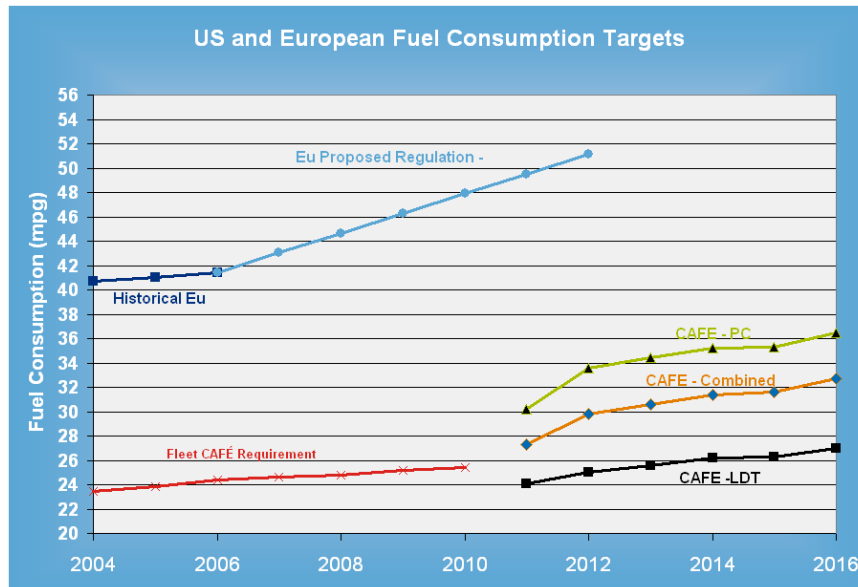


Honeywell

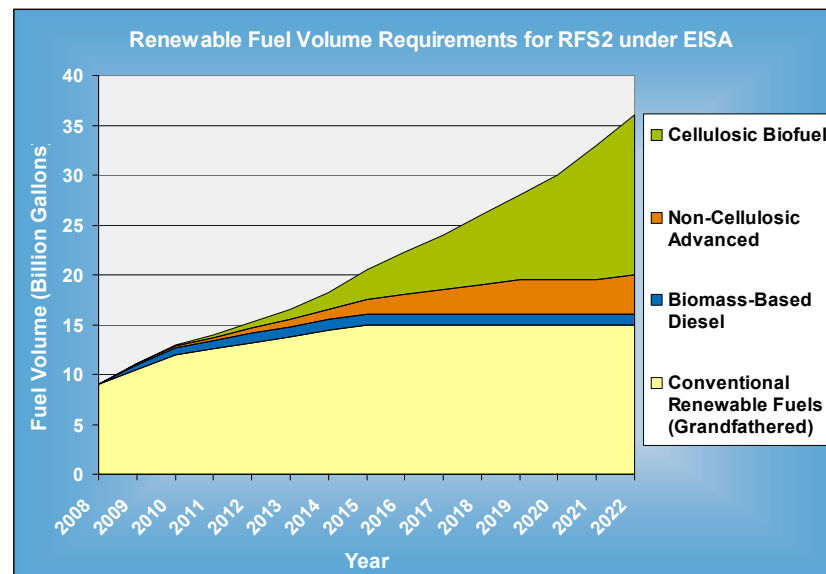
DELIVERING VALUE THROUGH INNOVATION & TECHNOLOGY

www.ricardo.com

EBDI Drivers



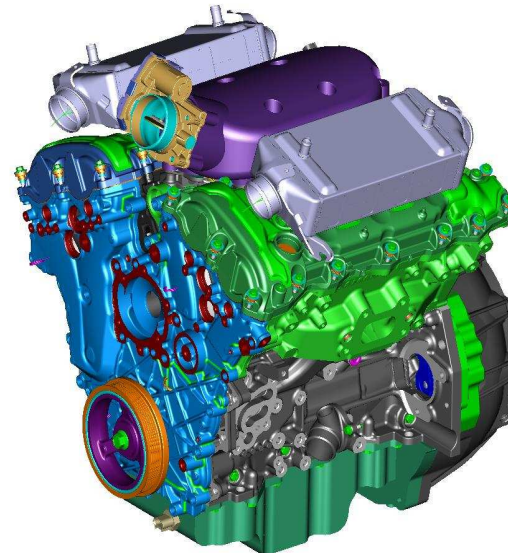
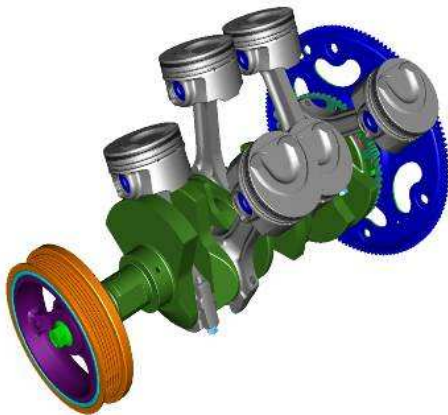
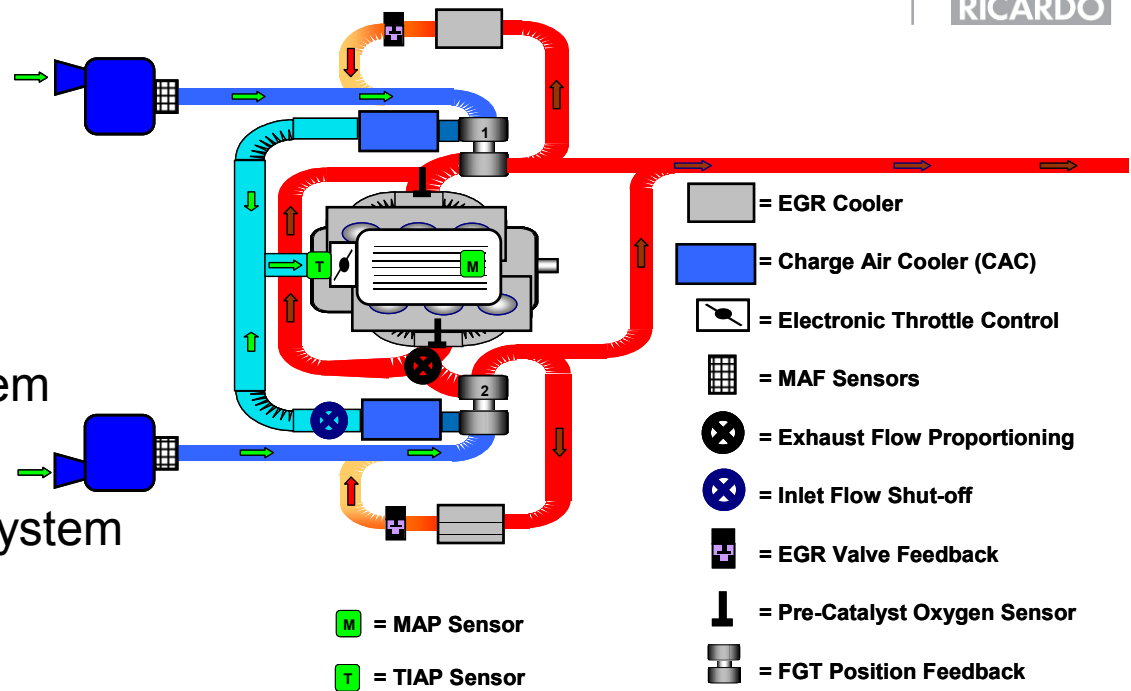
- Reduced Fuel Consumption
 - 2016 35.5 mpg CAFE
 - Eu 2012 120 g/km CO2 target
 - Energy Security
 - EPA RFS2
- Low Criteria Emissions
 - CARB LEV 3 / Euro 6



EBDI Concept and Test Hardware



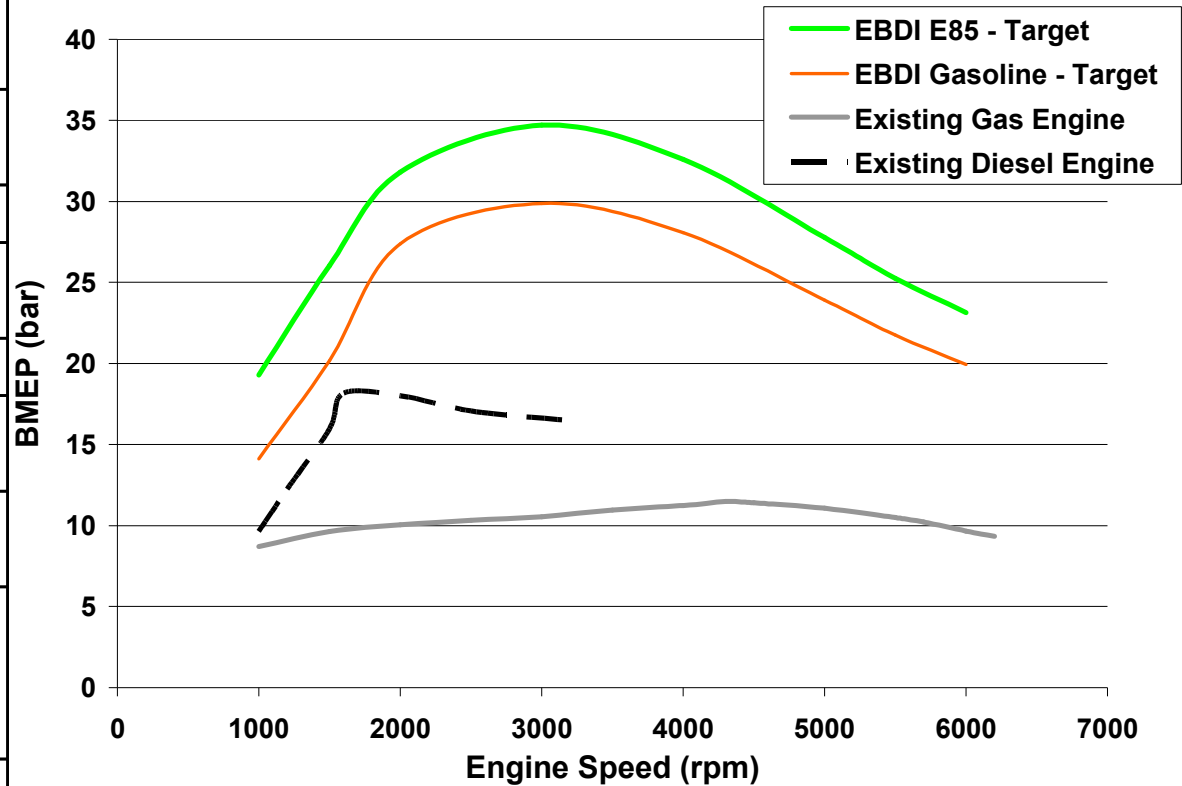
- 3.2L V6
 - Modified for 180 bar Pmax
- DOHC VVT
- Parallel sequential turbo system
 - Wastegate controlled
 - VNT turbos for optimized system
- Long route EGR



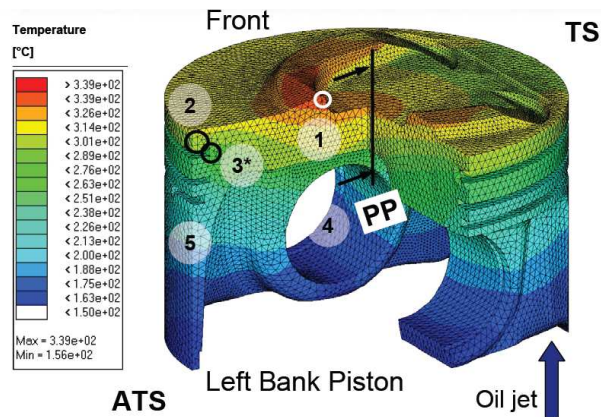
EBDI Targets and Specifications



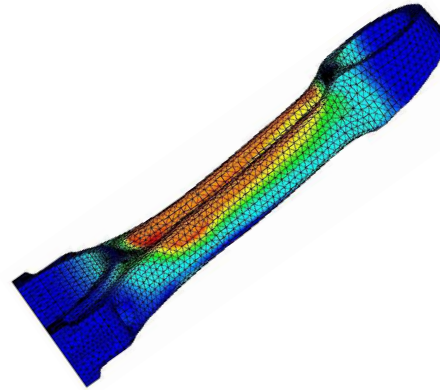
Base Engine	Prototype V6 with IEM
Swept Volume	3190cc
Max Power @ 5,000rpm	450 hp on E85, 400 hp on 98 RON gasoline
Target Max Torque	900 Nm on E85, 775 Nm on 98 RON gasoline
Max Torque RPM	3000 rpm
Target Max BMEP	35 bar on E85, 30 bar on Indolene (98 RON)
Compression Ratio	10.0:1
Maximum Cylinder Pressure	180 bar
Cam Phaser Authority	50 degCA
Transient Torque Response time	<1.5s to 90% SS torque at 1,500 rpm, <1.0s to 90% SS torque at 2,000 rpm
Fuel System	Twin pump DI, 20 MPa capable



EBDI Hardware



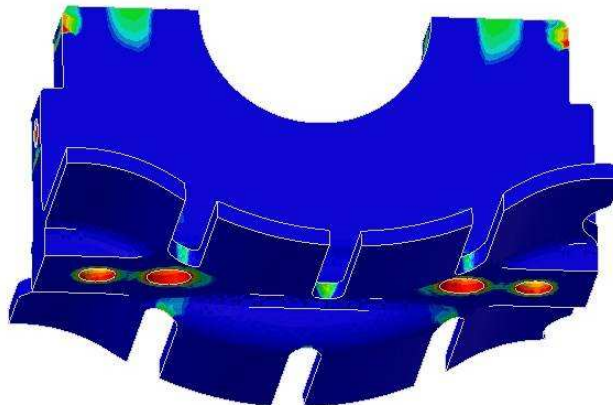
*Piston FEA model
max temperature condition*



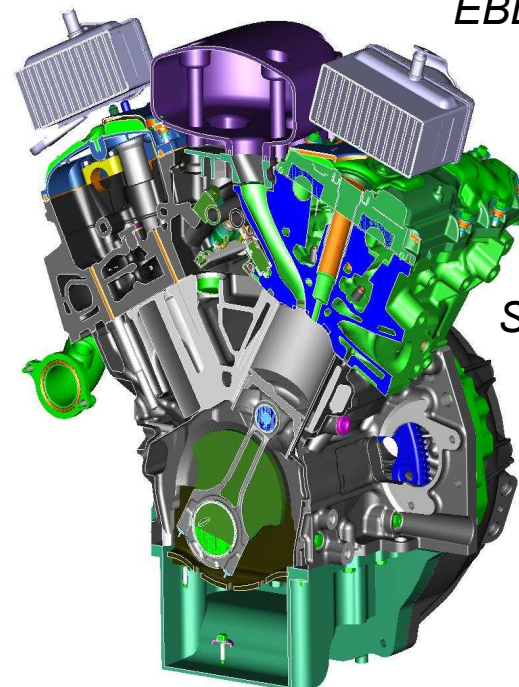
*Connecting rod FEA model
max bending condition*



EBDI hardware on test

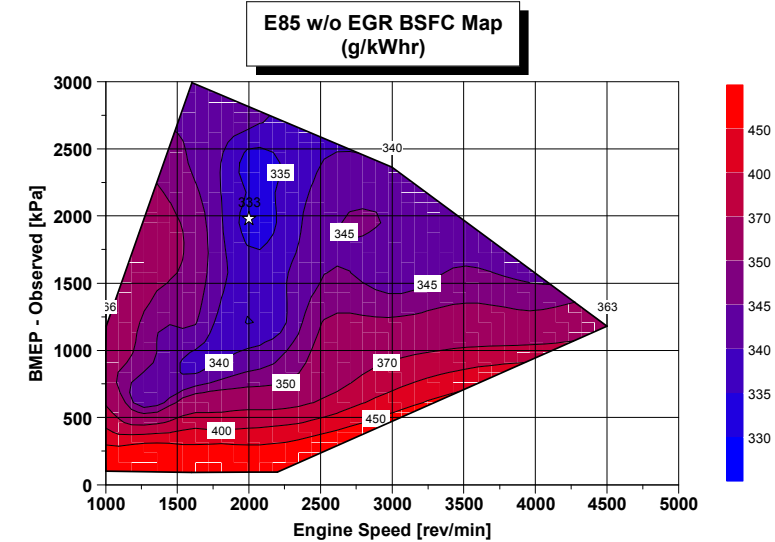
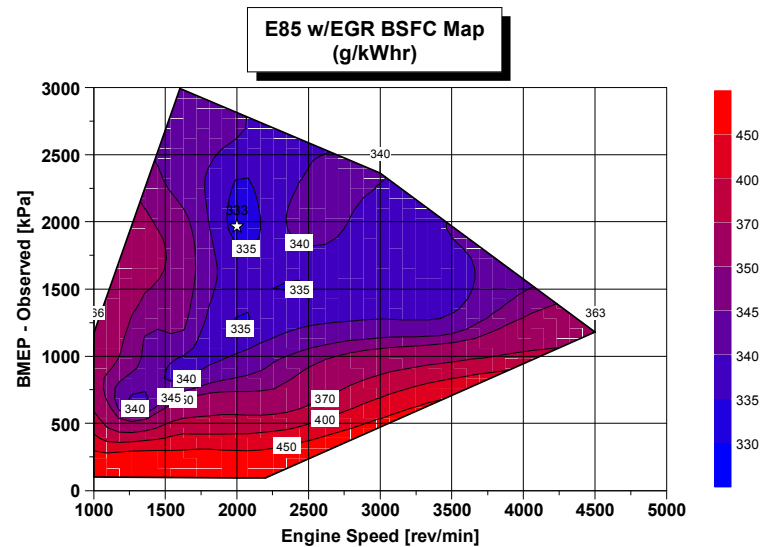
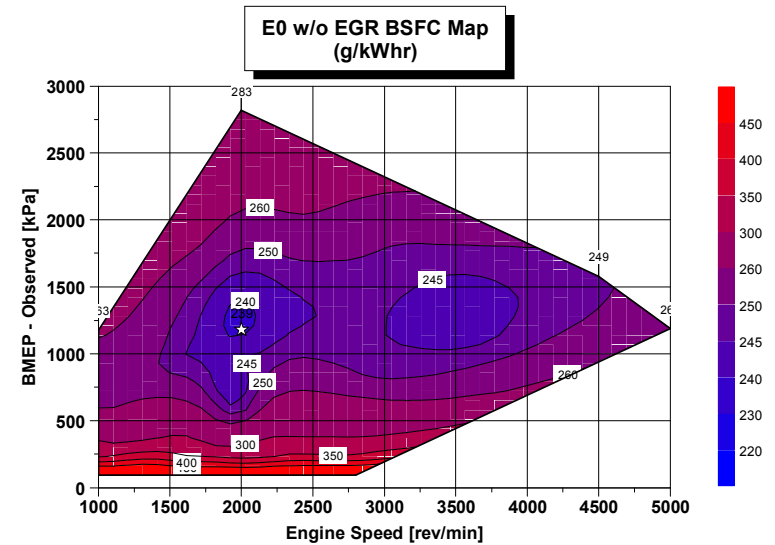
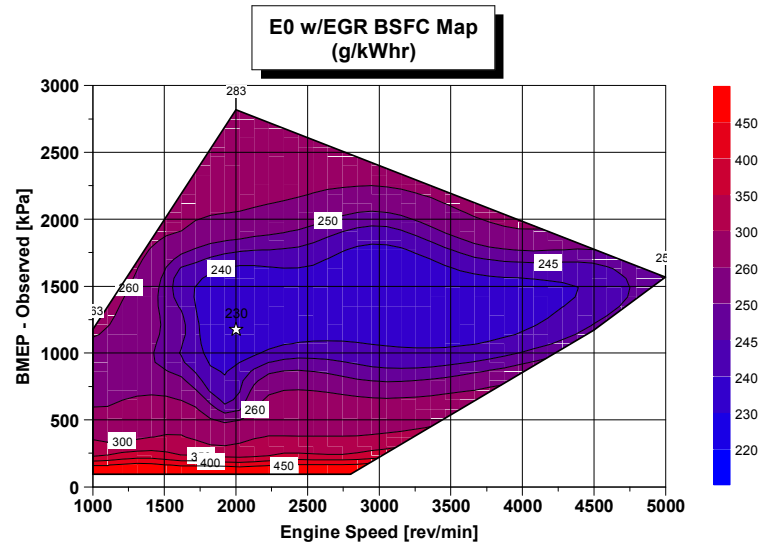


*Integrated ladder frame
and main bearing cap
analysis model*



*Section view of
EBDI dyno
hardware*

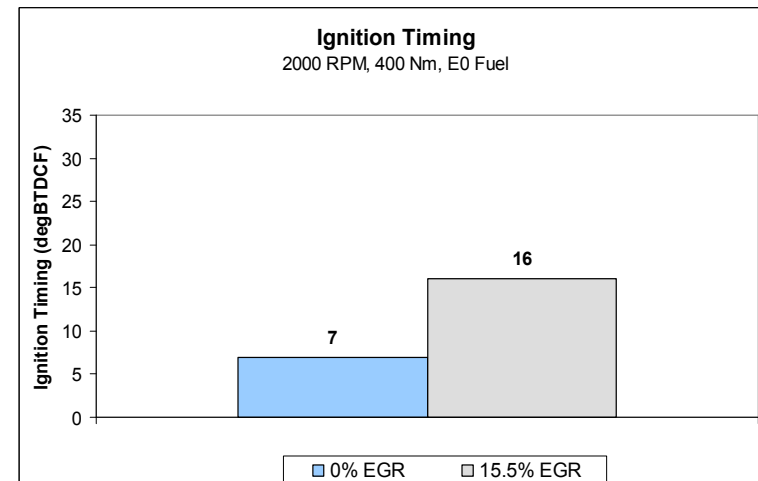
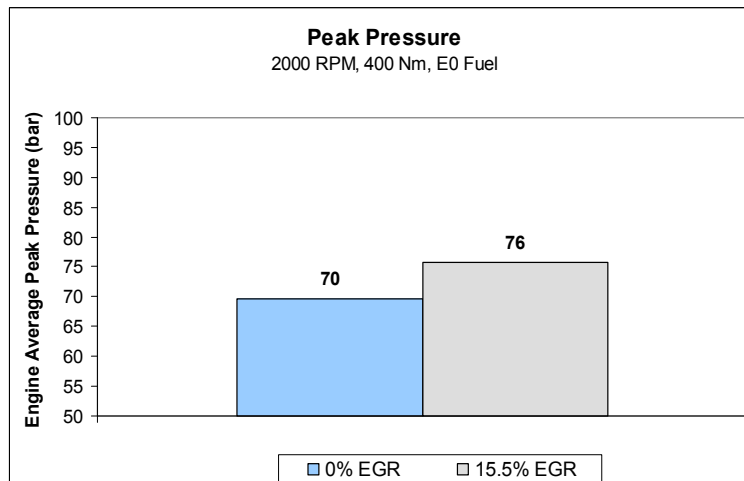
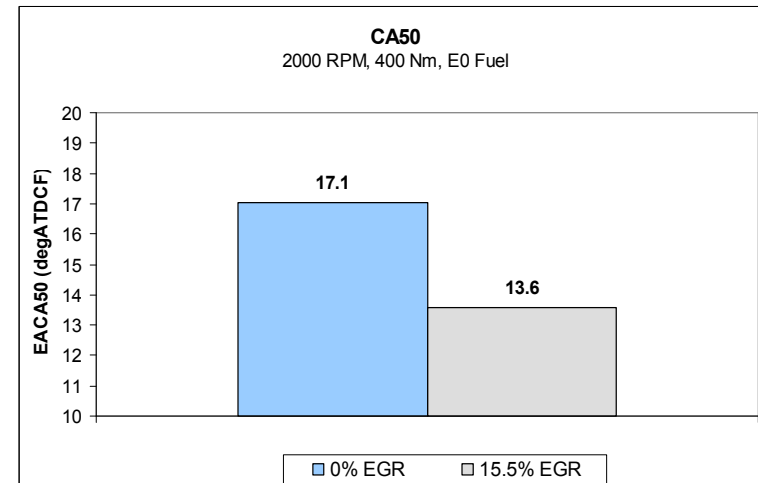
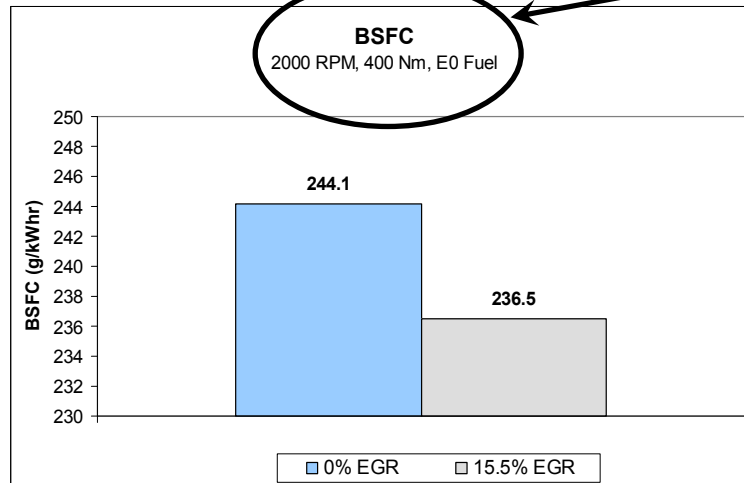
EBDI Efficiency Maps



EBDI Example Operating Point



2,000 rpm 16 bar BMEP on E0

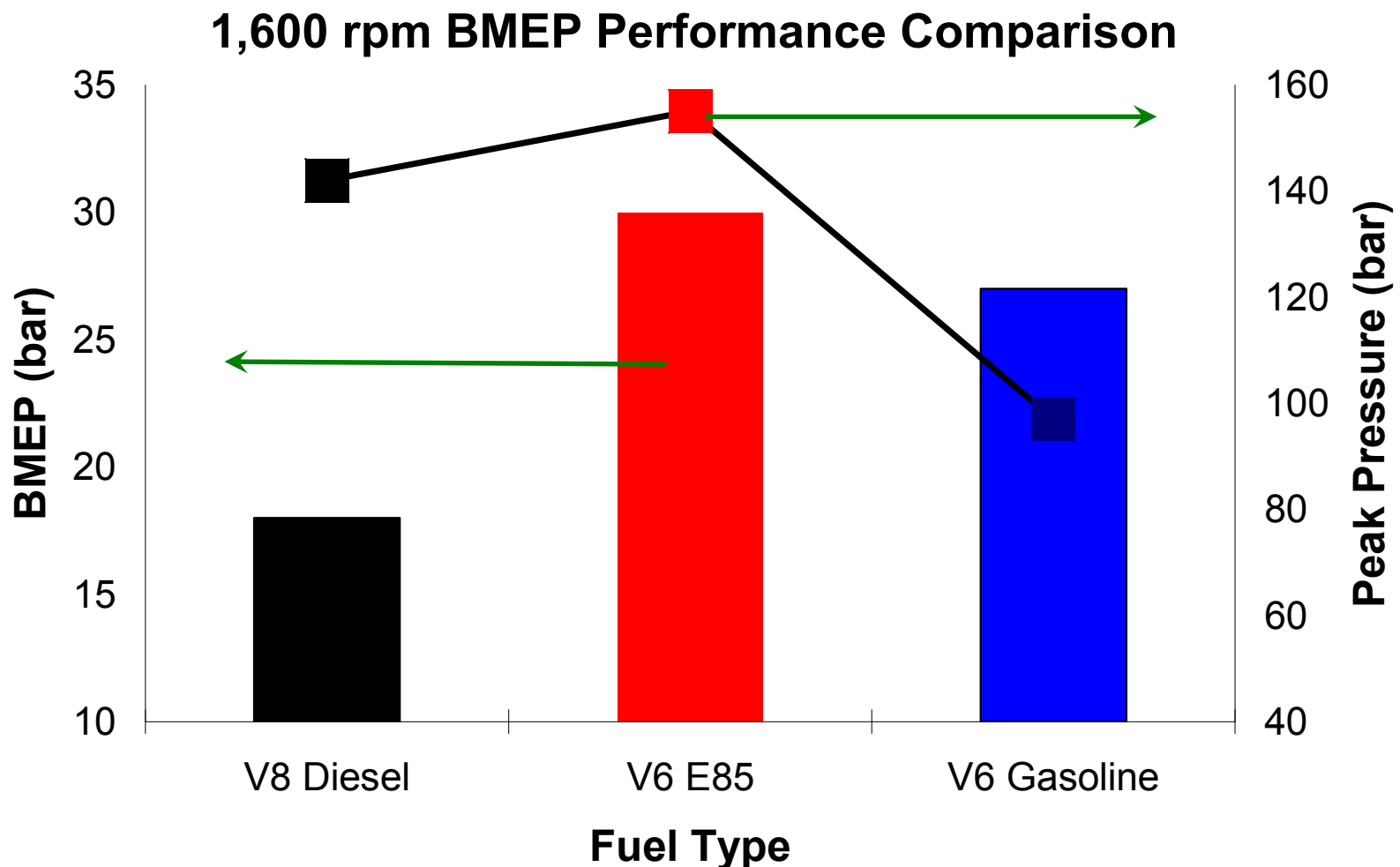


Data acquired at equivalent knock intensity and air / fuel ratio

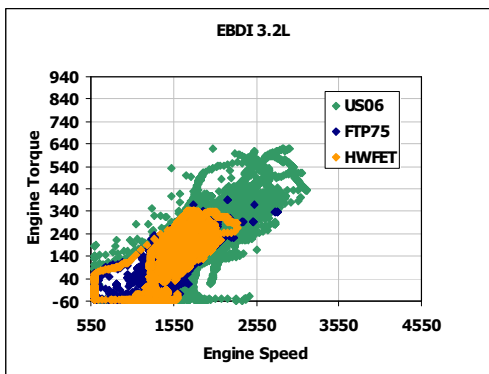
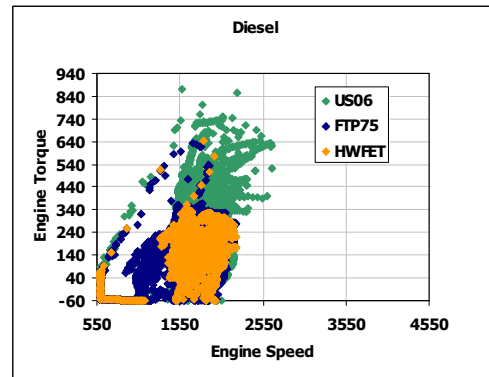
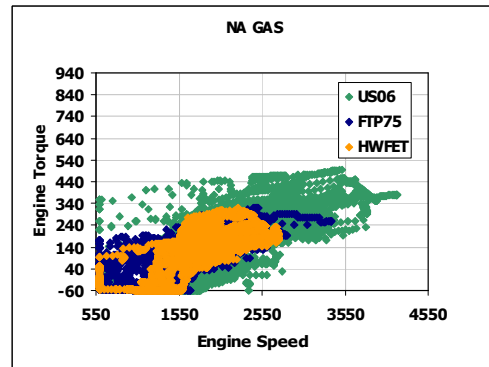
EBDI Low Speed Torque Comparison



- Data shows that “high low speed torque” is not unique to diesel engines
 - SI engines achieve higher low speed torque with less cylinder pressure

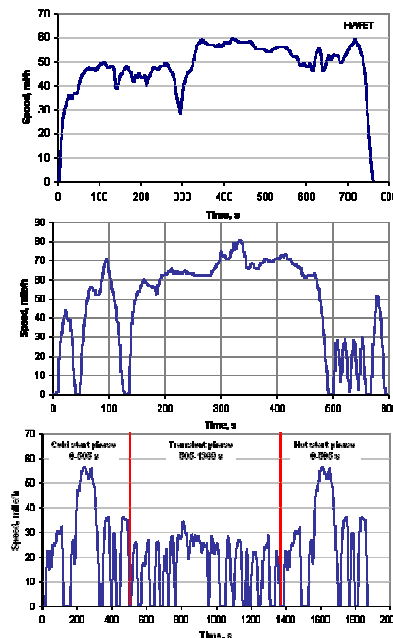


EBDI Vehicle Simulation Results

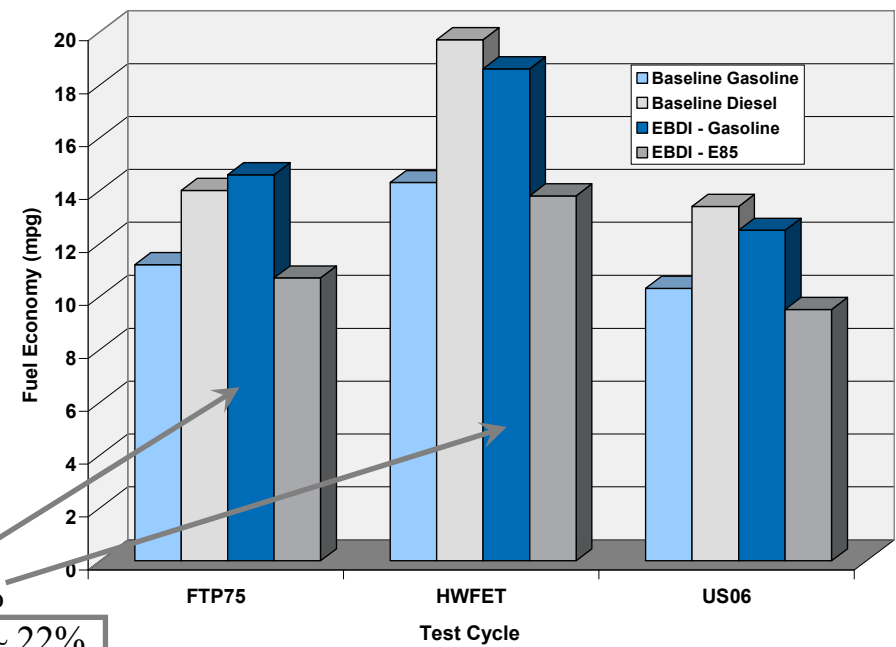
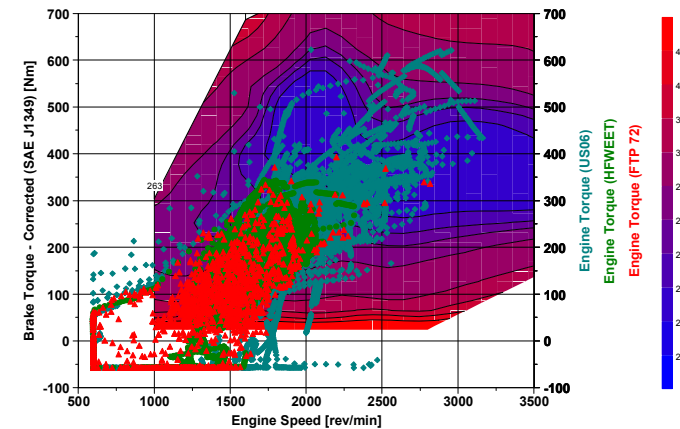


Simulation of target 8,000lb pickup truck

Standard transmission ratios assumed



E0 w/EGR BSFC Map vs. US06, HWFET, and FTP72 Cycles



FTP75 FE gain ~27%
HWFET FE gain ~16%
Combined FE improvement ~22%

EBDI Next Steps



- Based on initial test results an updated design was specified to improve performance and efficiency and implement into a vehicle

