DEER Conference 2009
Directions in Engine-Efficiency and Emissions Research

Turbocharged Spark Ignited Direct Injection – A Fuel Economy Solution for The US

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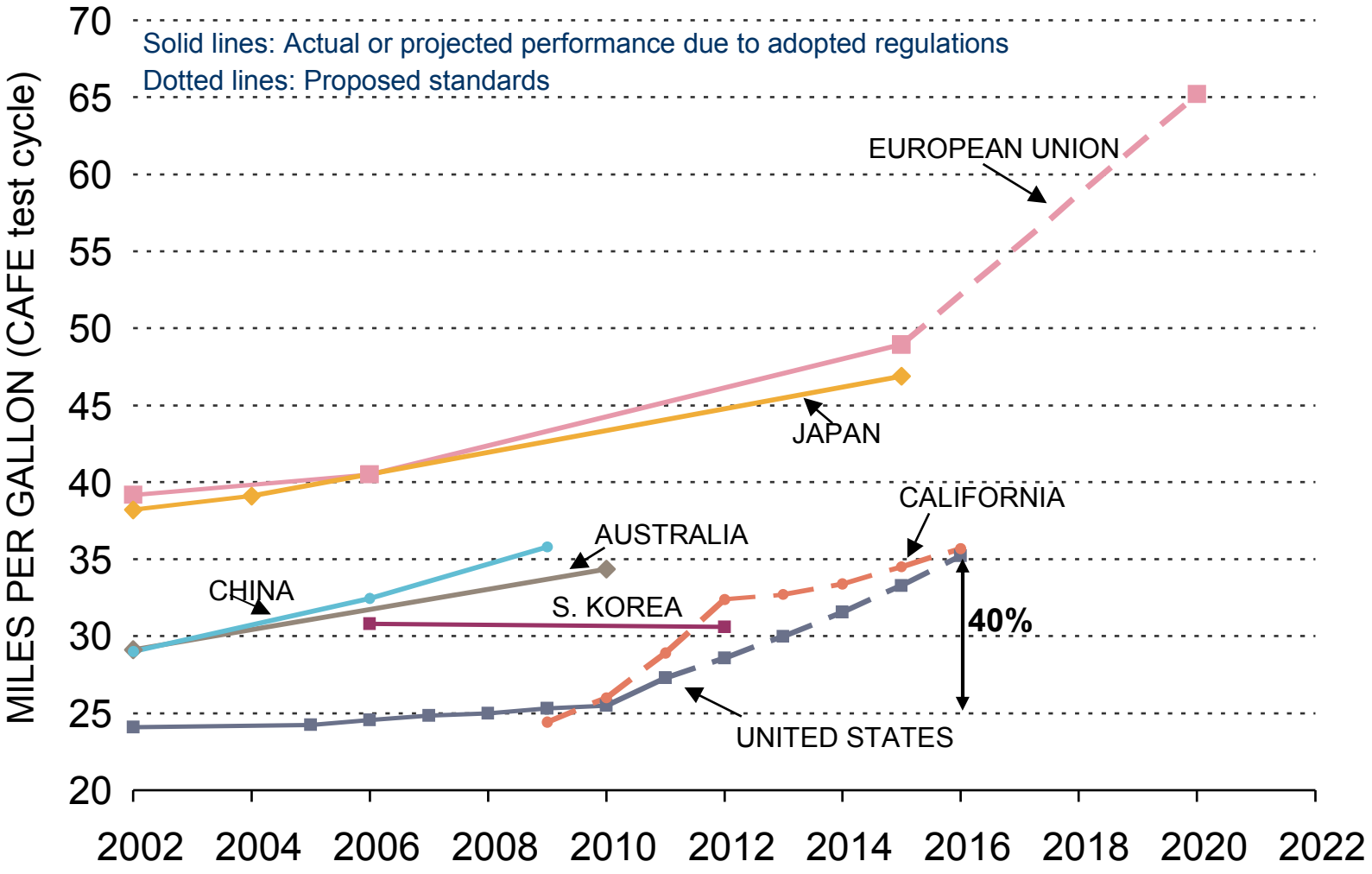
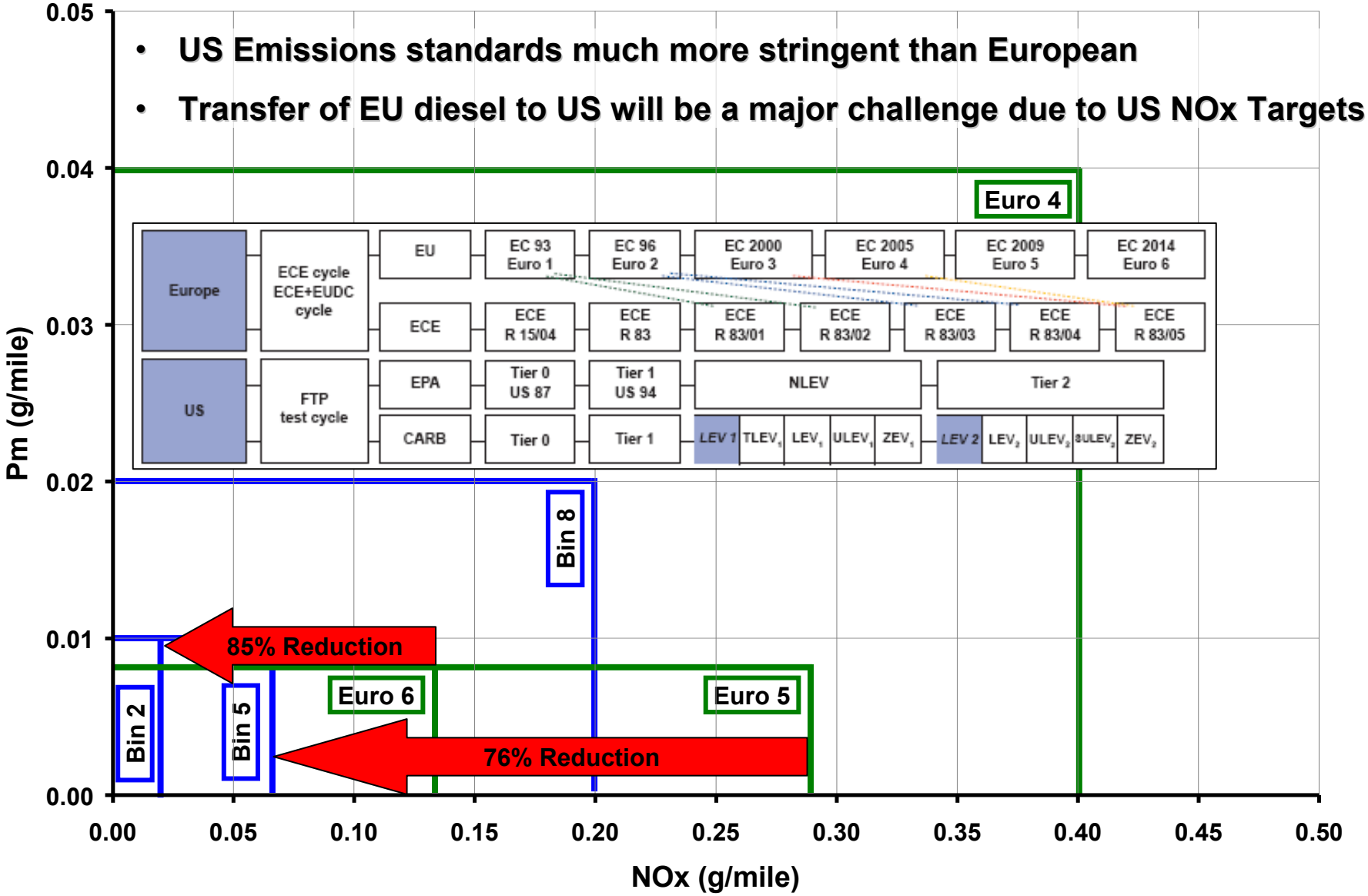
Worldwide Fuel Economy Standards for New Passenger Vehicles by Country/Region, 2002-2020



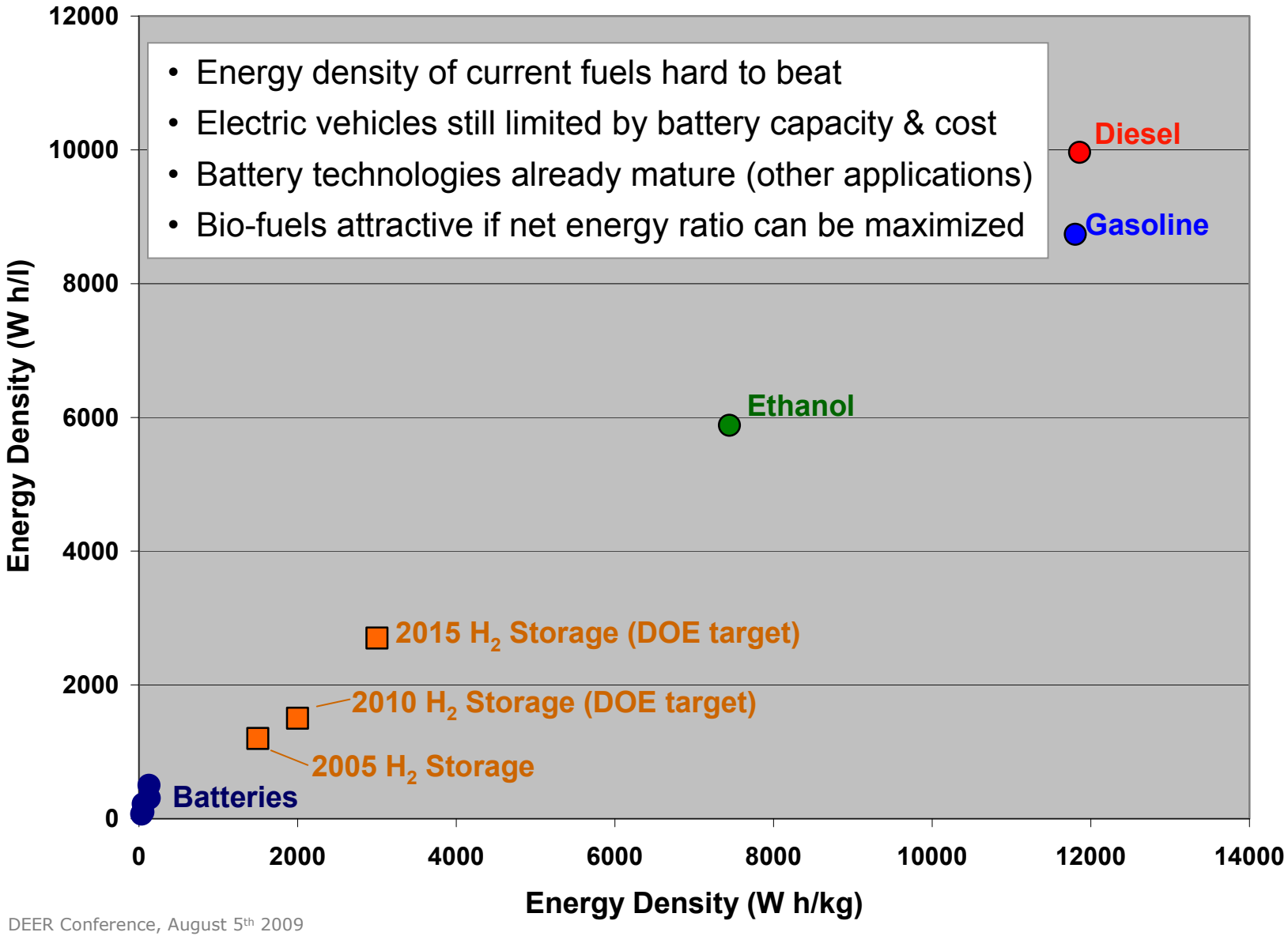
Source: *Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update,* ICCT. May 2009 update

The US Diesel Emissions Challenge



Source: *Delphi Worldwide Emissions Standards Passenger Cars and Light Duty Trucks 2008*

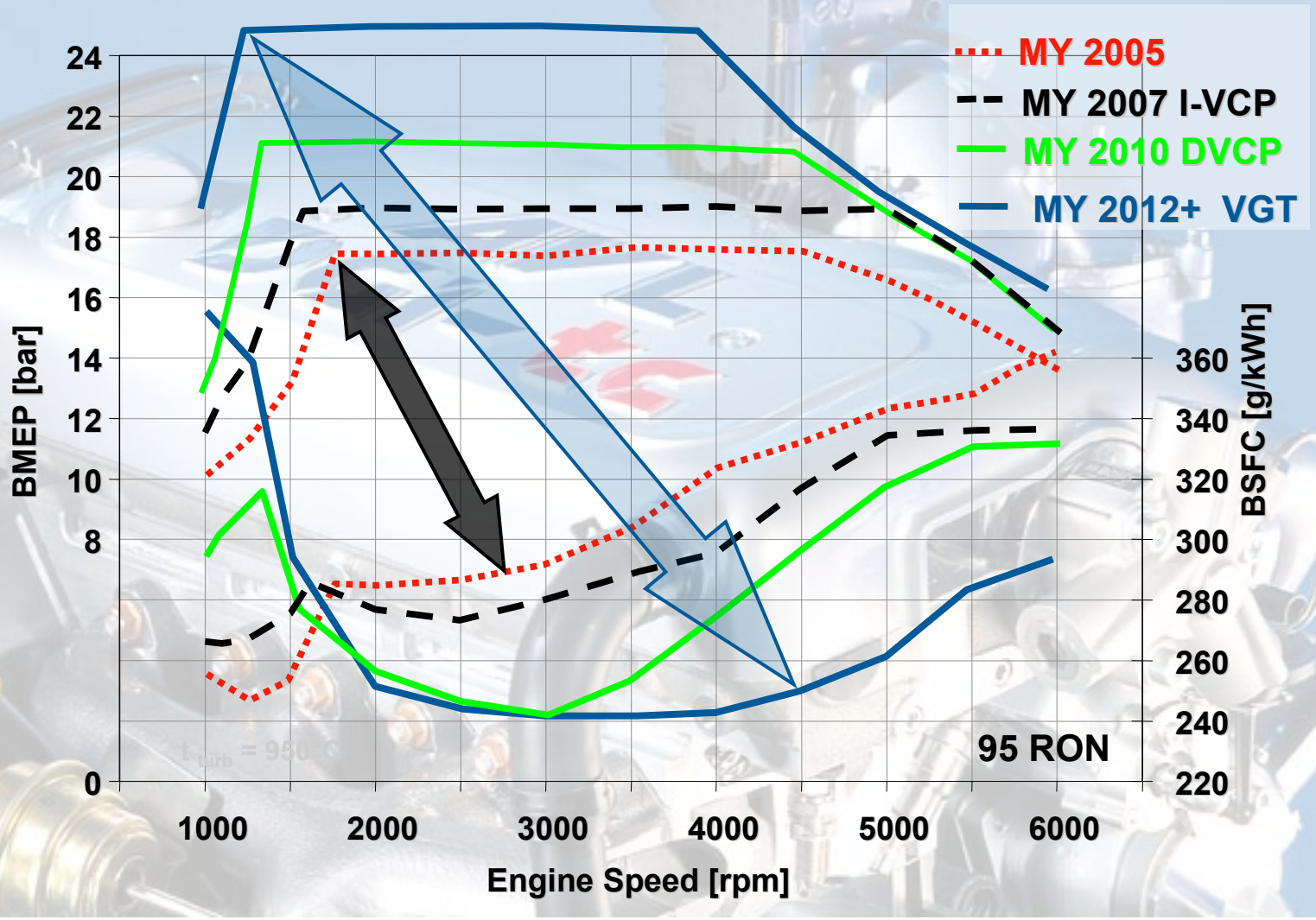
Energy Density of Current & Future Automotive Energy Carriers



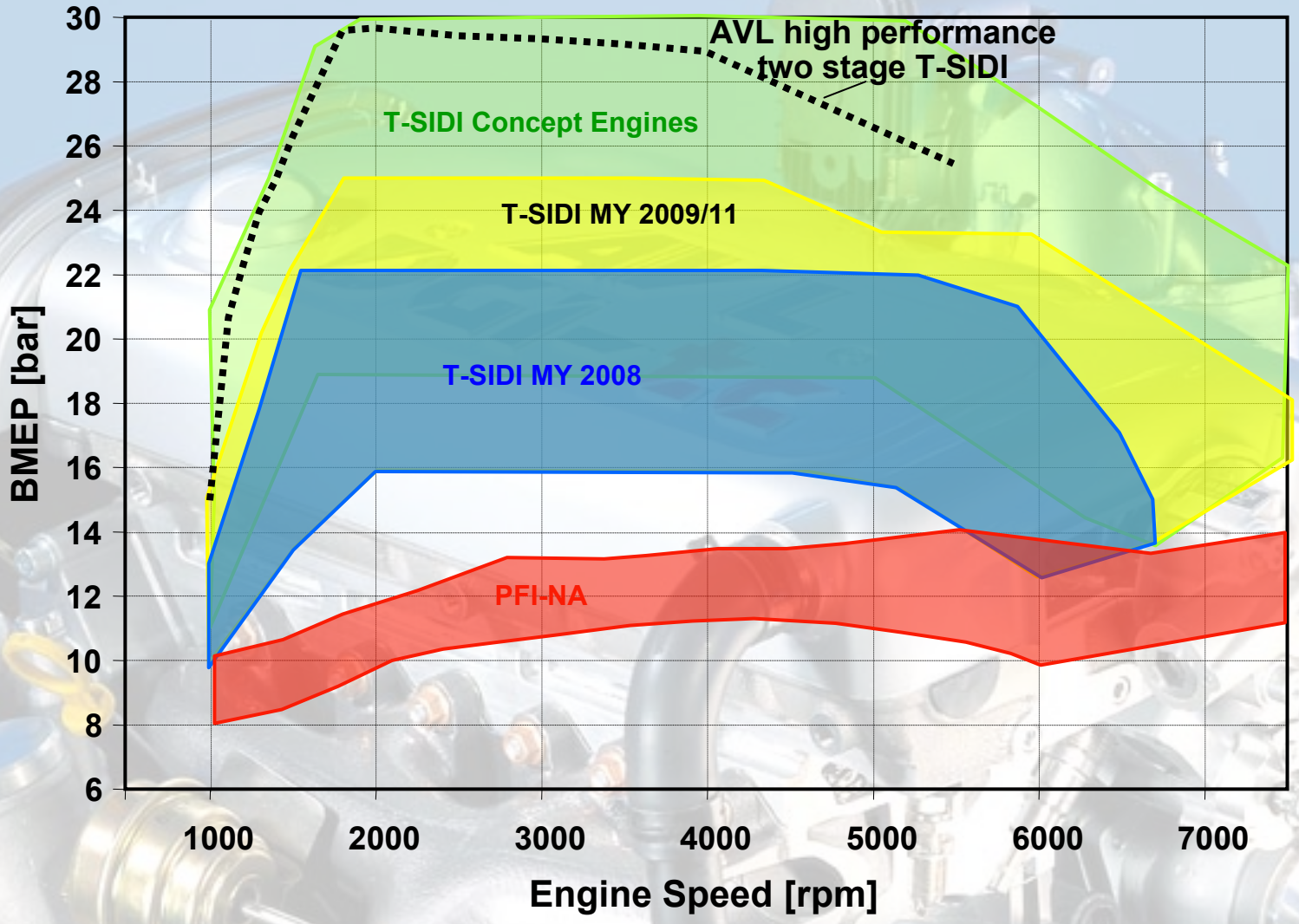
Market & Technology Trends - Gasoline Engines

Technology	Micro PC Engines < 1,0 l	Small PC Engines 1,0 - 1,5 l	Medium PC Engines 1,5 - 2,4 l	Large PC Engines > 4 cyl	LDT / MDT Truck
Variable Cam Timing					
Variable Valve Lift 2 / 3 Step					
Variable Valve Lift Continuous				?	
Cylinder Deactivation			?		
NA Homogeneous SIDI					
TC Homogeneous MPI / SIDI					
SIDI Stratified		?	?	?	?
Controlled Auto Ignition			?	?	?

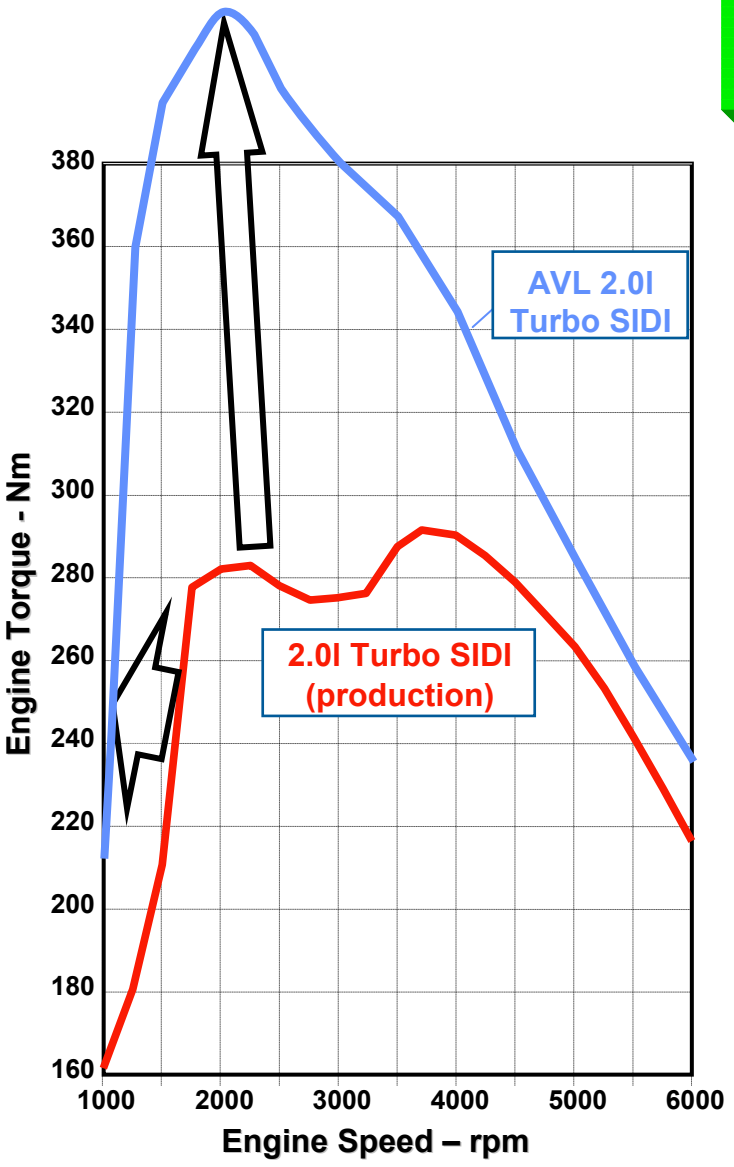
Turbocharged SIDI
Low End Torque Vs. Mid / High Speed BSFC



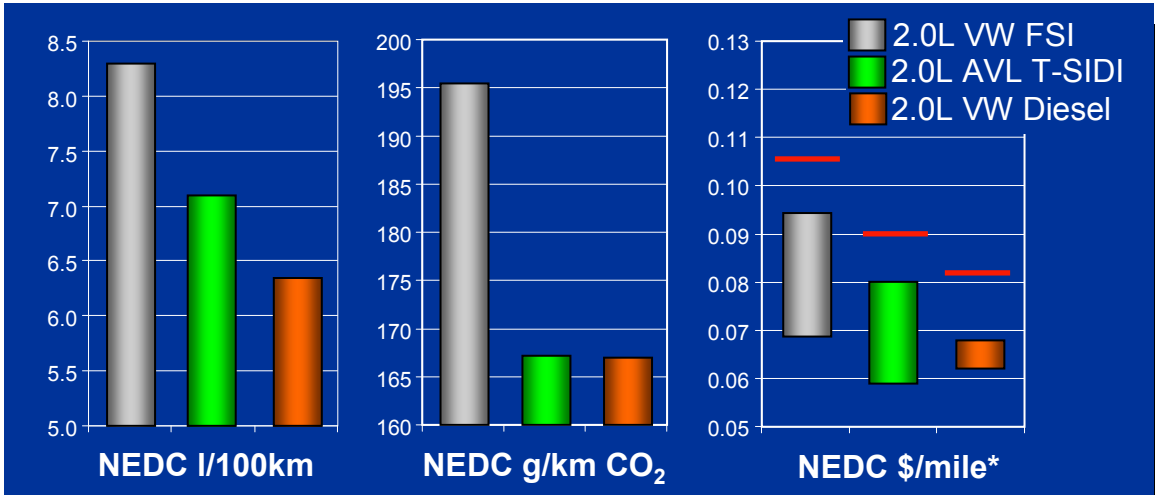
Full Load Potential Of Gasoline Engines



Showing The Potential Of Turbocharged SIDI
AVL- Turbo SIDI Demonstrator

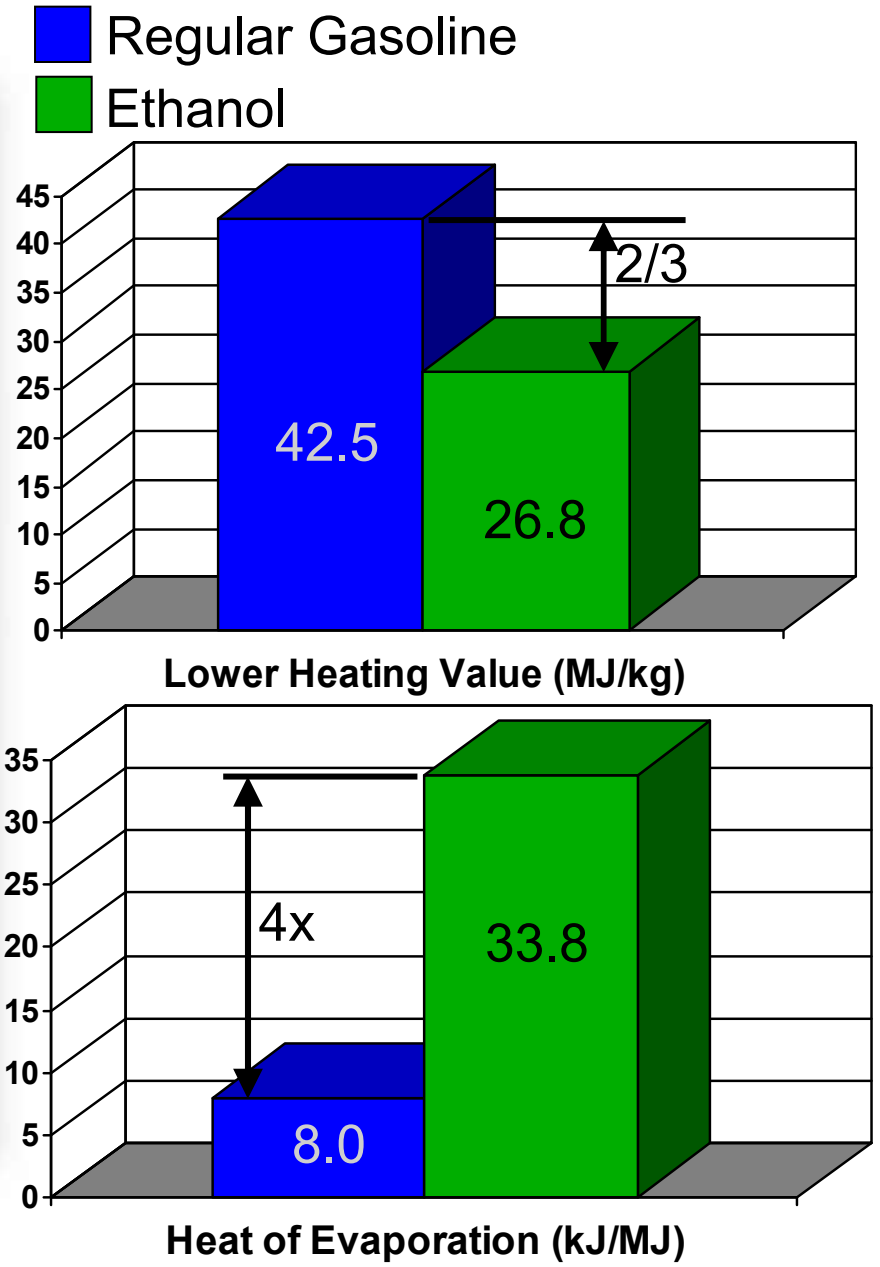


➡ **Increased full load performance allows longer final drive ratio for improved fuel economy**

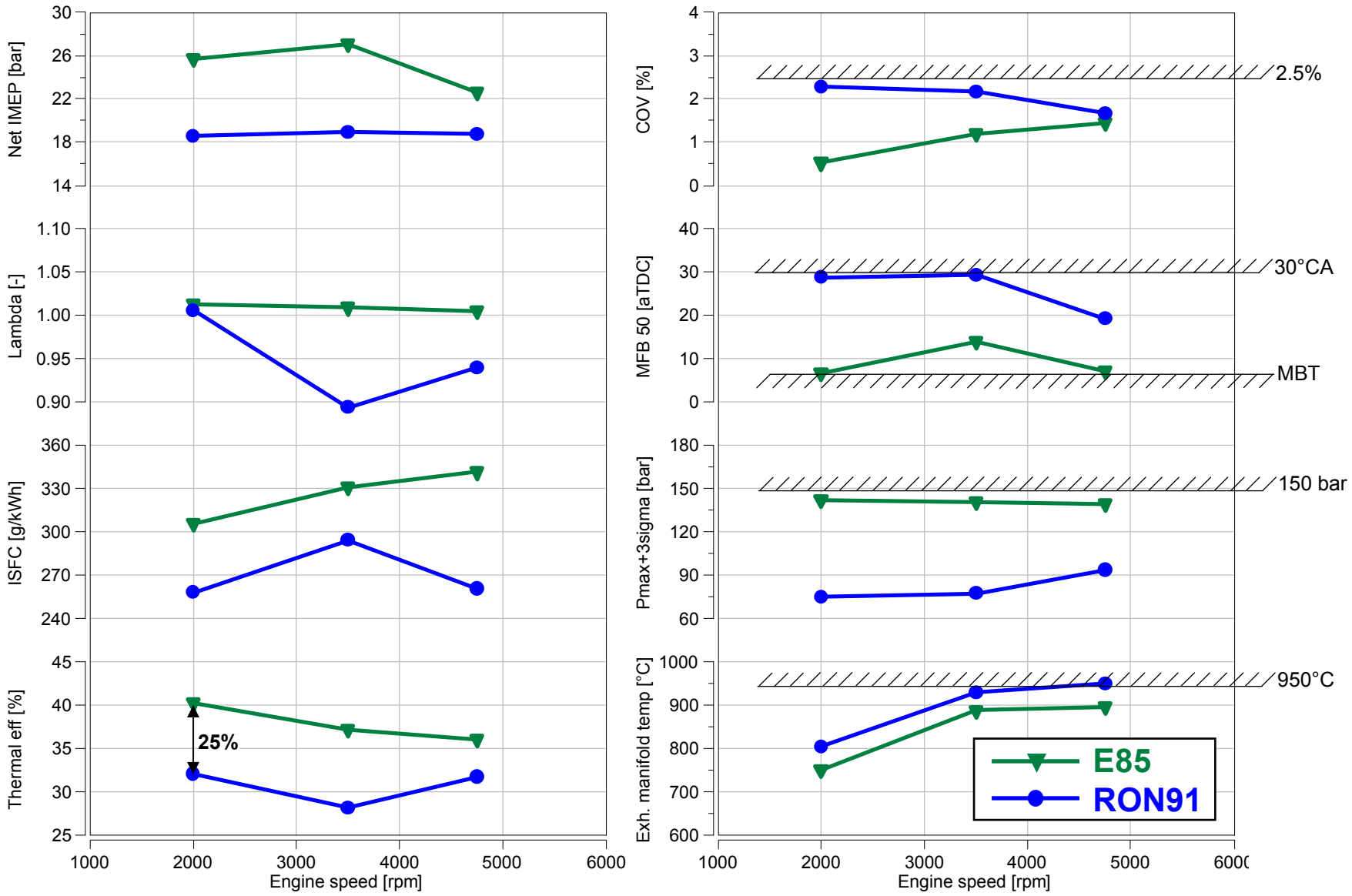


*Cost per mile comparisons show best & worst case gasoline vs diesel fuel costs US fuel costs Feb '07 – Jul '09. Red bars for average fuel costs in that period.

Ethanol Turbocharged Direct Injection



Ethanol DI Full Load Benefits - E85 vs. 91 RON (regular gasoline)



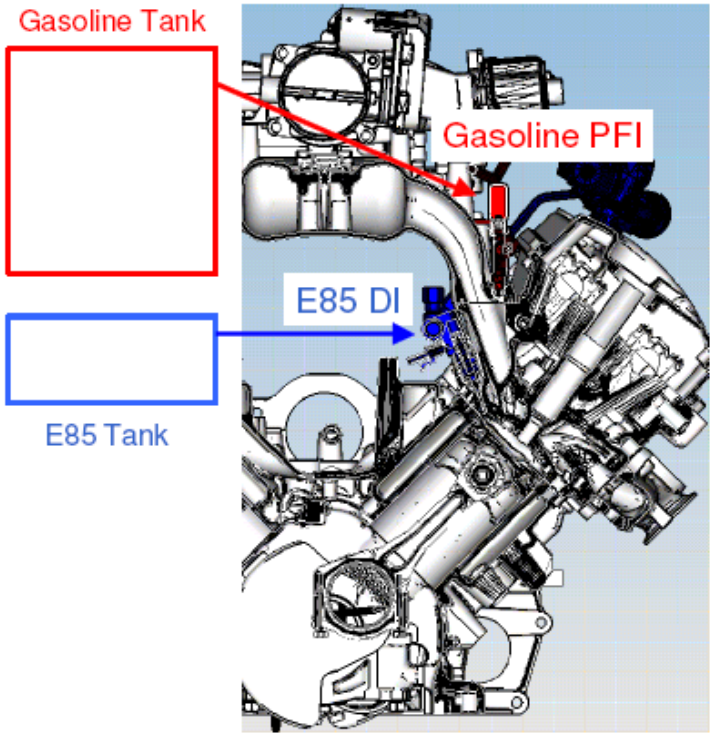
Source: *Ford/AVL DOE Merit Review Presentation May 2009*

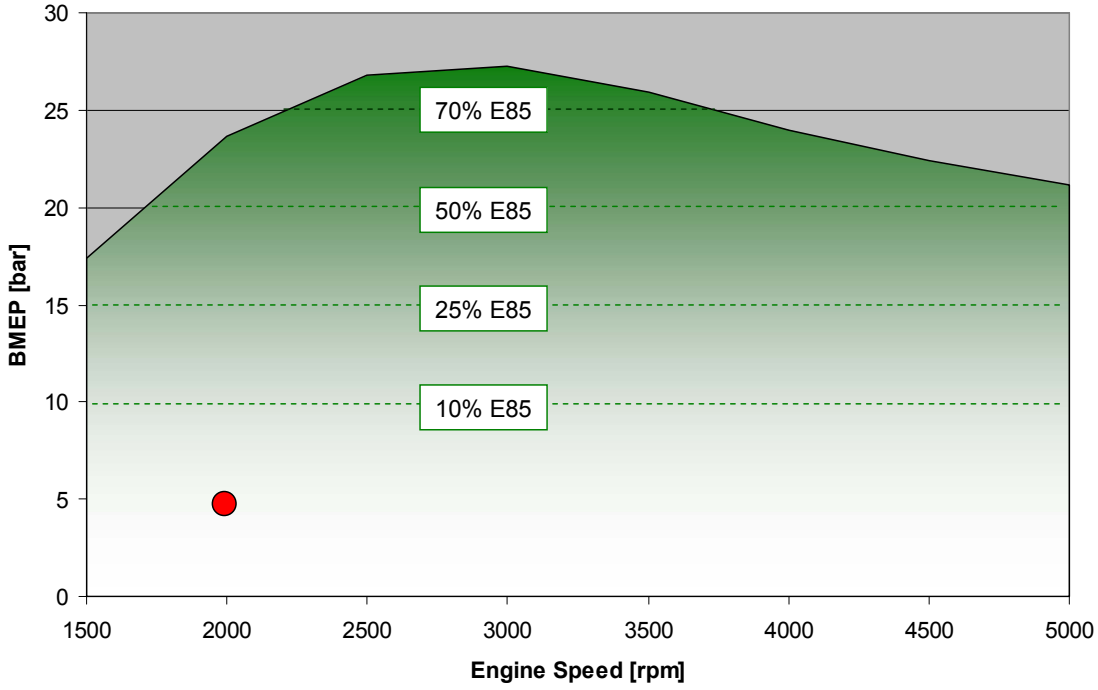
EBS Dual Fuel Strategy

- E85 provides significant octane benefit with DI due to high latent heat of vaporization and high octane rating
- Allows knock-free operation at high CR and high BMEP with very high thermal efficiency

but…

- Low E85 heating value is a disadvantage

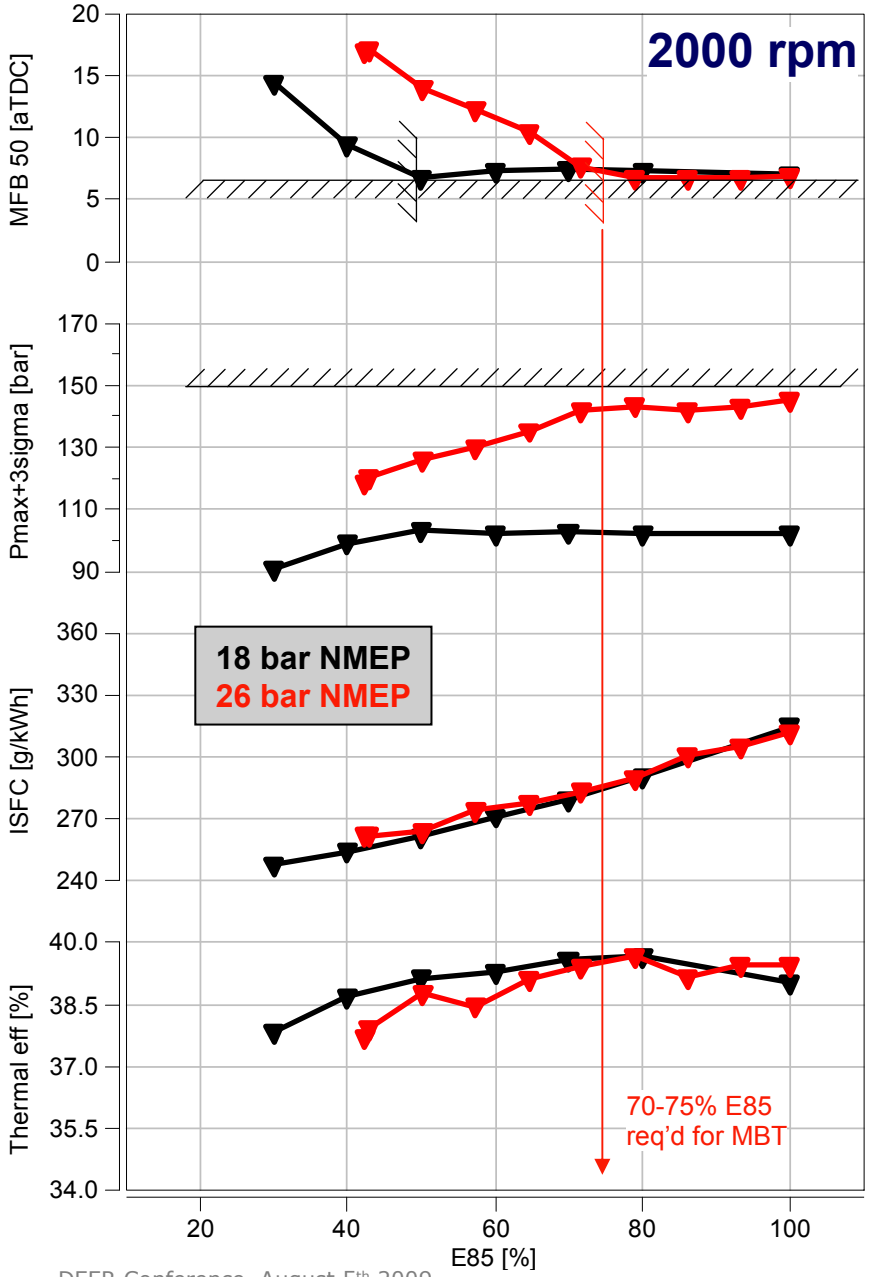


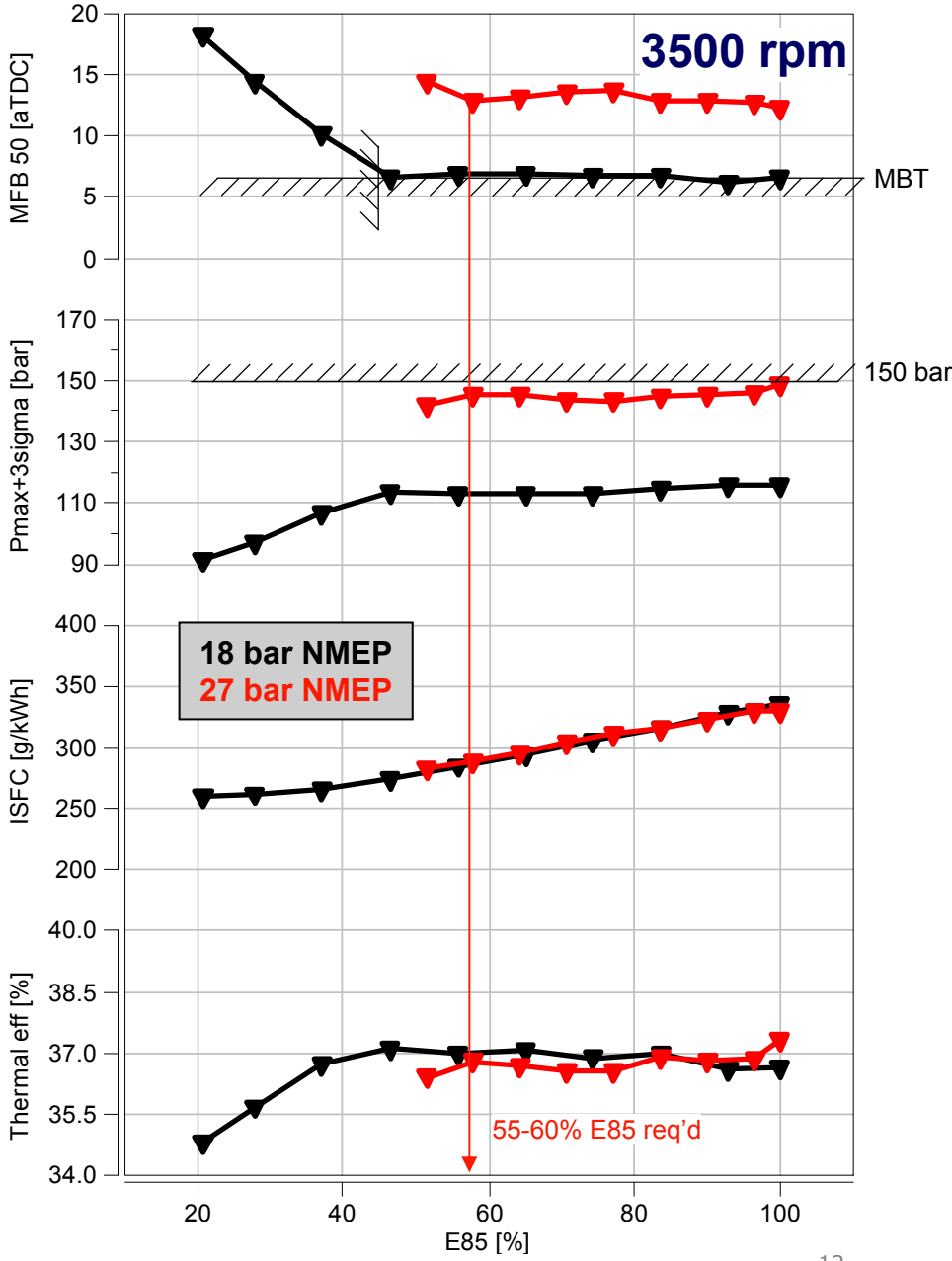


- Dual fuel strategy uses E85 DI only as required to eliminate knock in a high CR gasoline engine.
- Combines high load E85 octane benefit with part load gasoline heating value advantage
- Provides maximum leveraging of available ethanol

Source: *Ford/AVL DOE Merit Review Presentation May 2009*

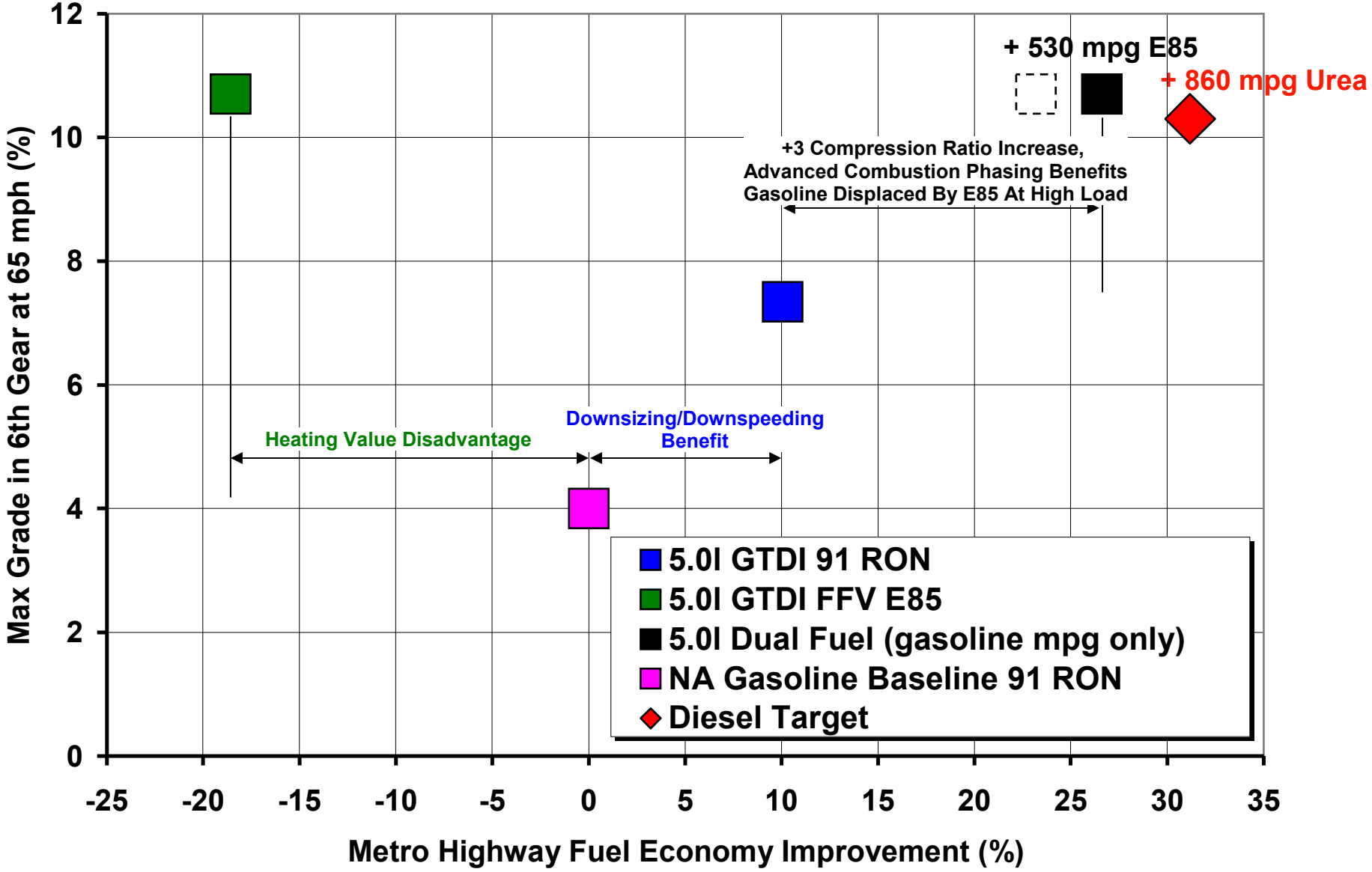
Dual Fuel E85 DI % sweep, Full Load, 9.3 CR





Source: *Ford/AVL DOE Merit Review Presentation May 2009*

Cycle Simulation Results
Dual Fuel Optimized E85 Engine vs. Competitors
Medium Duty Truck



Source: *Ford/AVL DOE Merit Review Presentation May 2009*

Summary

- Future fuel economy improvements will come from a variety of technologies
- Gasoline engines will be the dominant US powertrain for the foreseeable future
- Turbocharged SIDI is the most promising advanced gasoline technology:
  - ✓ Combines existing & proven technologies in a synergistic manner
  - ✓ Offers double digit fuel economy benefits
  - ✓ Much lower cost than diesel or hybrid
  - ✓ Can meet future emissions standards with inexpensive gasoline aftertreatment
  - ✓ Can be applied across an OEM's entire engine portfolio in high volume
  - ✓ Provides benefits when operating on E85 in Flex Fuel applications
  - ✓ Dual fuel (PFI gas + DI ethanol) concept new benchmark for SI fuel economy