

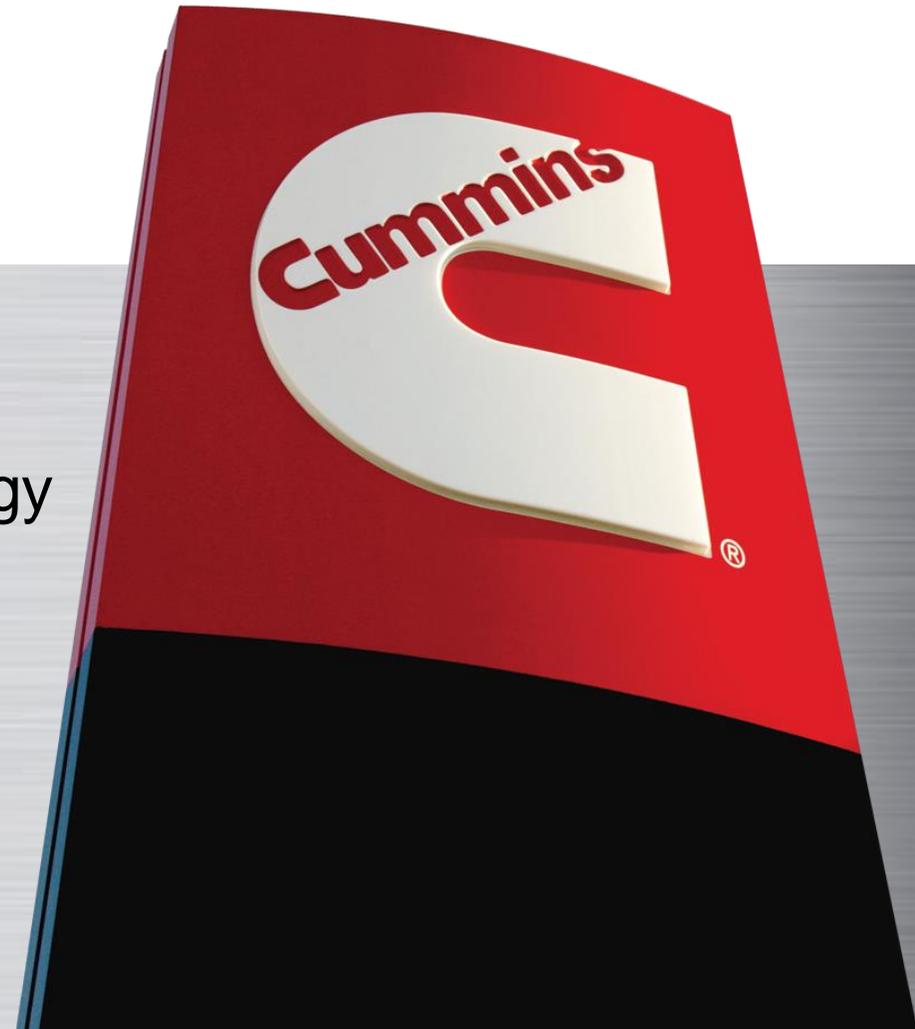
Engine Technologies for GHG and Low NOx

ARB Symposium on Phase 2 GHG

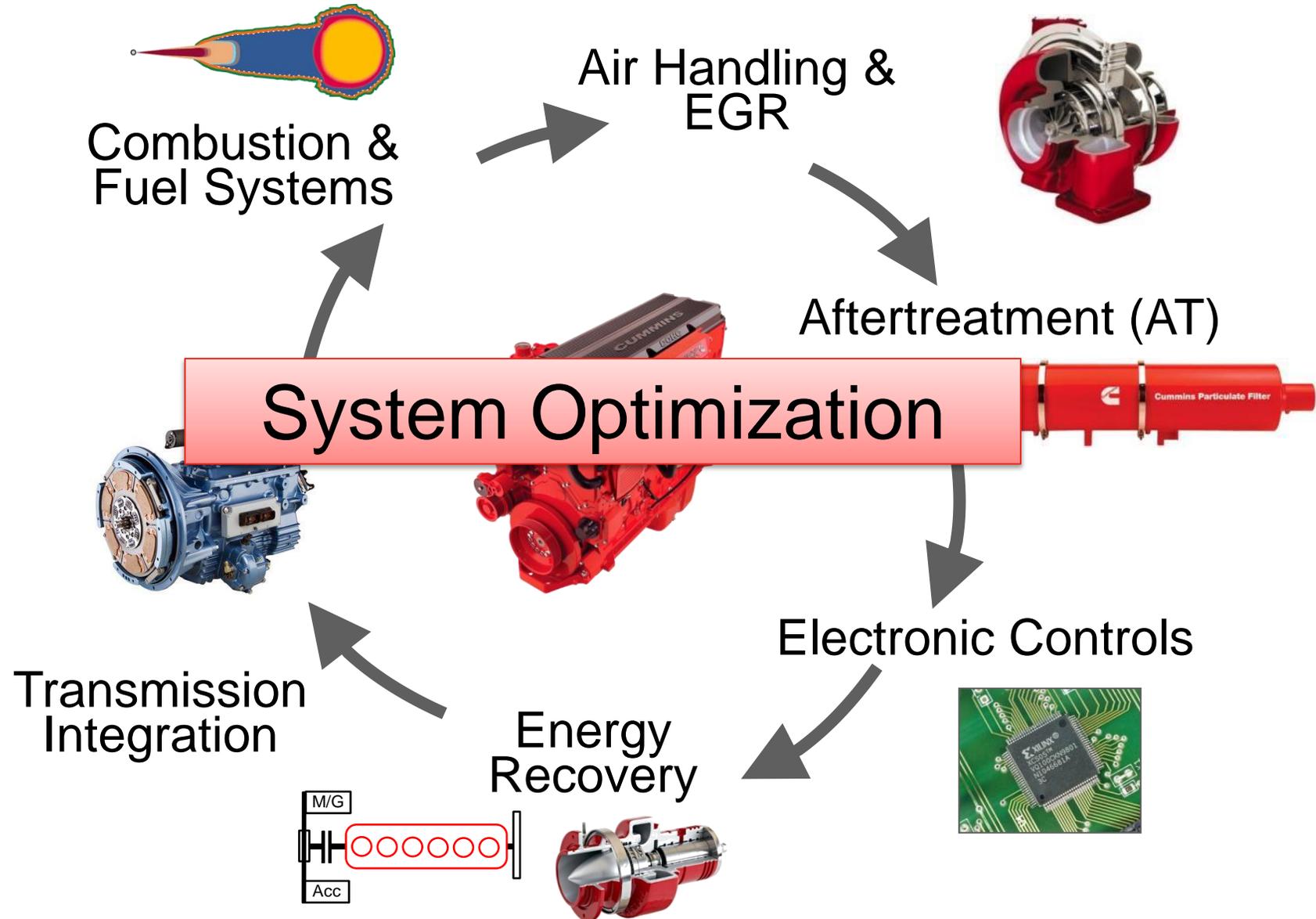
Dr. Wayne Eckerle

Vice President, Corporate Research & Technology

April 22, 2015



Subsystem Technology Palette



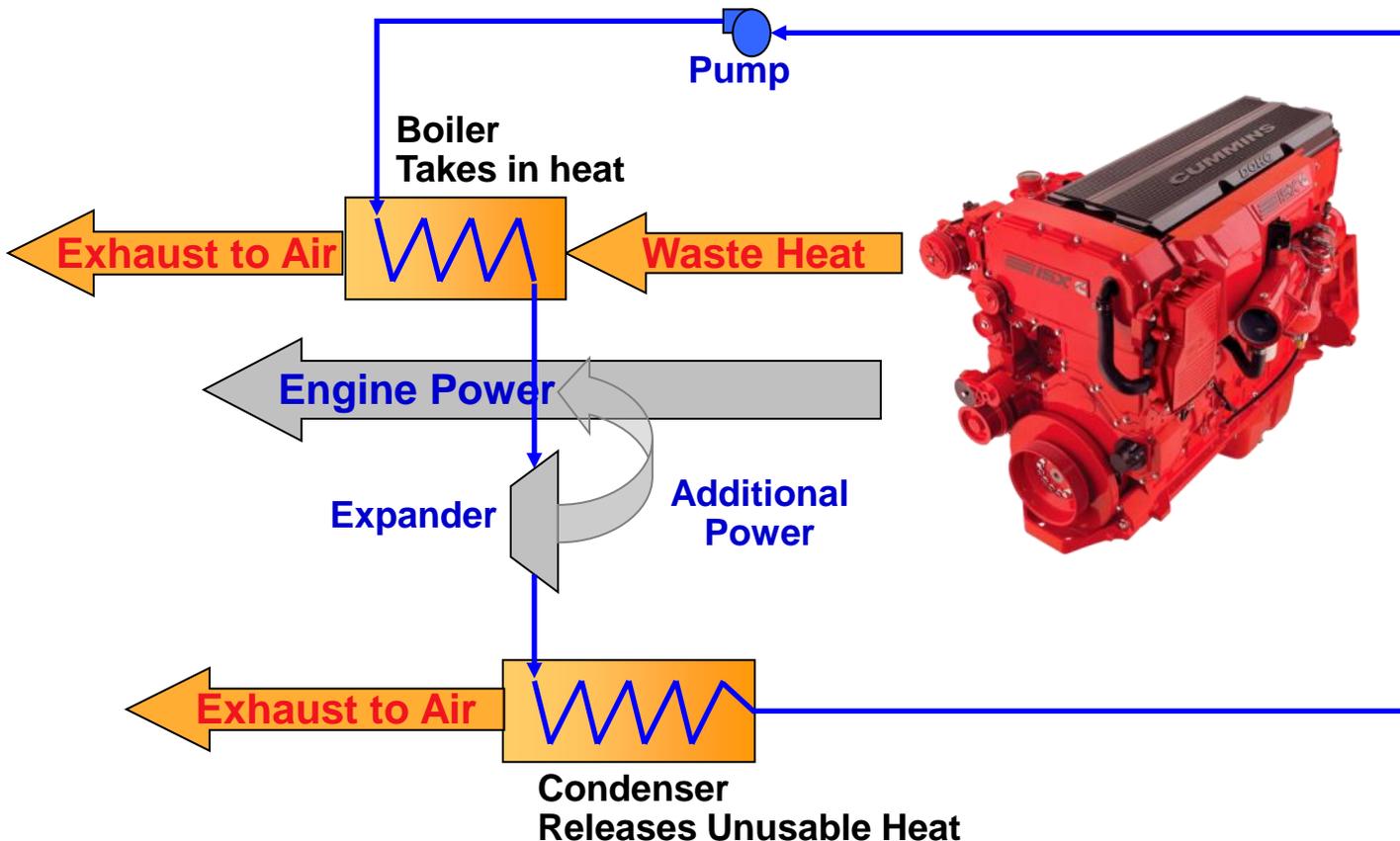


2020 – 2030 CO₂ Reduction Potential (Diesel)

	Potential % Improvement vs. 2017/2018 Standards (On the Certification Cycle)	
	% Improvement	Key Technologies
Heavy-Duty Pickup Engines	8 - 13 (Engine Contribution to Vehicle Chassis Cert)	Combustion and Air Handling Friction and Parasitics High Efficiency Aftertreatment Variable Valve Actuation Weight Management Stop Start Transmission Integration
Medium Heavy-Duty Vocational Engines	5 - 11	Combustion and Air Handling Friction and Parasitics High Efficiency Aftertreatment Variable Valve Actuation
Heavy Heavy-Duty Tractor Engines	9 - 15	Combustion and Air Handling Friction and Parasitics Heat Transfer Management Waste Heat Recovery (WHR)

Waste Heat Recovery Technology

4-5% Fuel Consumption Benefit



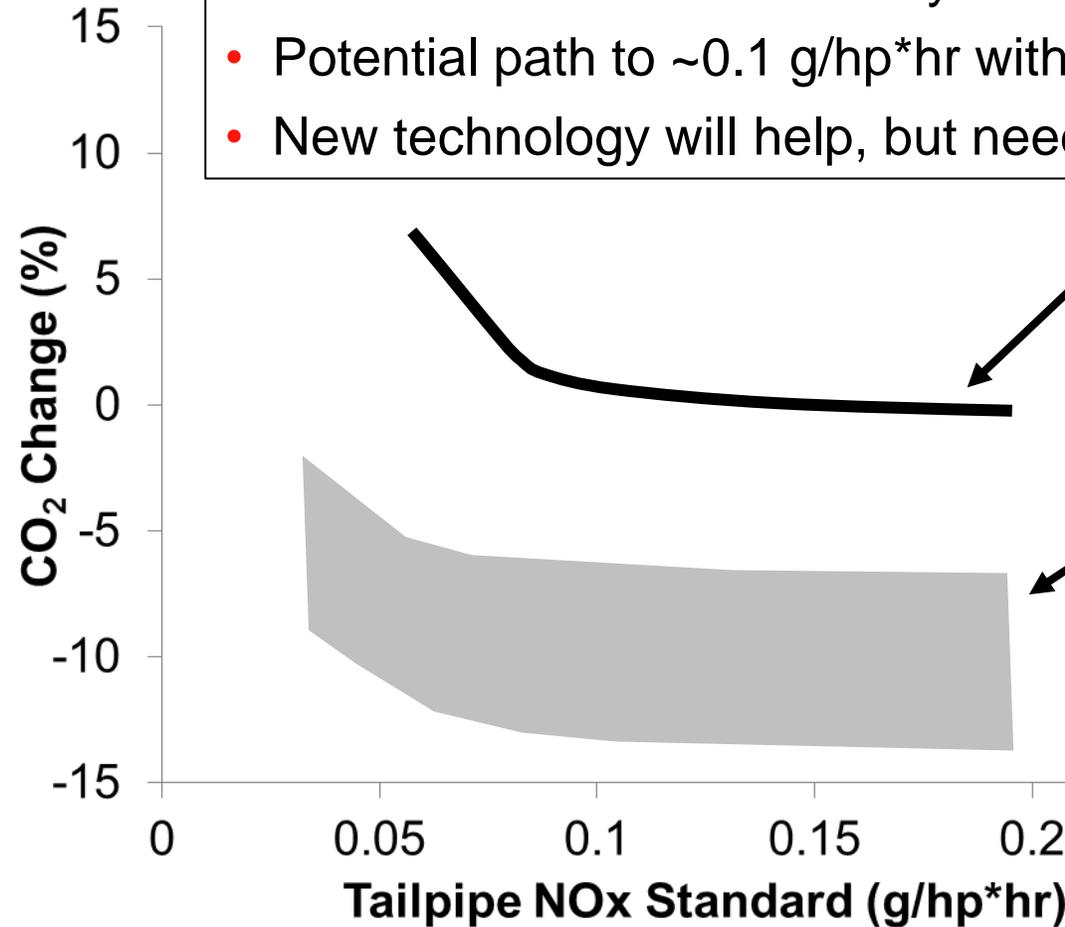
Beyond SuperTruck

- 4th generation design
- Improvements for packaging, cost, reliability
- End-user testing planned for late 2015
- Production possible by ~2020

GHG Penalty at Low Tailpipe NOx

Diesel

- More work needed to identify a robust 0.02 g/hp*hr diesel solution
- Potential path to ~0.1 g/hp*hr with minimal CO₂ penalty
- New technology will help, but needs development



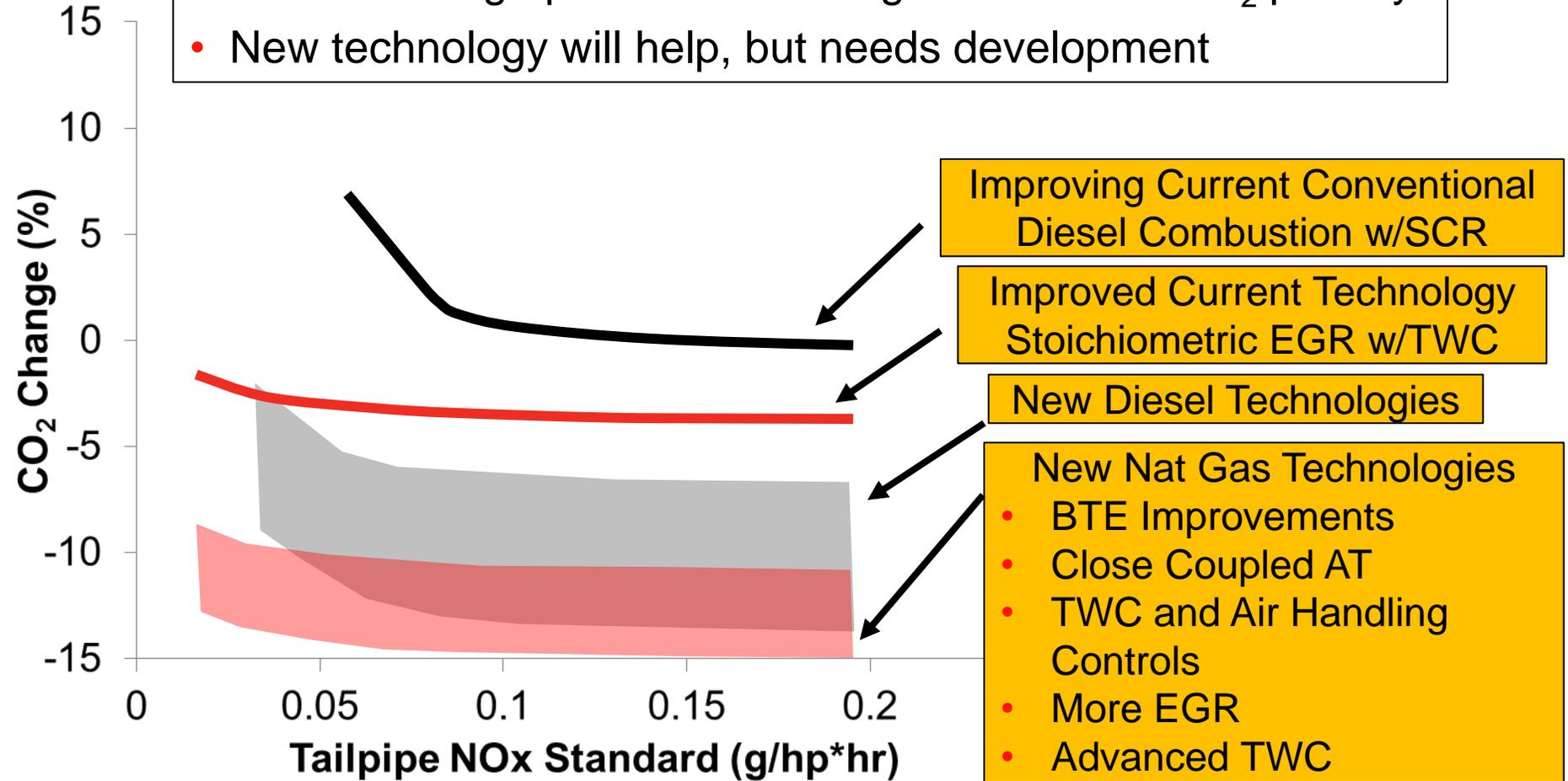
Improving Current Conventional Diesel Combustion w/SCR

- New Diesel Technologies
- BTE Improvements
 - Catalysts (SCR, NOx Storage)
 - Urea Dosing Controls and Strategies
 - Thermal Management

GHG Penalty at Low Tailpipe NOx

Diesel
Natural Gas*

- Path to 0.02 g/hp*hr with natural gas with small CO₂ penalty
- New technology will help, but needs development

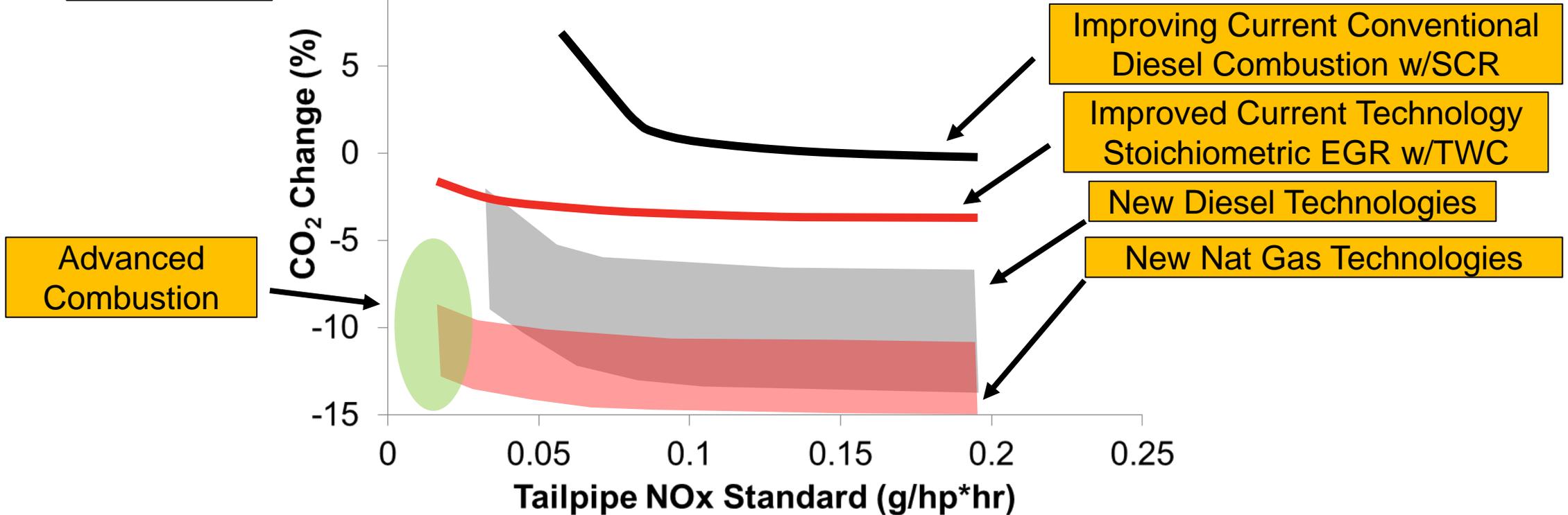


* Includes methane emissions as equivalent CO₂

GHG Penalty at Low Tailpipe NOx

Diesel
Natural Gas*
 Advanced
 Combustion

- Path to 0.02 g/hp*hr with advanced combustion with good CO₂
- Still in research



* Includes methane emissions as equivalent CO₂

Summary

- Engine can provide significant improvement in fuel consumption and CO₂ emissions
- Lower NOx levels achievable with minimal CO₂ penalty
 - 0.1 g/hp*hr for diesel
 - 0.02 g/hp*hr for natural gas
- Research needed to reach 0.02 g/hp*hr for diesel
- Additional considerations
 - Identifying the right levers for reducing NOx – certification standards, cycles, etc.
 - Other challenges in certifying to low NOx such as design margin and OBD
 - Keeping CO₂ and NOx certification protocols linked