

# **SwRI's HEDGE Technology for High Efficiency, Low Emissions Gasoline Engines**

**DEER Conference  
Detroit, MI  
29 September 2010**

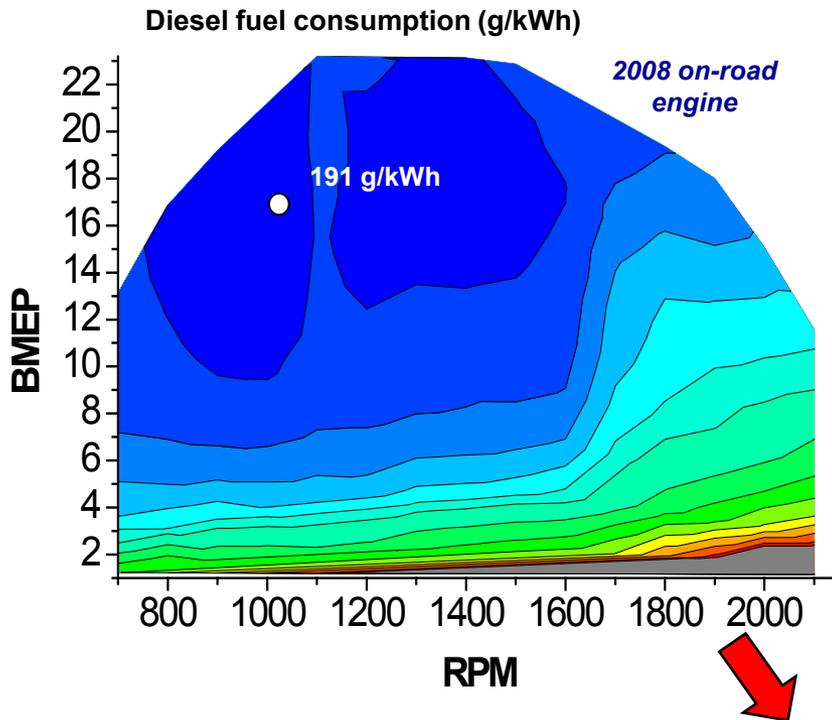
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# Current State-of-the-Art Engine Technology

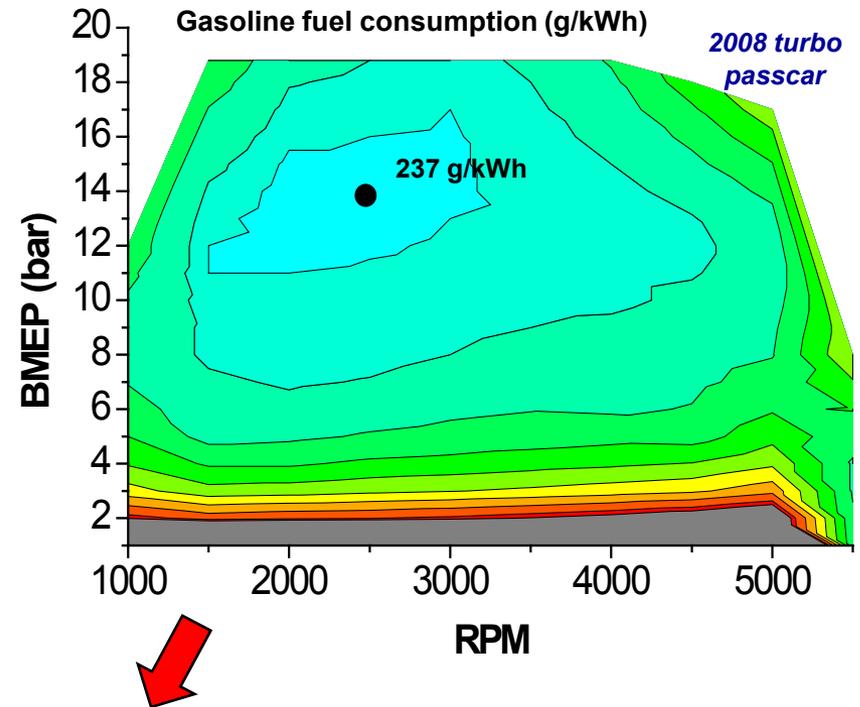
## ■ Diesel

- World-class efficiency, but expensive NOx & PM aftertreatment



## ■ Spark ignited gasoline

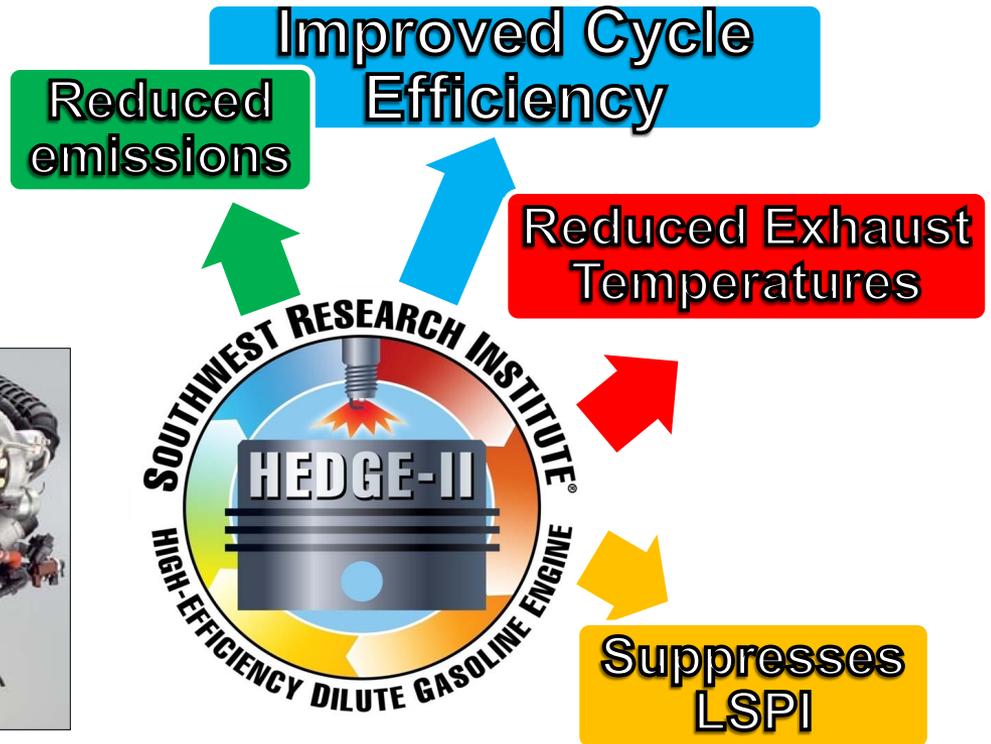
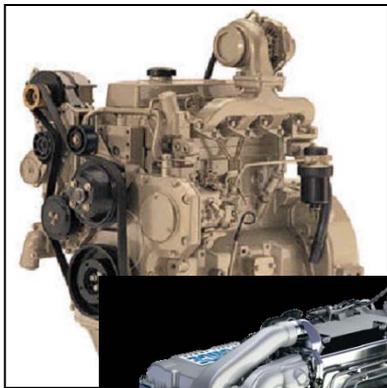
- Less efficient, but best tailpipe emissions w/ inexpensive catalyst



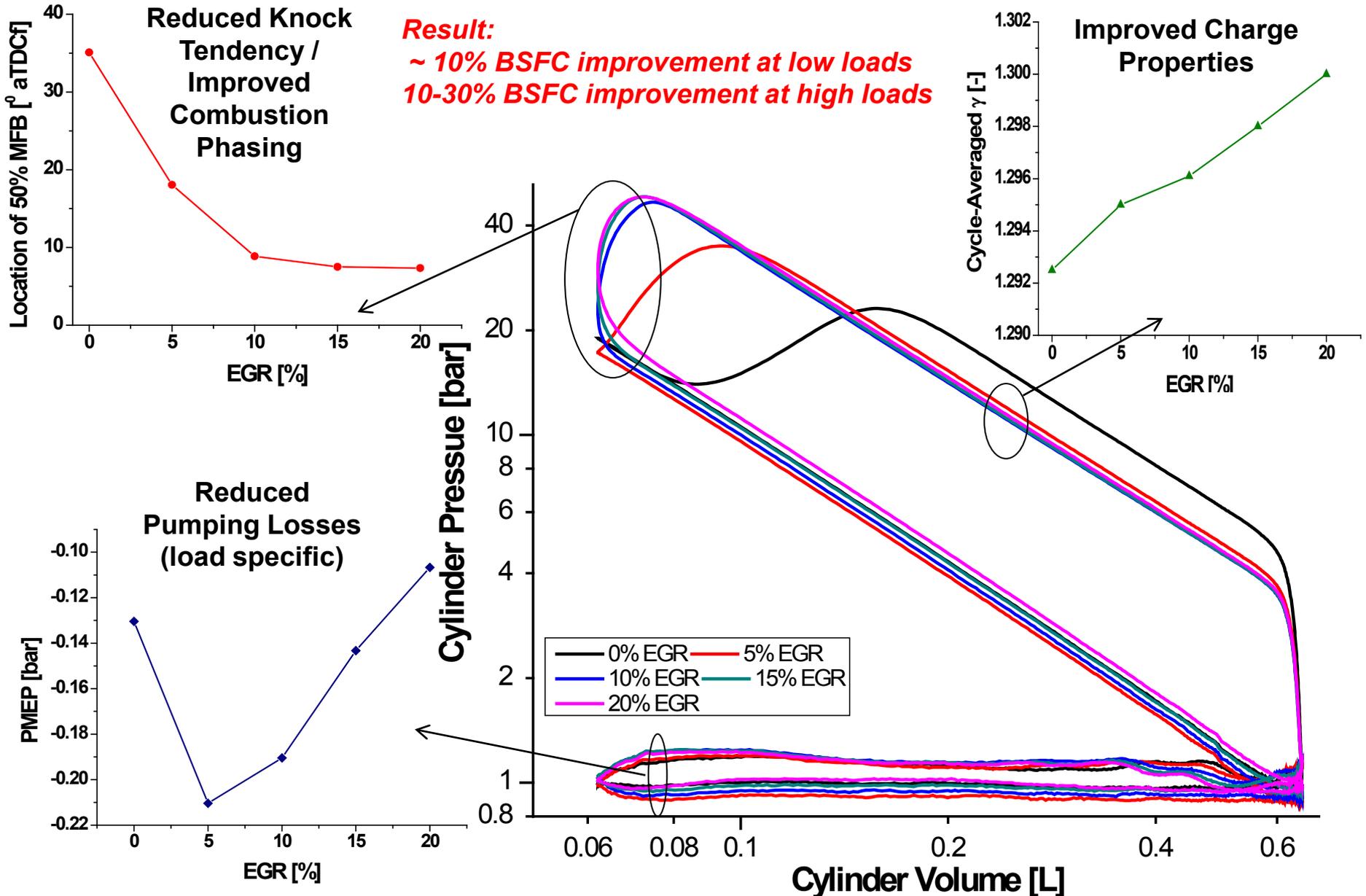
At what cost / emissions level  
can SI and CI engine efficiencies  
converge?

# SwRI HEDGE™ Technology

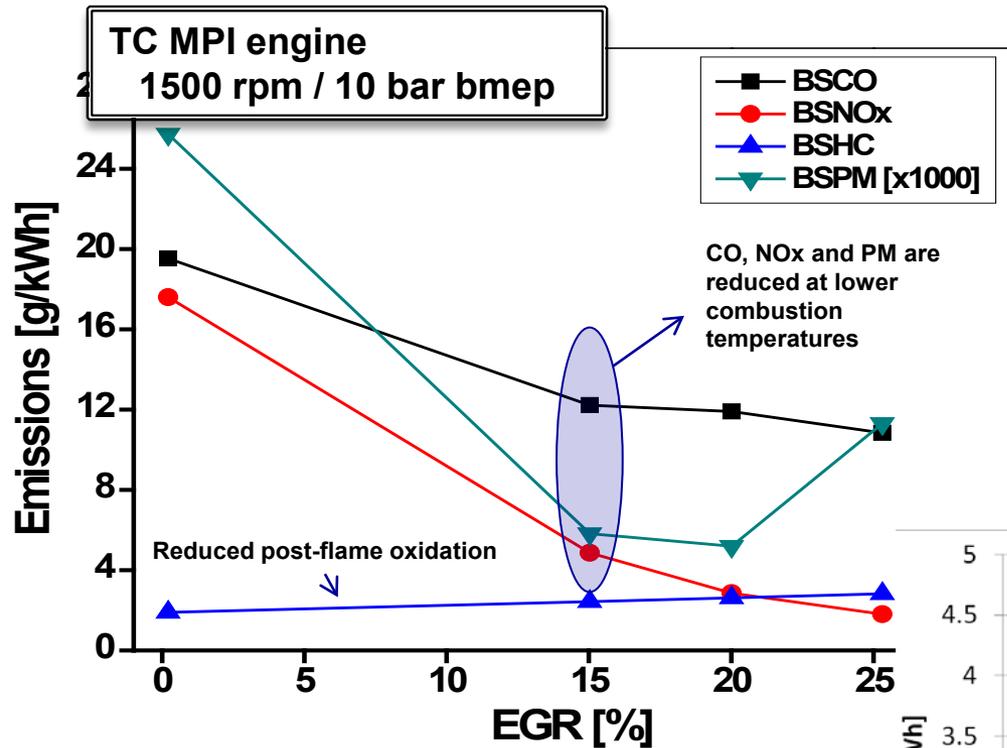
- A high efficiency solution for the gasoline engine
  - Improved low-load BSFC → high CR and reduced PMEP
  - Improved high-load BSFC → high CR and reduced knock
  - Eliminates need for enrichment → cooler PTT at high load
  - Suppresses low speed pre-ignition (LSPI)
- Applicable to many platforms (LD-HD)



# Cycle Efficiency Improvement with EGR

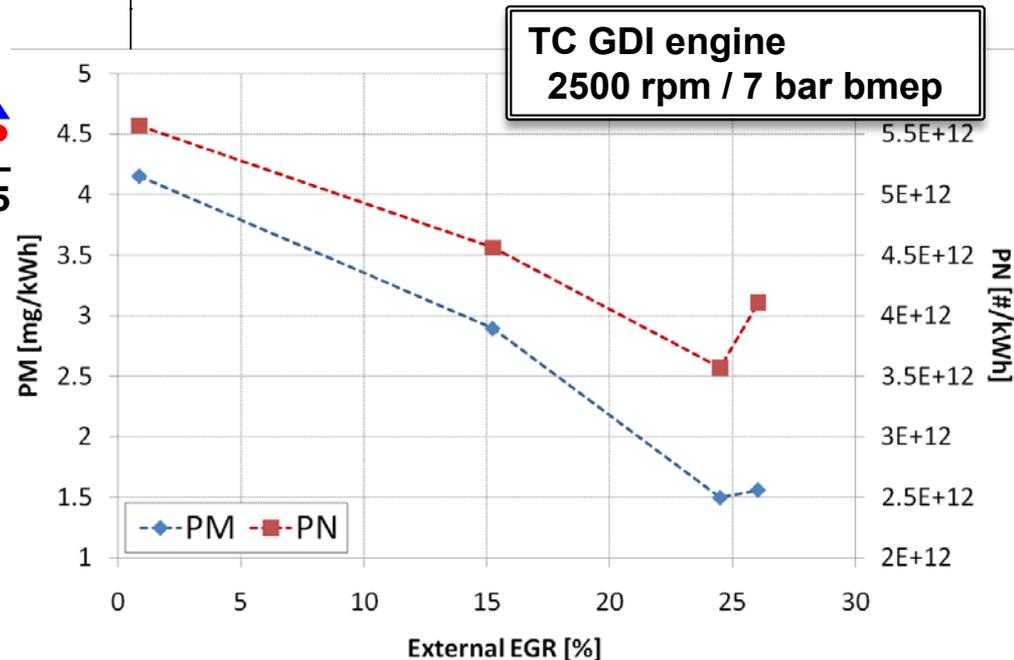


# Emissions Reduction with EGR

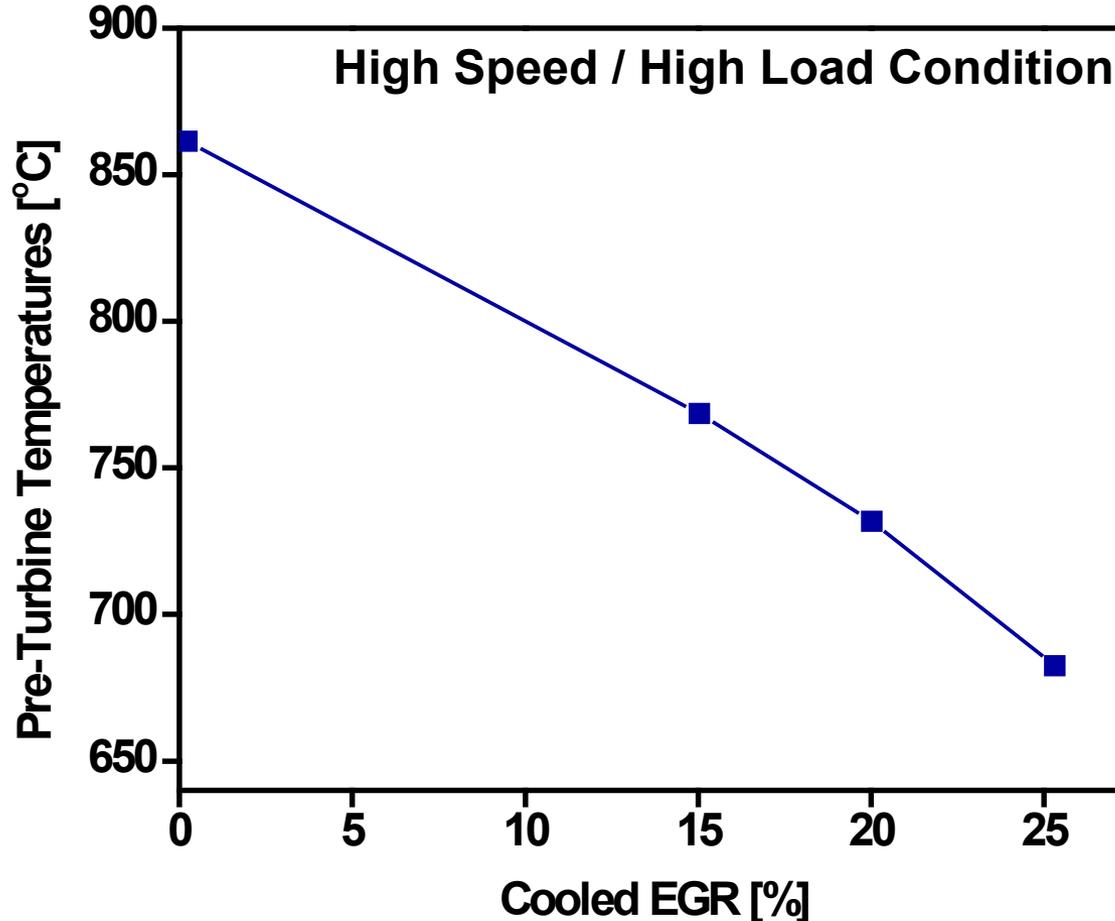


- Gaseous emissions reduction is platform independent
- GDI PM/PN reduction with EGR may offer emissions compliance without a filter
  - PM/PN reduction maintained at high power levels

- Significant emissions reductions possible
- May reduce aftertreatment costs / PGM use
- Lack of enrichment means emissions compliance on highly-loaded cycles



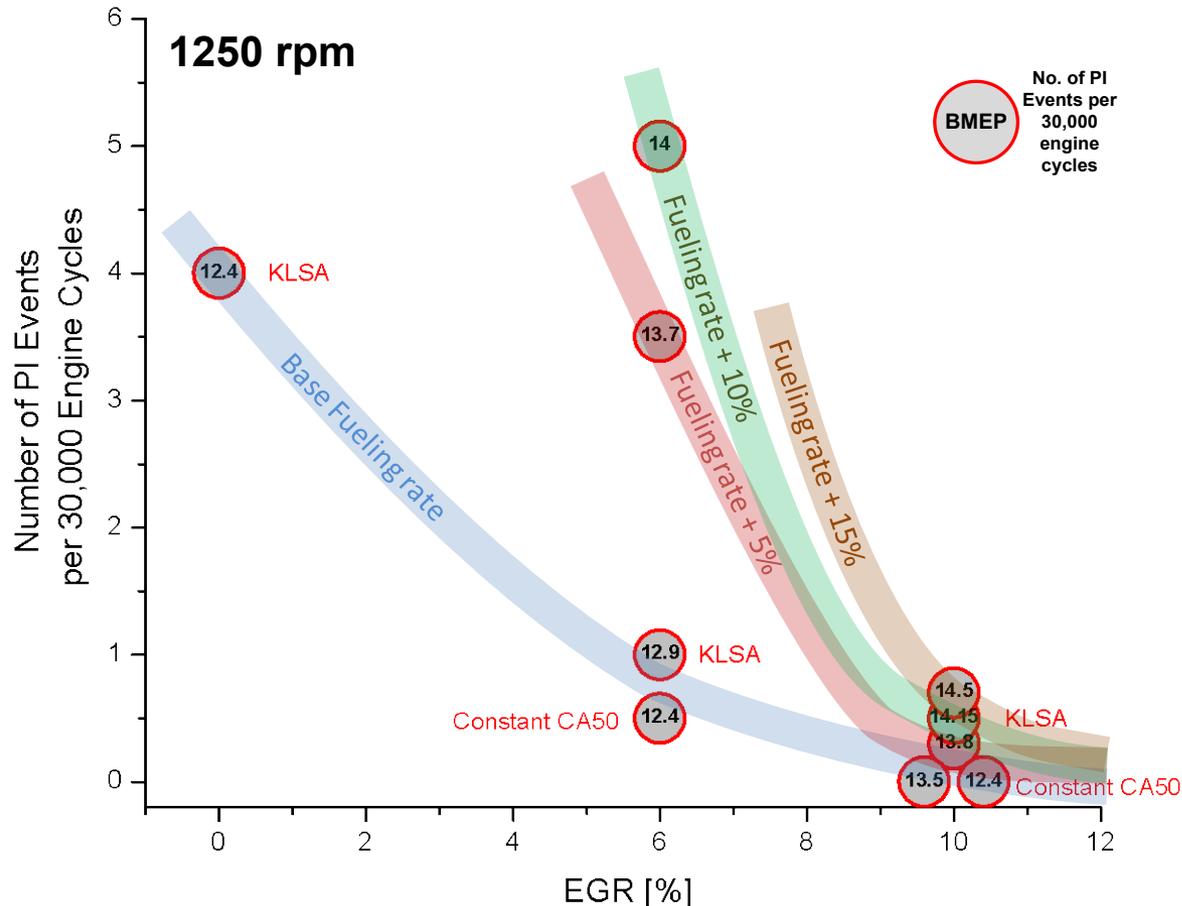
# Reduced Exhaust Temperatures



- Reduced exhaust temperatures eliminated enrichment requirement
  - Can meet emissions at WOT for HD / off-road certification
  - Immediate 5-30% reduction in BSFC at WOT
- Allows for variable geometry turbines
- May reduce catalyst aging / durability requirements
- Potentially decrease the cost of exhaust hardware

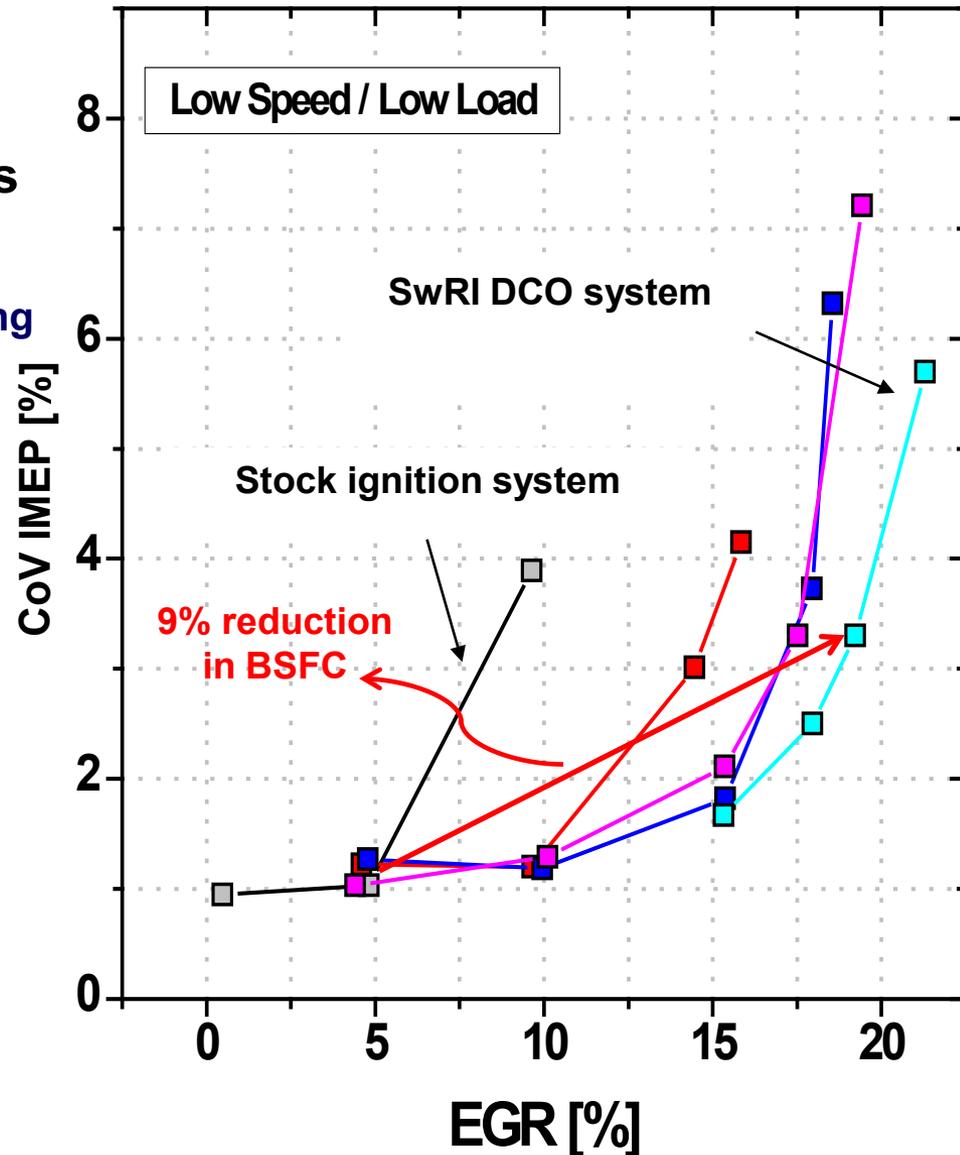
# Elimination of LSPI

- EGR suppresses LSPI occurrence
  - > 15% cooled EGR eliminates it completely
- Combination of improved phasing / earlier spark and increased ignition delay with EGR



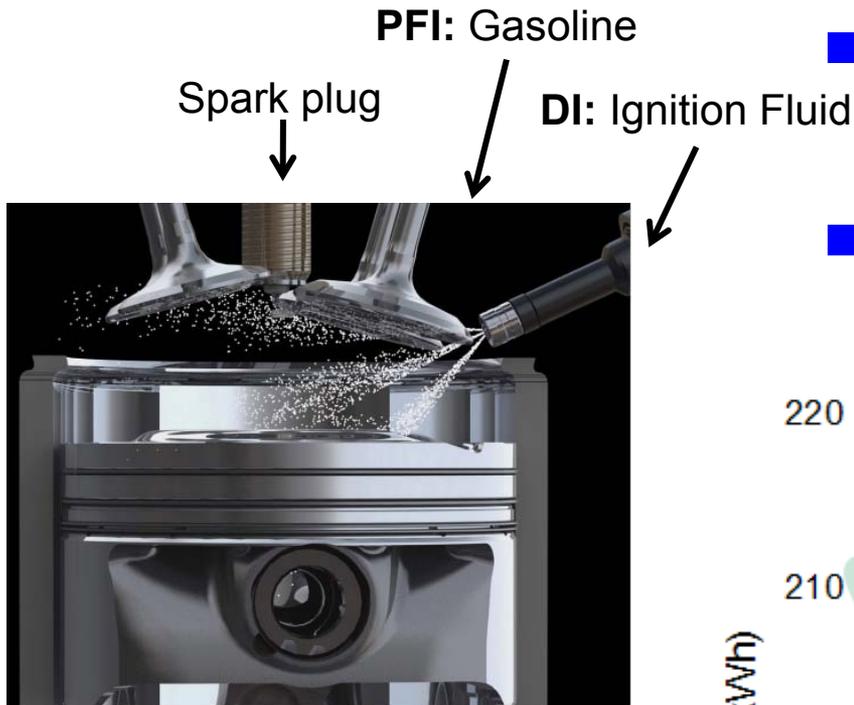
# Advanced Ignition Systems: Electrical Ignition

- High EGR mixtures are difficult to ignite
  - EGR rate limited by combustion instability
- SwRI 's DCO™\* system maximizes EGR tolerance
  - Long duration discharge
  - Energy use can be tailored for operating conditions
- Sole ignition source in LD applications
- Used in SI mode for dual-fuel applications



\* Patent Pending

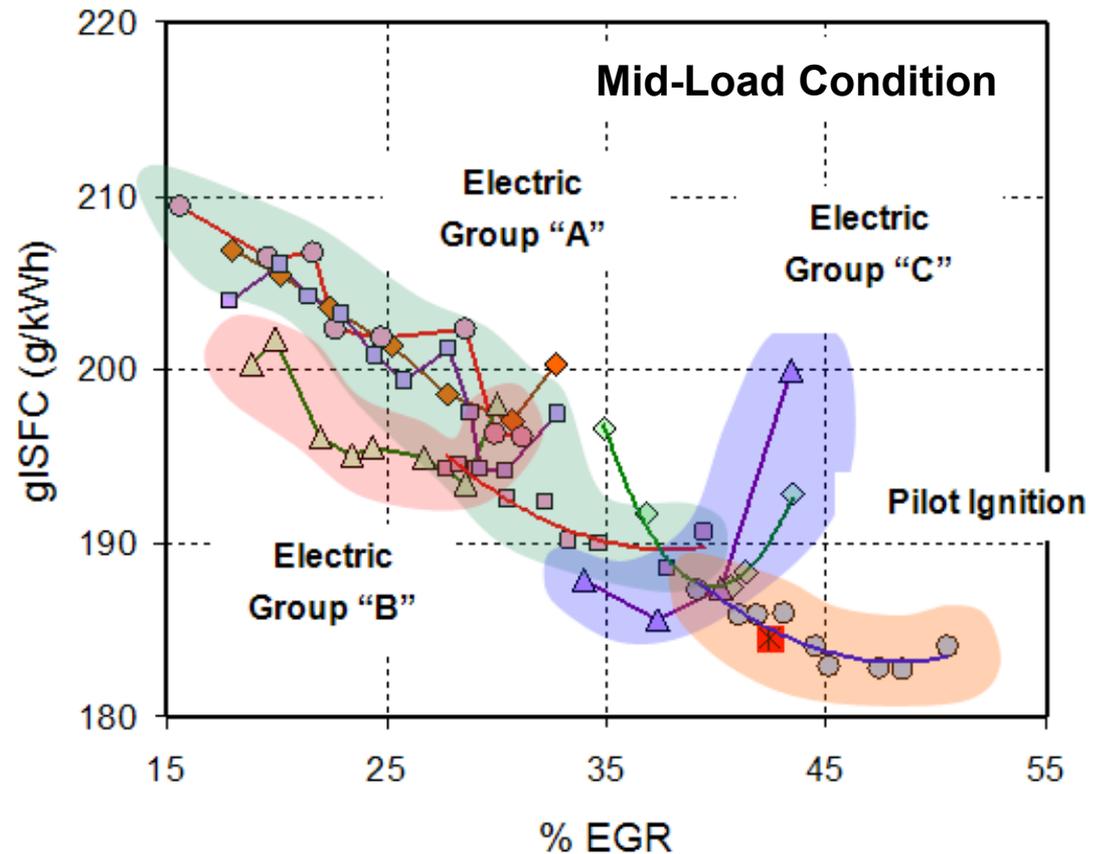
# Advanced Ignition Systems: Pilot Ignition



SwRI Dual-Fuel Multi-Mode  
Concept

- Typical fuel fractions:
  - 85-95% gasoline
  - 15-5% diesel fuel
- High pressure not required

- For best efficiency, use pilot ignition
  - Ignition fluid is a “chemical spark plug”
- Useful in applications that typically employ a diesel engine

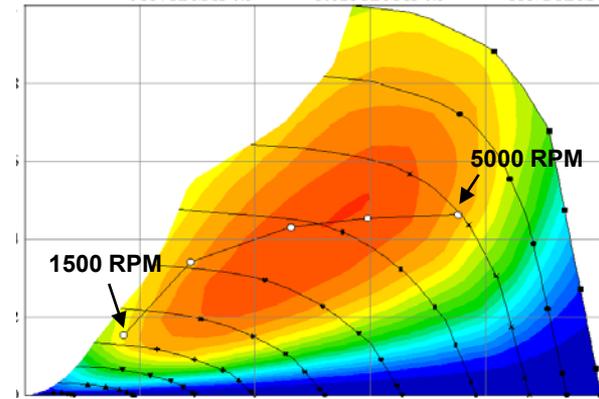


# Enabling Technologies: Boost System

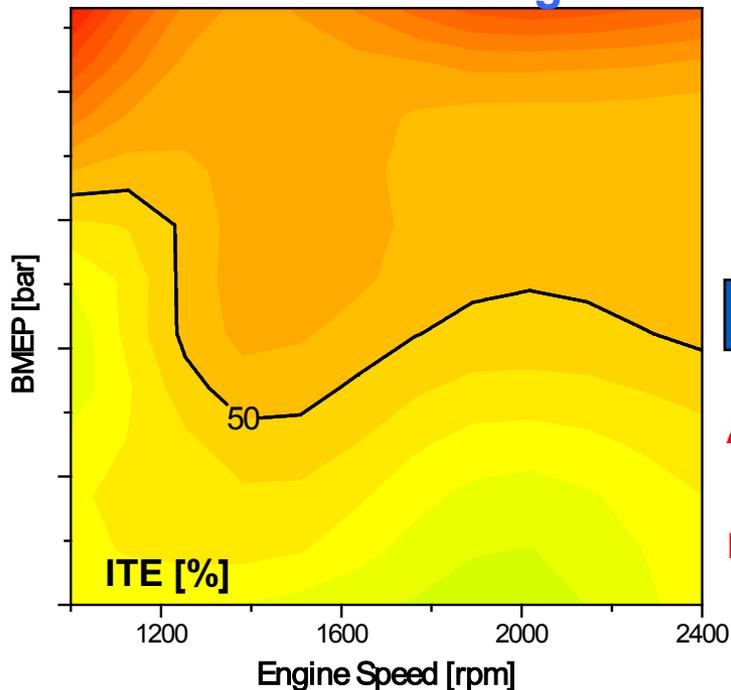
■ Boosting at high dilution levels (EGR with or without lean burn) is challenged by

- High pressure ratios
- Low exhaust temperatures reduce the blade speed ratio and maximum turbine efficiencies
- For LD - broad speed range (800 RPM to 5000 RPM) requires wide flow range
- Transient performance must be maintained

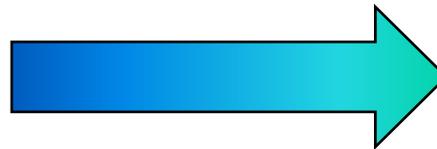
■ 2-stage boosting is required for dilution levels  $> 25\%$



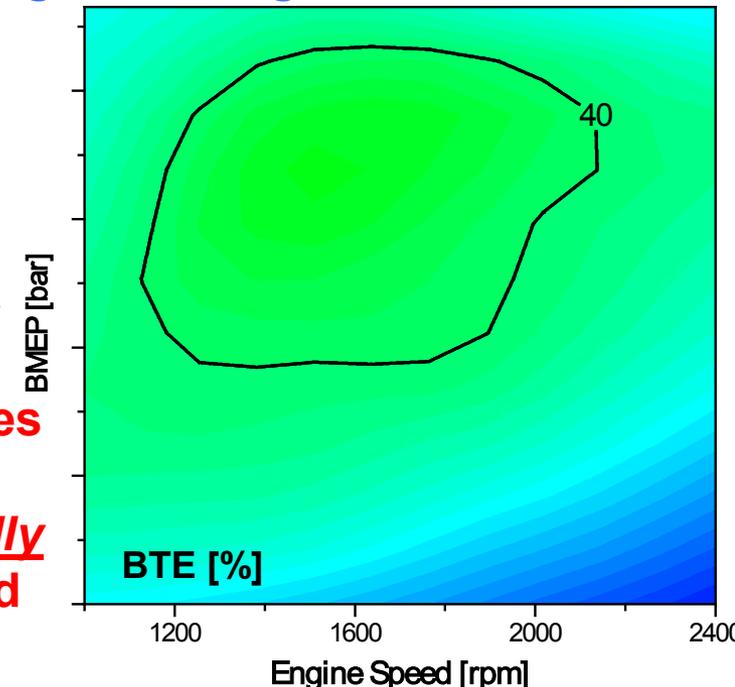
## High dilution engine with 2-stage boosting



- $> 40\%$  EGR
- $0.85 < \phi \leq 1$



**Air handling realities and transient requirements rapidly decrease indicated efficiencies**

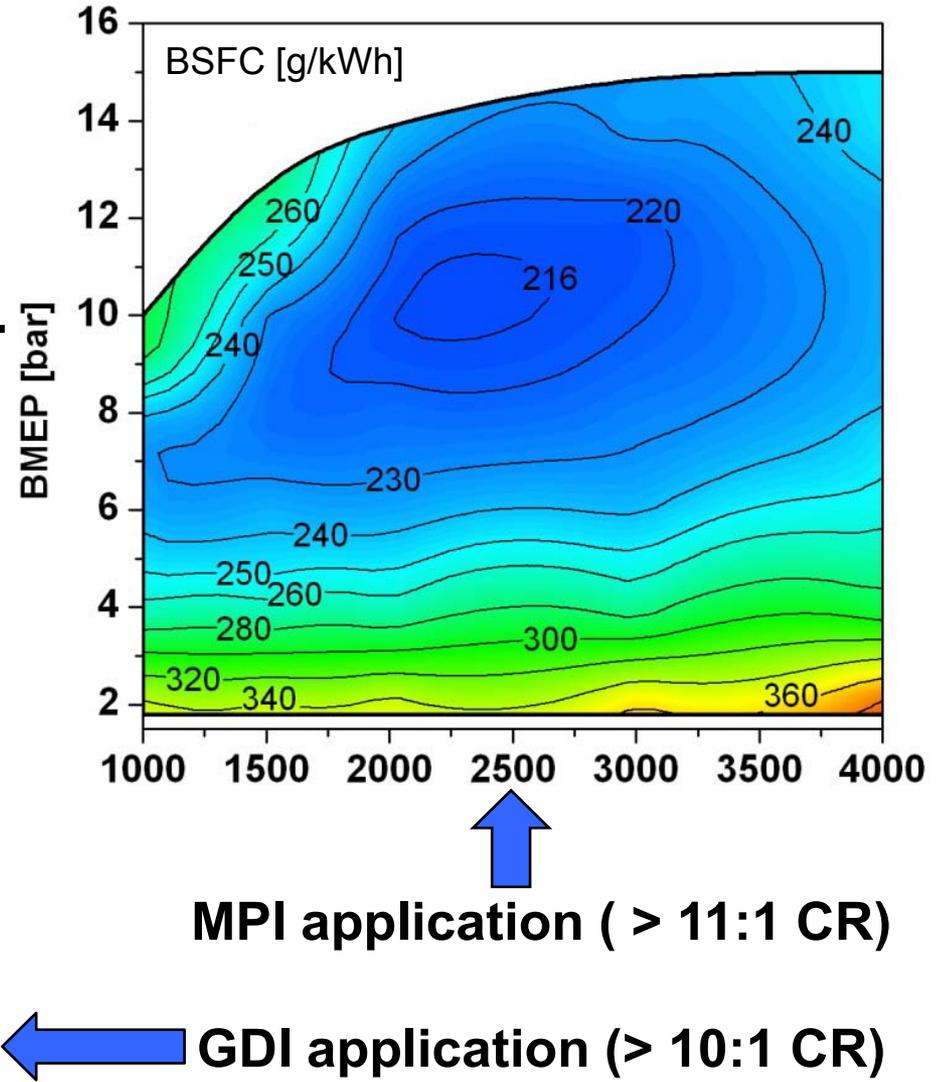
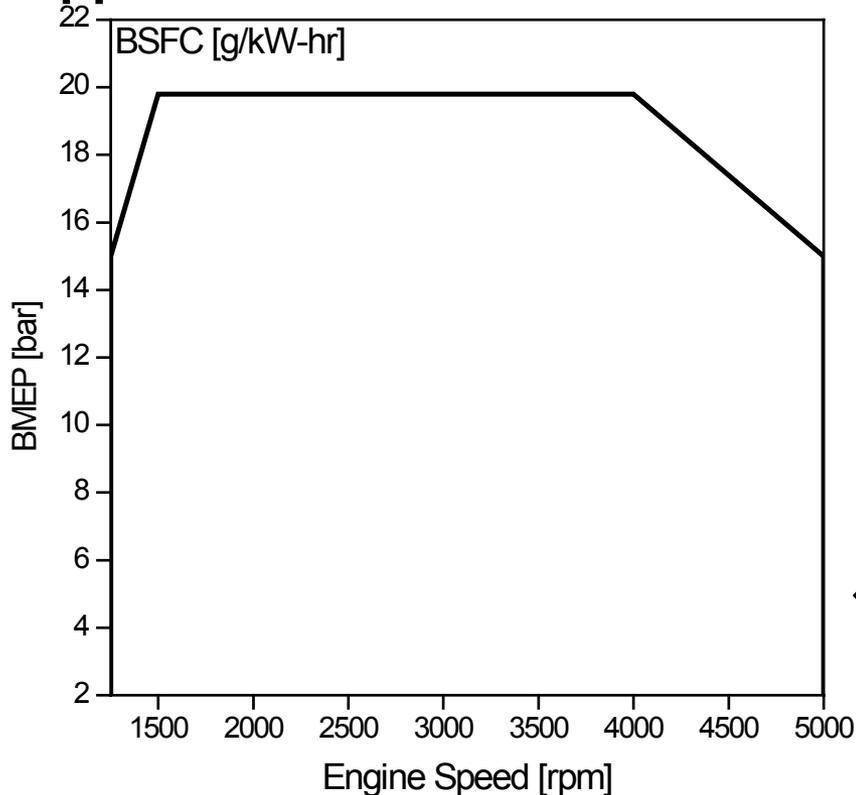


# Light Duty Results

- Fuel consumption significantly reduced from baseline

- 5-11% at low loads
- 10-40% at high loads

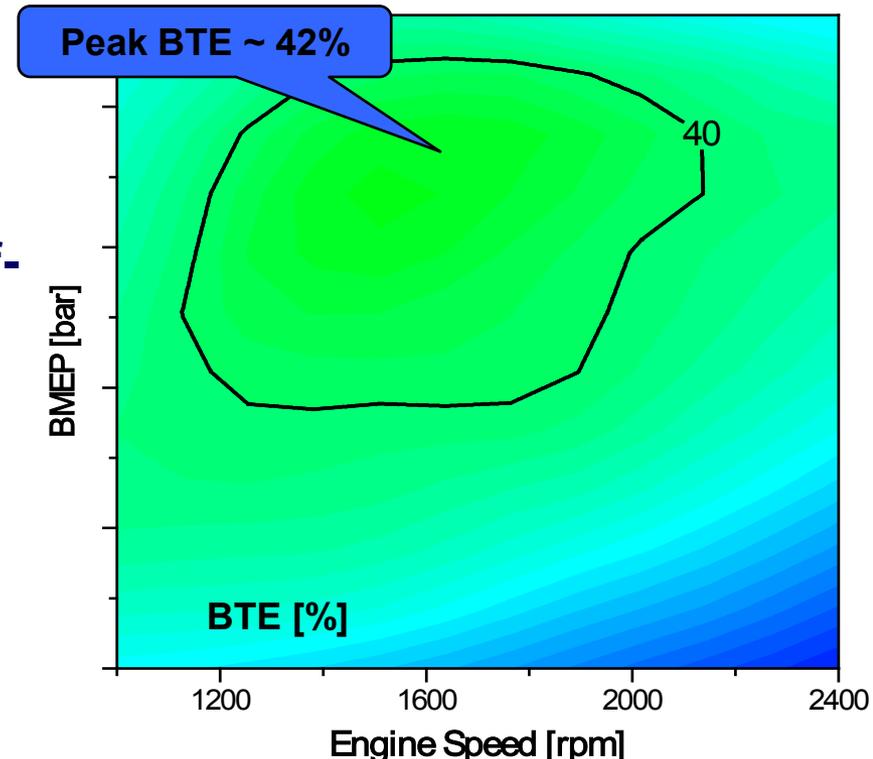
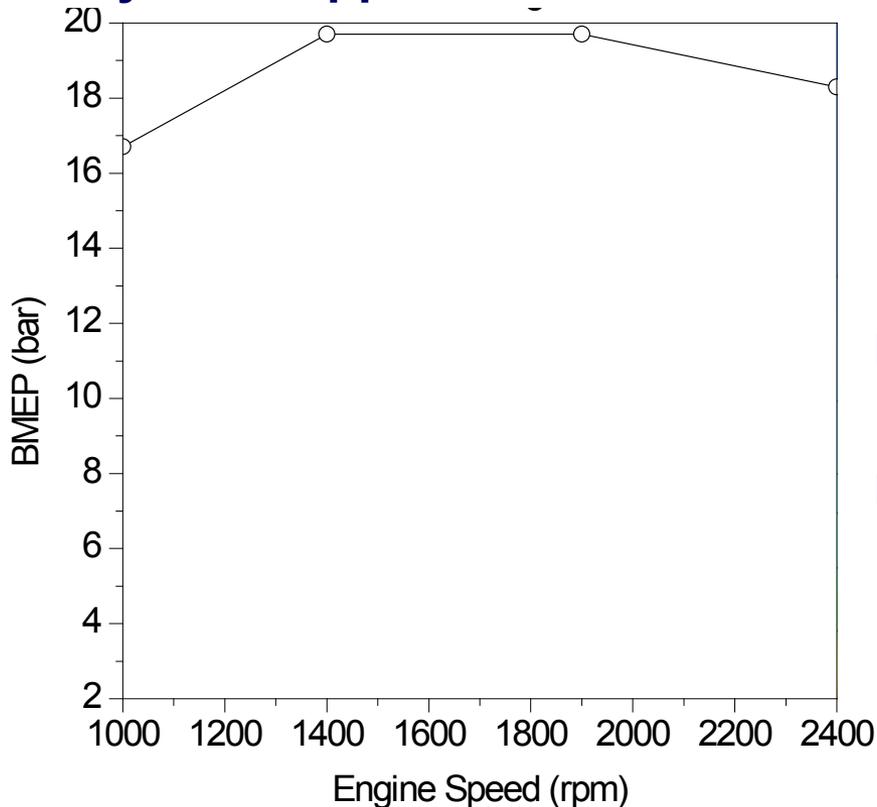
- Demonstrates potential for high-efficiency downsized application



# MD Results

- MD application can match diesel torque and BSFC with ultra-low emissions

- TWC compliant
- Packaging and cost benefits for off-road applications
- SwRI working on large-bore, multi-cylinder application



- Option for all-electric application with small BTE penalty

- Alternative fuel compatible

- CNG
- LPG
- Alcohols

# Summary

## ■ Cooled EGR is a solution to both efficiency and emissions concerns

- Very low cost / benefit ratio compared to alternative options
- Significant efficiency increases while maintaining or reducing emissions
  - May present solution for GDI PM challenge

## ■ SwRI's HEDGE technology addresses many of the issues in cooled EGR performance

- Control
- Stability
- Performance

