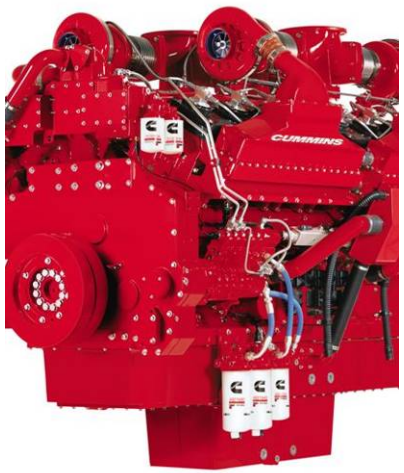
Potential Efficiency Impacts of HECC

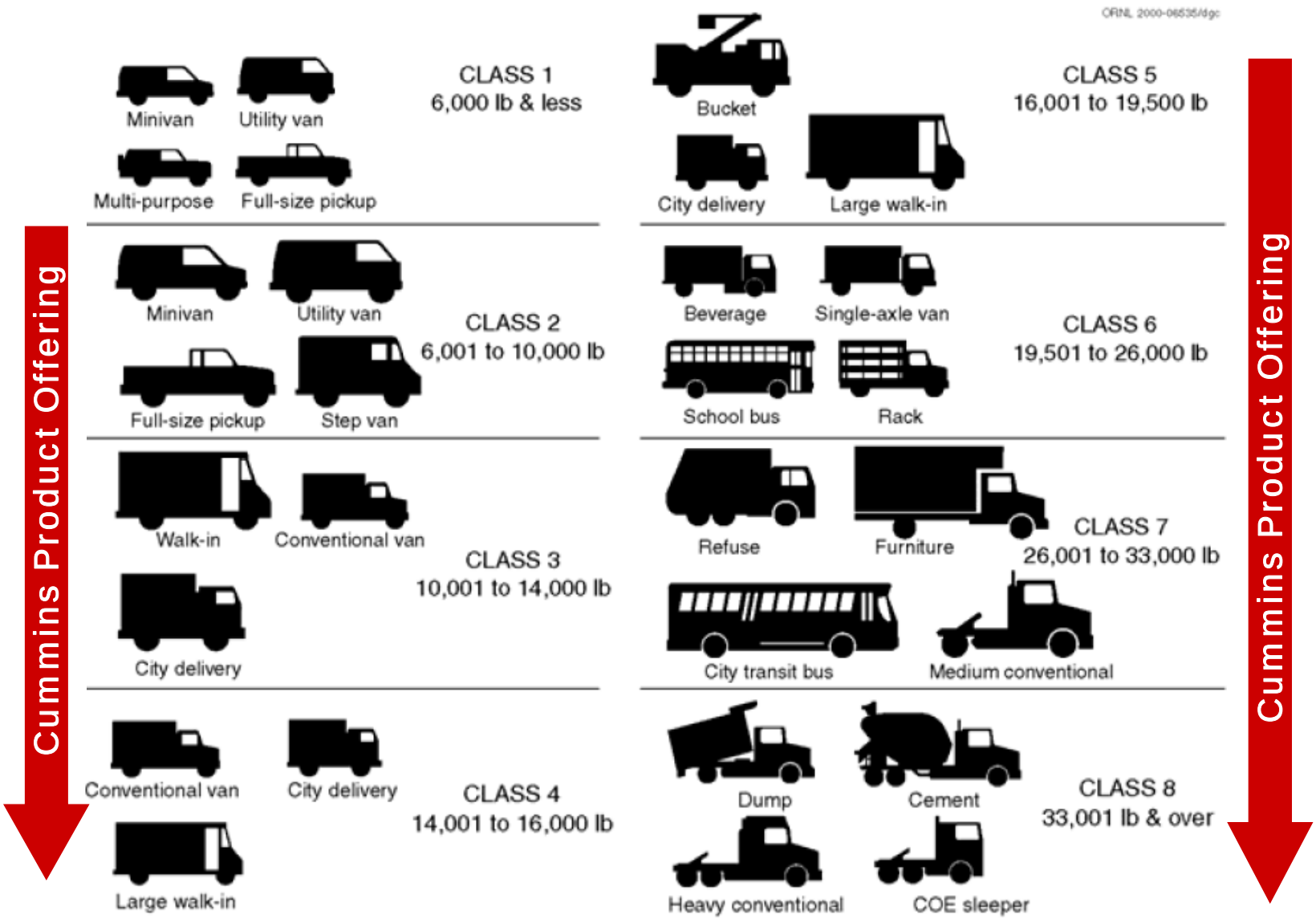
Engine Stretch Efficiency Colloquium at USCAR

Donald Stanton

March 3, 2010



Vehicle Classes – Cummins Diesel Engine Applications



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Impact of Vehicle Application on Efficiency

- Dyno vs. Chassis Emission Certification
- Duty Cycle
- Miles Traveled
- Power Requirement
- Hauling Capacity
- Safe Operation
- Reliability
- Total Cost of Ownership
  - Maintenance cost
  - Initial Cost
  - Other

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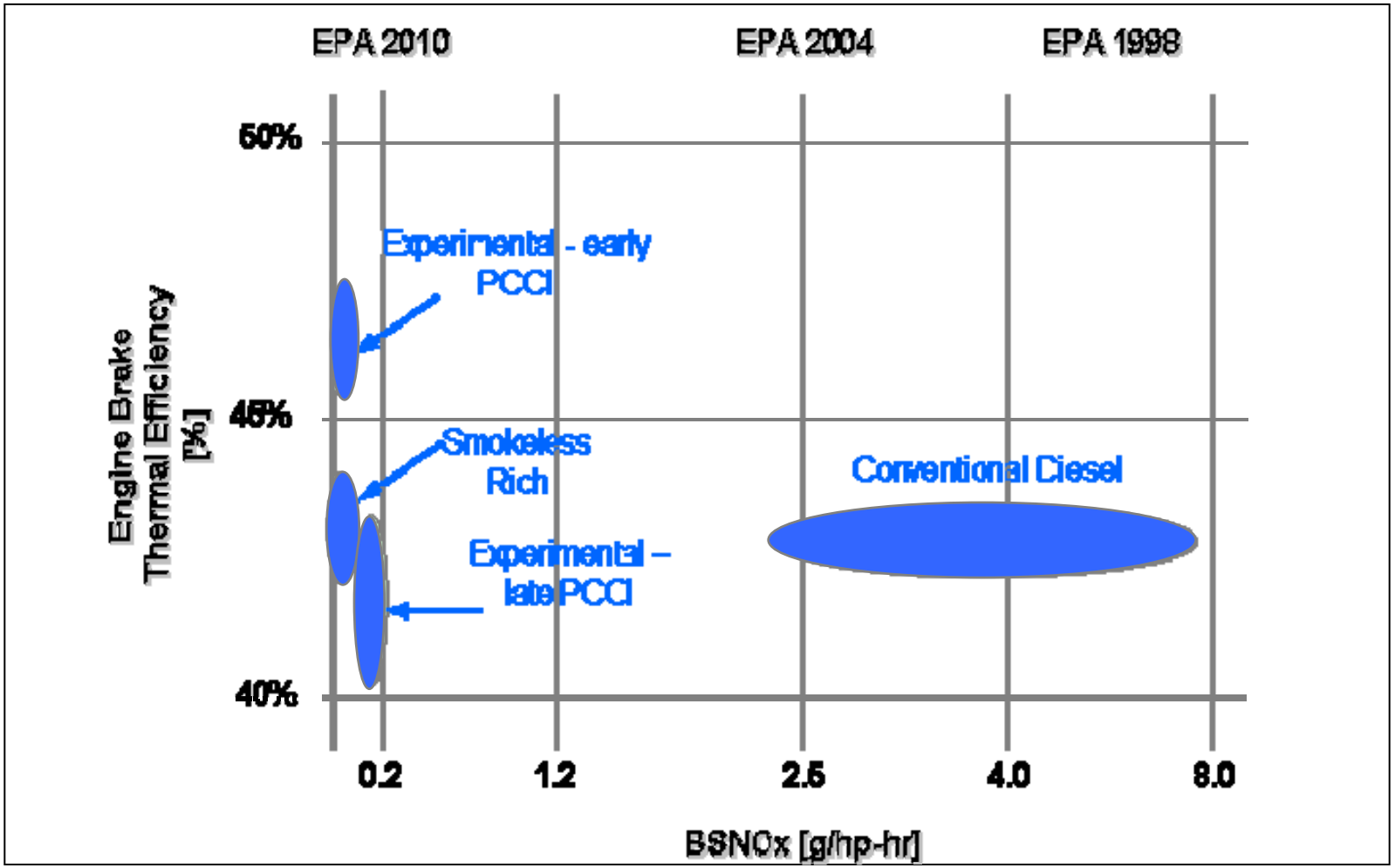
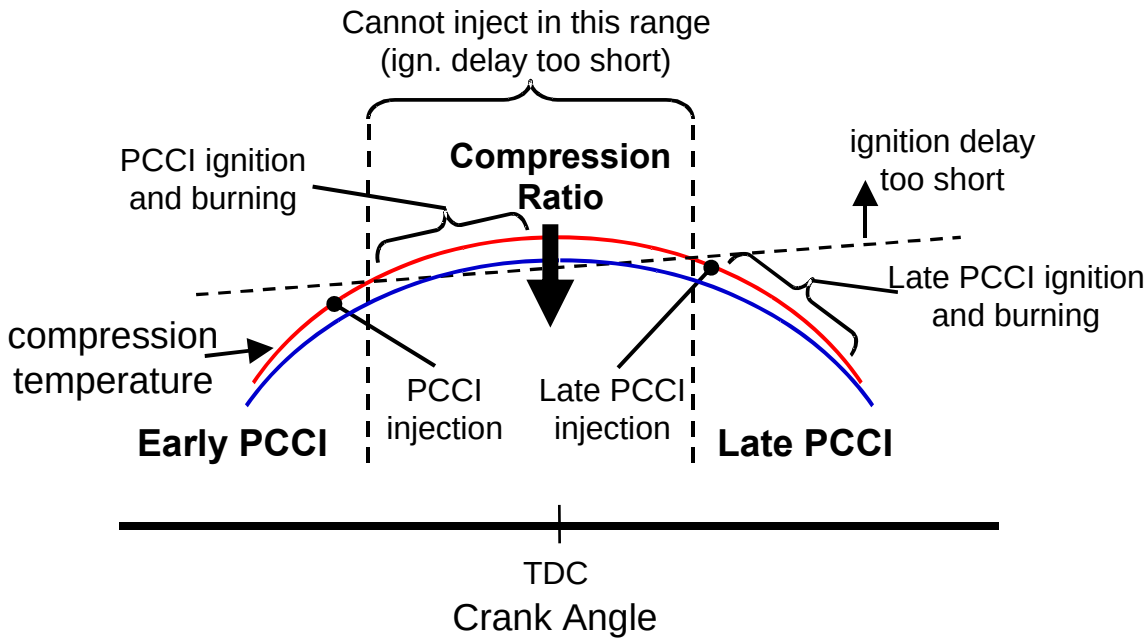
Advanced Modes of Combustion



Highly Premixed Combustion Modes



Mode	Advantages	Disadvantages
Early PCCI	**- Good stability** **- Good fuel consumption**	**- High peak cyl. pressure** **- Limited BMEP** **- Noise** **- Higher cooled EGR rates**
Late PCCI	**- Low peak cyl. pressure** **- High BMEP capability (20 bar)** **- Low noise**	**- Narrow stability range** **- Higher fuel consumption** **- Needs combustion sensor**

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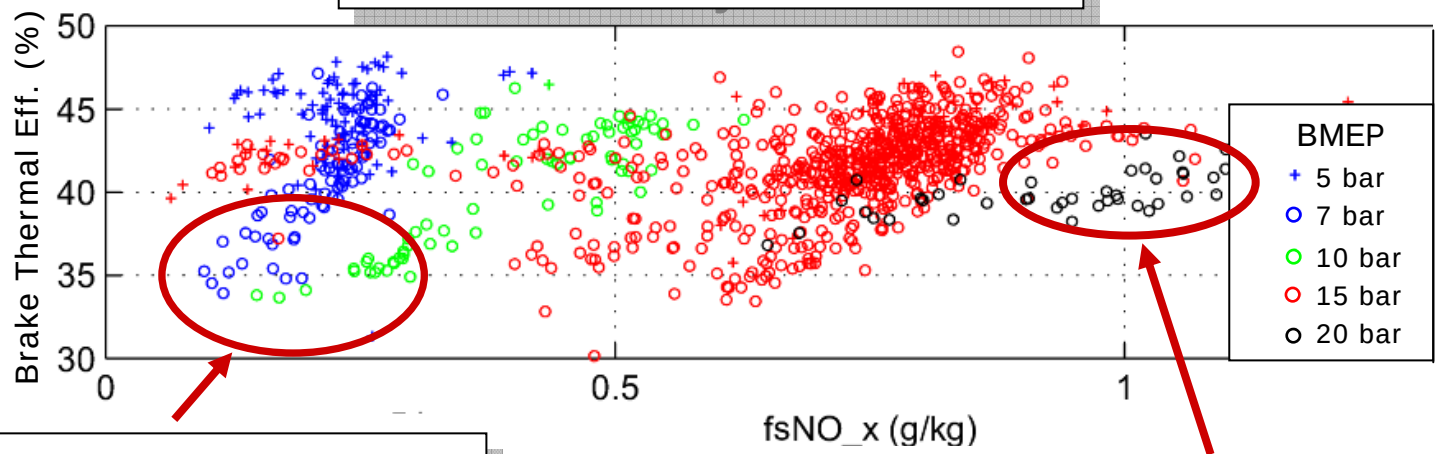
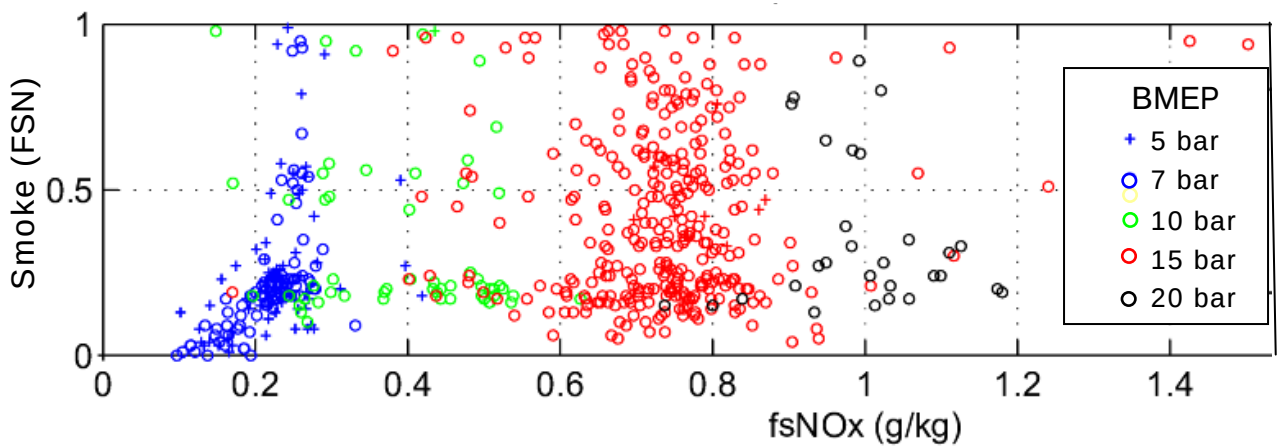
Extending the Engine Operation Range of PCCI

Combined Early and Late PCCI

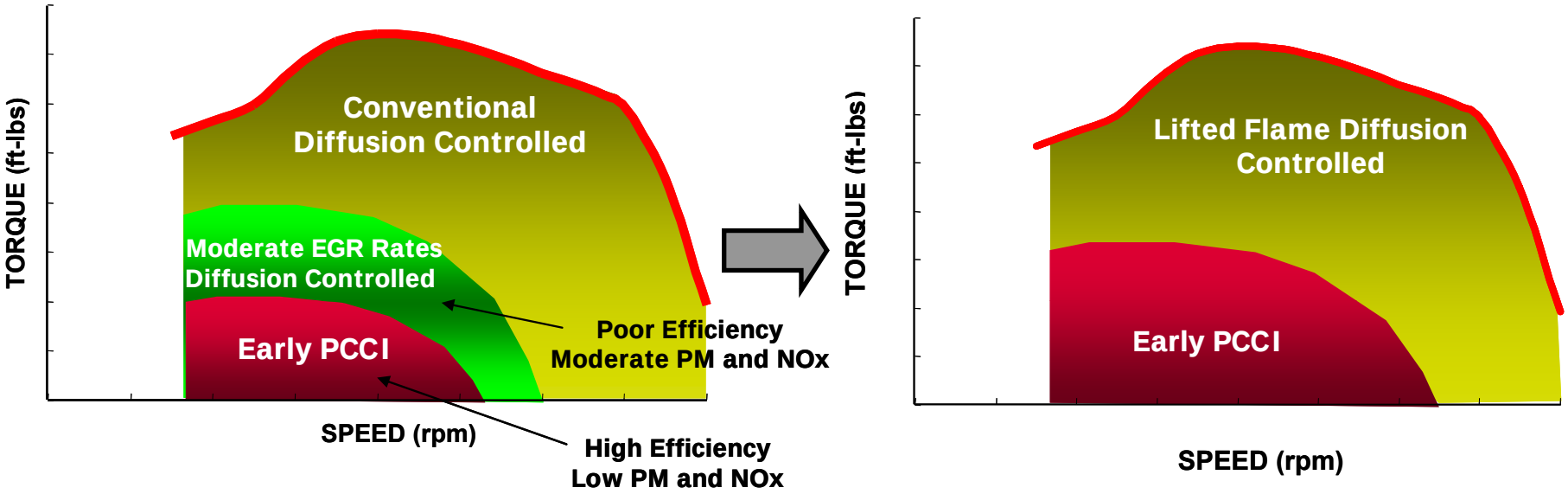


Reduce CO & UHC while maintaining acceptable NVH (especially below 5 bar BMEP)

Late PCCI limits fuel economy improvement potential and robustness

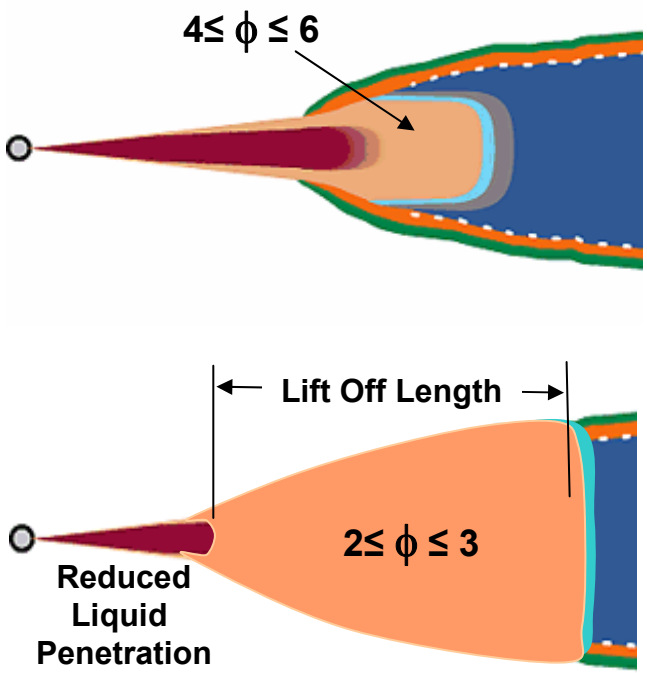


Mixed Mode Combustion – Pragmatic Implementation



Creating Lifted Flame Combustion

Reduce Liquid Fuel Penetration and Enhance Fluid Entrainment



Conventional Diffusion Combustion

Lifted Flame Diffusion Combustion

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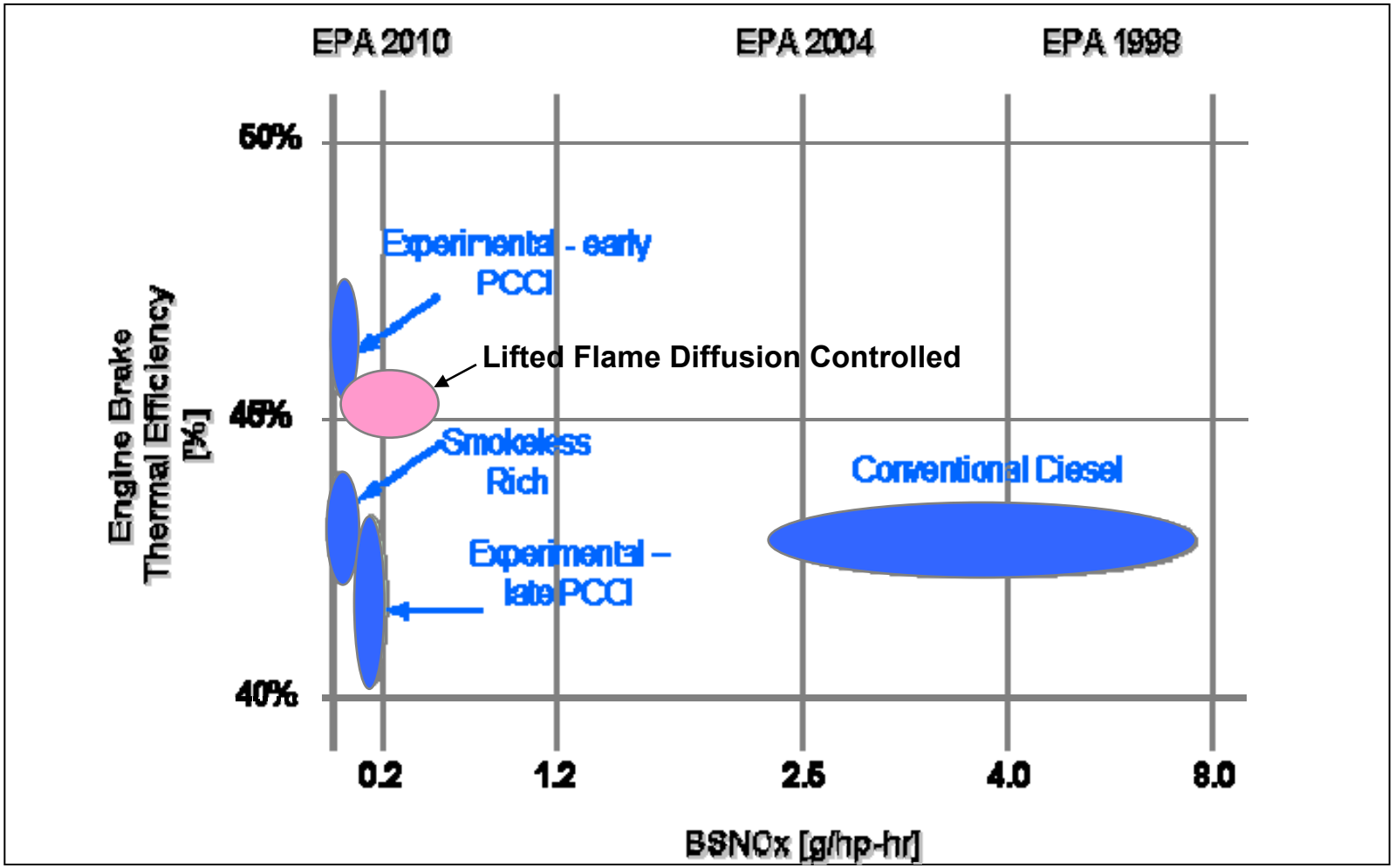
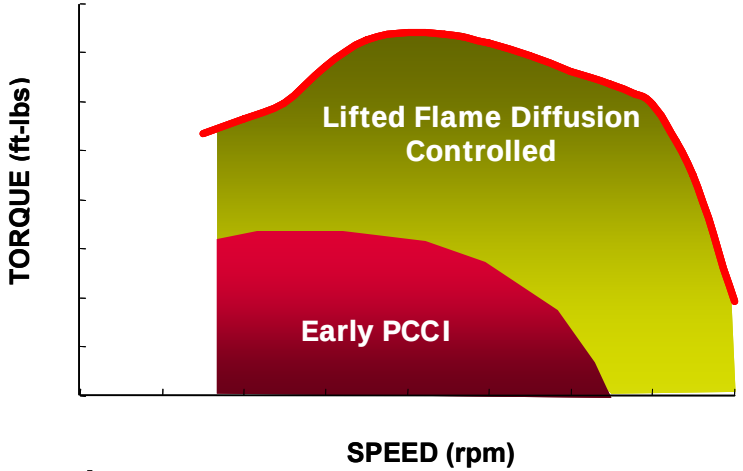
Advanced Modes of Combustion



Challenges for Lifted Flame Combustion

- Creating desired intake valve closing conditions
  - A/F, EGR, IMT
- Fuel injection system technology
  - Injection pressure
  - Nozzle configuration
- Fuel injection plume to plume interaction
- Combustion surfaces
  - Difficult to scale to smaller bore engines
- Controls development for transient operation



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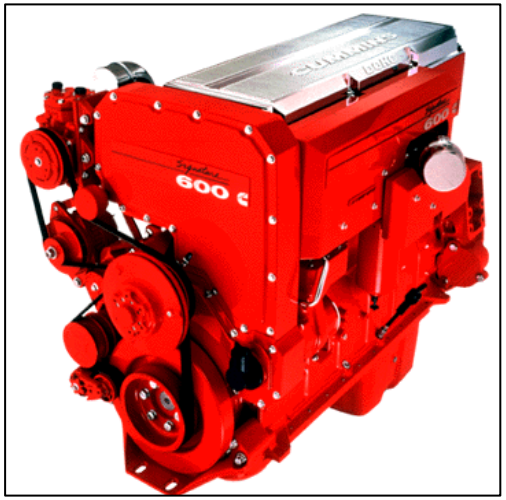
Technology Exploration

Variable Valve Actuation

Fuel System
-High Injection Pressure
-Piston Bowl/Nozzle
-Multiple injections

Advanced LTC
-Enhanced PCCI
- Mixed Mode Combustion

Variable Intake Swirl



Controls
-Charge Air Manager
-MAF
-Closed Loop Combustion

EGR Loop
- Lower Pressure Drop
- Alternative Cooling

Electrically Driven Components

Turbo Technology
-Electrically Assisted
-2-Stage

Aftertreatment
-DOC
-DPF
-SCR
-Sensors

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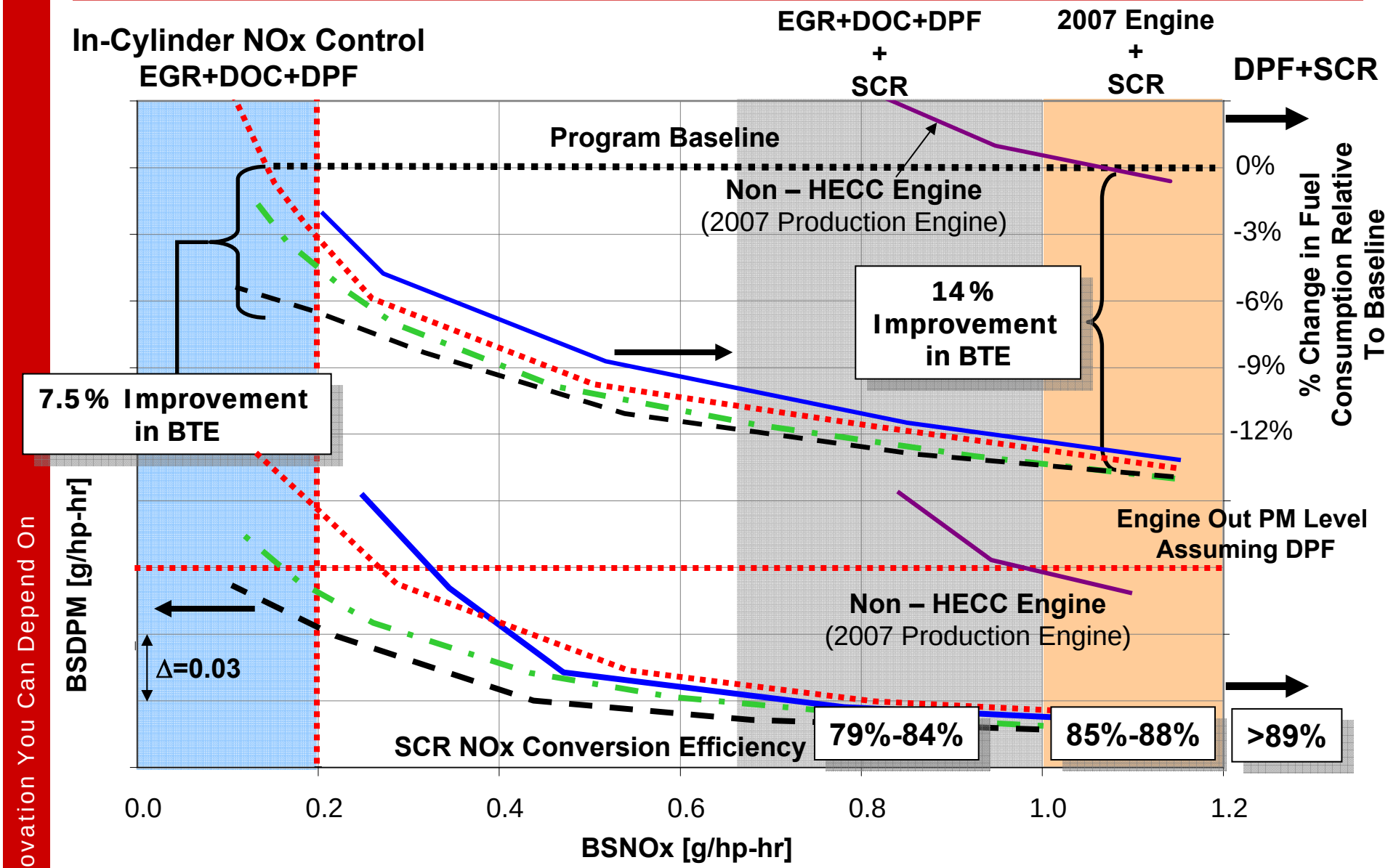
Impact of HECC Engine Technology for the In-Cylinder and SCR NOx Control Engine Architectures



Technical Barriers

In-Cylinder NOx Control

- Exhaust heat management
  - Vehicle cooling
  - Engine EGR
- Power density limitations
- Weight
- Robustness (PM and bsfc)
- Transient response

High NOx Conversion Efficiency SCR

- >97% conversion efficiency over relevant drive cycles
- System pressure drop
- Packaging
- Weight
- Fuel efficient thermal management for transient emissions (FTP)

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Areas for Consideration to Improve Engine Efficiency via HECC Implementation

In-Cylinder

- Finding an in-cylinder emissions controlled solution is important
- Alternative ways to control NOx beyond EGR
- Fuel efficient ways to move and cool EGR
- Engine + vehicle cooling system design to manage heat rejection (must extract useful work)
- Low PM levels with robust performance for transient operation (reduce DPF regeneration fuel consumption penalty)
- Air induction (turbomachinery and head design)
- Fuel delivery systems
- Cylinder pressure capability
- Reduce heat loss including cylinder components, ports, and manifolds

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Areas for Consideration to Improve Engine Efficiency via HECC Implementation

SCR

- Effective way to decouple NOx emissions from closed cycle efficiency
  - Added weight and cost to vehicle
- Alternative ways to control NOx beyond EGR
- Fuel efficient ways to move and cool EGR
- Air induction (turbomachinery and head design)
- Fuel delivery systems
- Cylinder pressure capability
- Reduce heat loss particularly of the ports and manifolds

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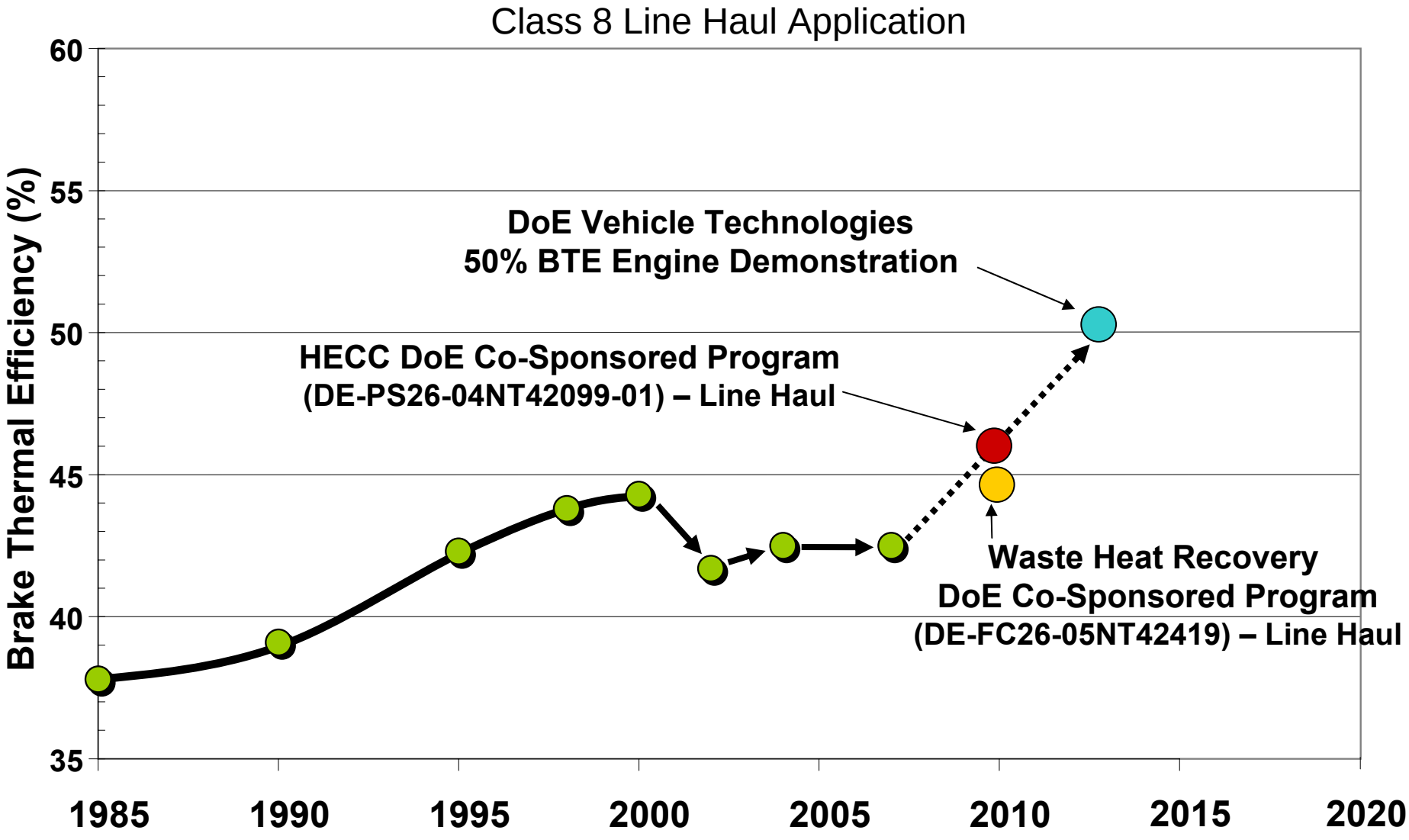
Evolution of Heavy Duty Diesel Engine Efficiency



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