



Green House Gas Reduction Potential Pathway

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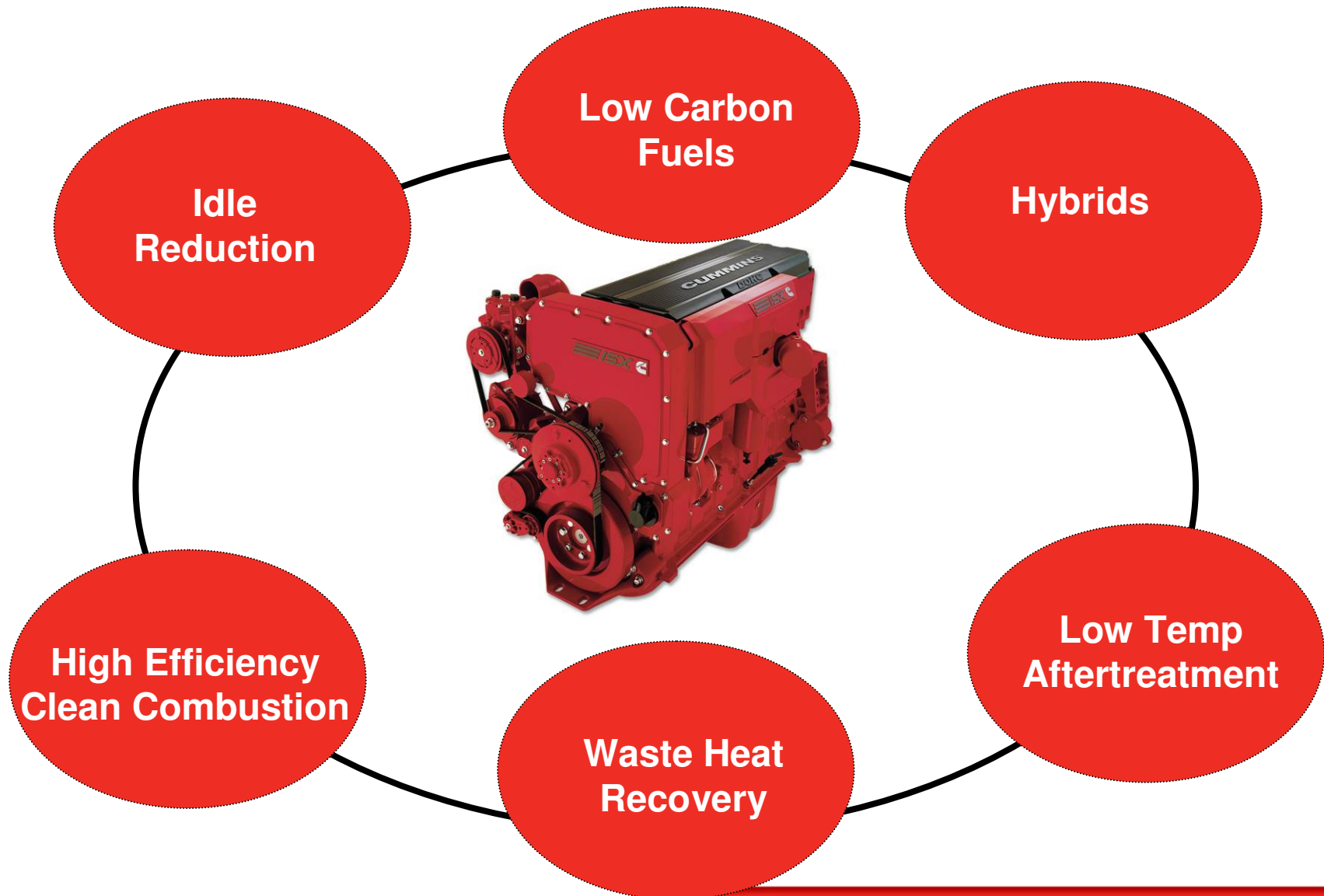
Wayne Eckerle

Vice President, Corporate Research & Technology

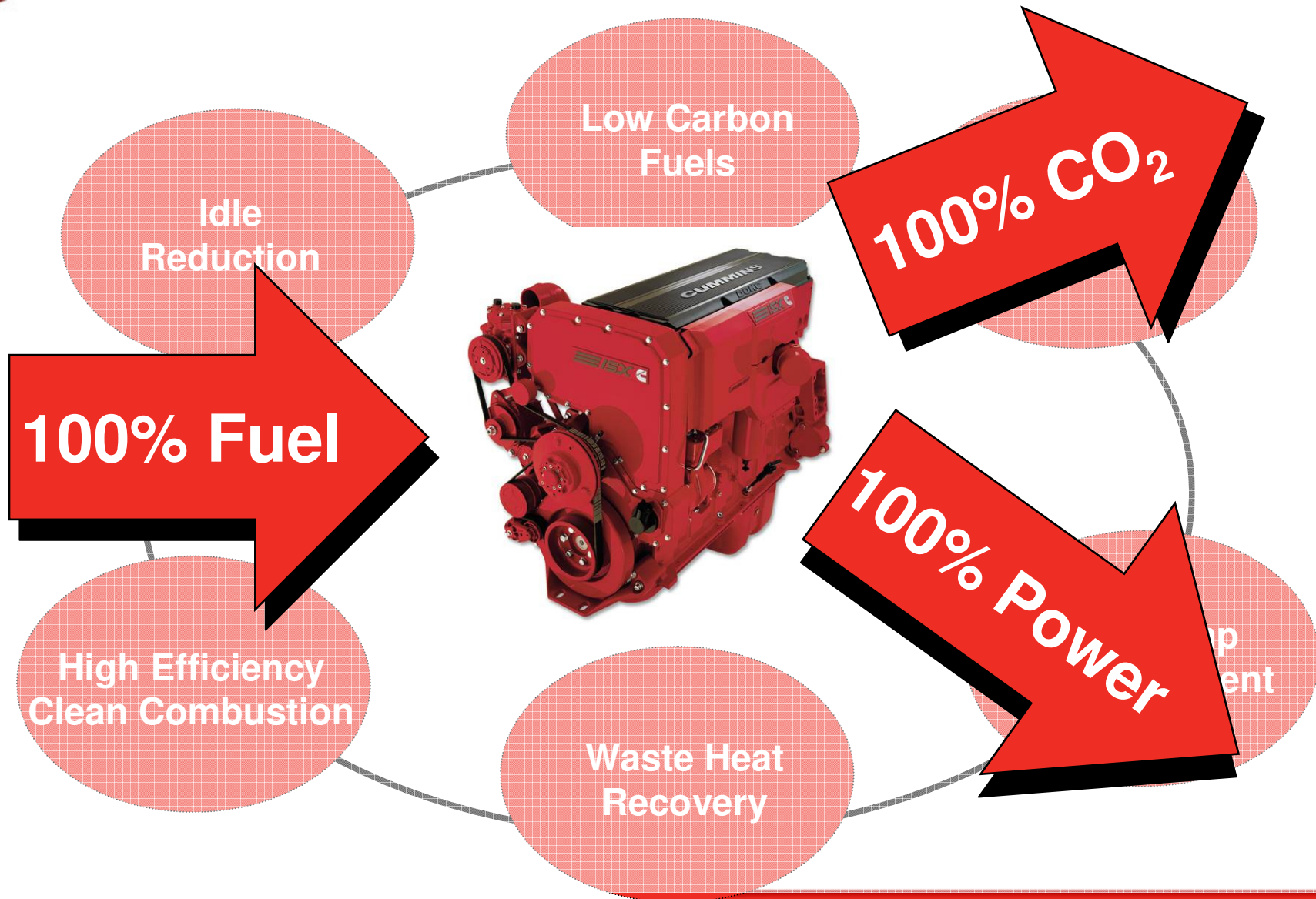
Electric Drive Vehicles Staff Workshop

Diamond Bar, CA 9/9/09

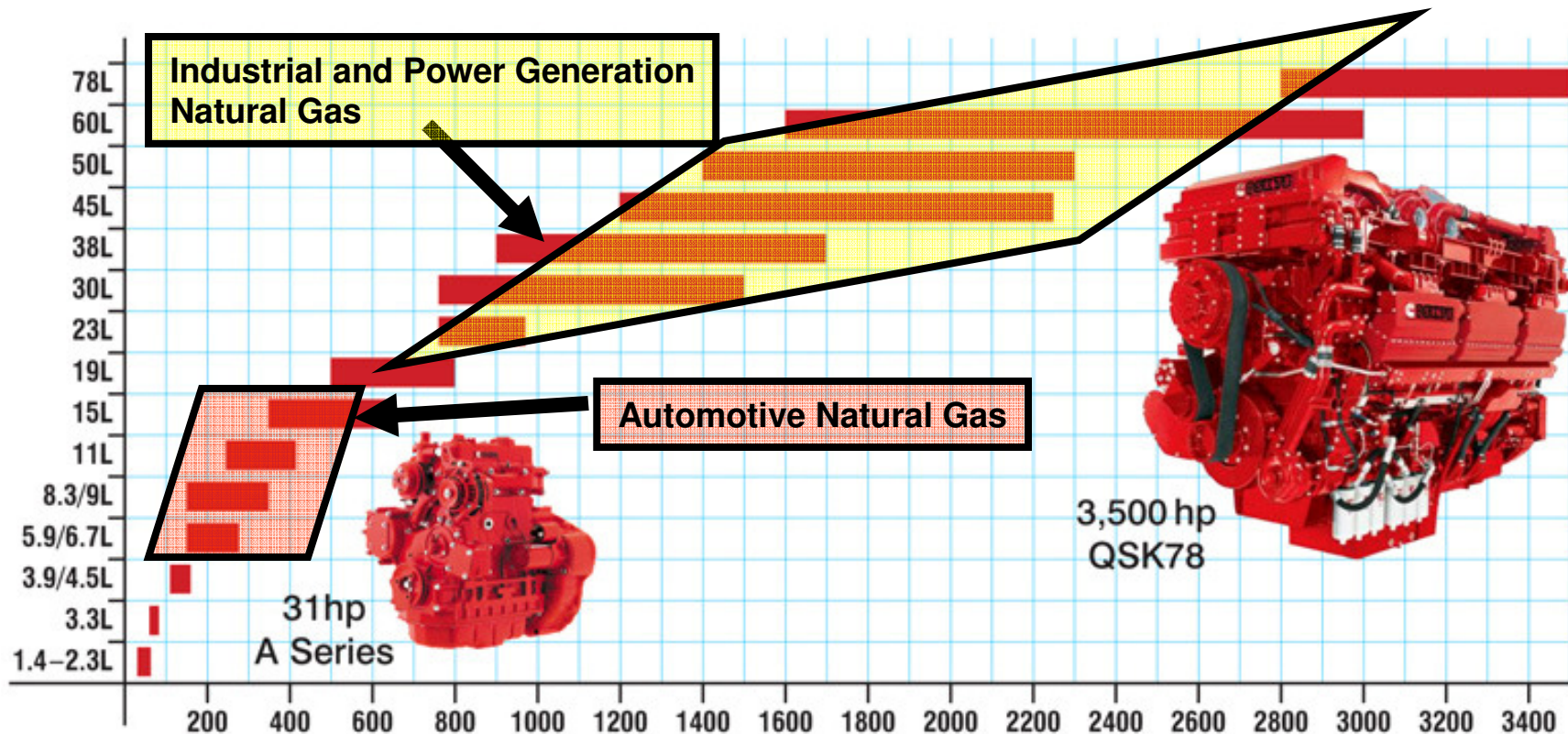
Reducing CO2 Footprint



Reducing CO2 Footprint



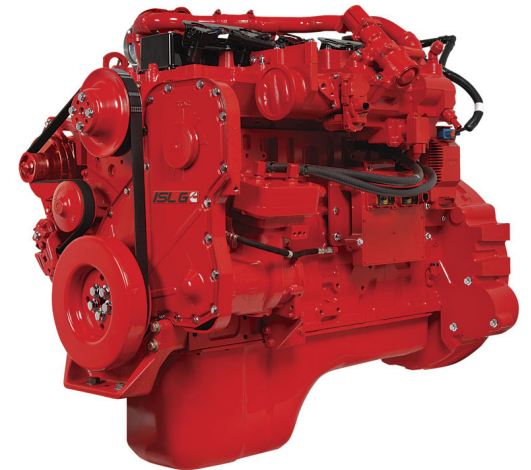
Cummins Engines 31 to 3,500 HP



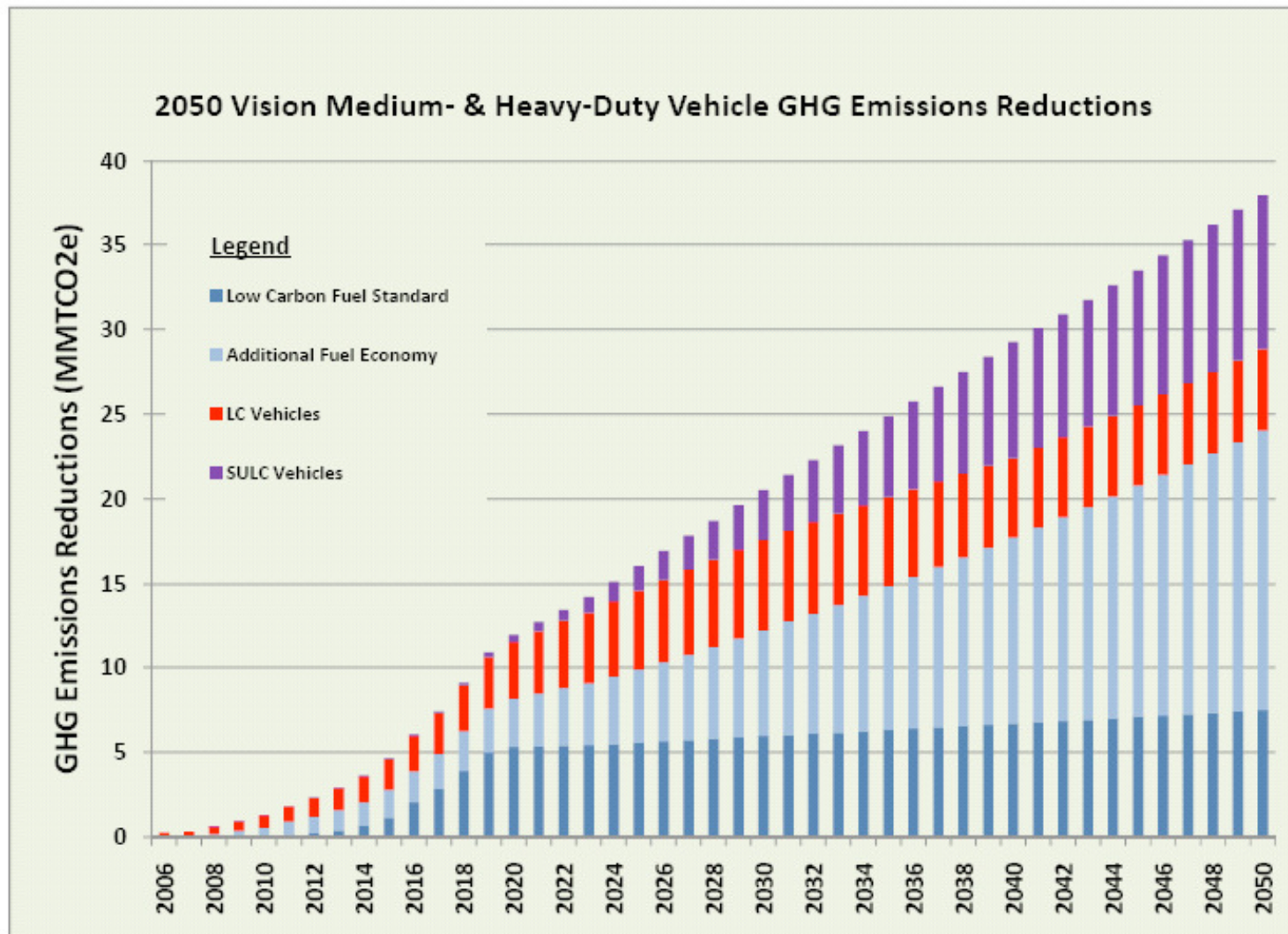
Lower Carbon Fuel Engines



- Low carbon fuels: natural gas, ethanol, butanol, biodiesel etc
- Renewable
- Cummins experience with on road natural gas engines for over two decades
- ISLG met 2010 emissions three years early – SI engines
- California important market



GHG Reduction – CEC Estimate



Medium and Heavy duty GHG Emissions Reductions (2009 to 2020) - CEC



Category	GHG Reduction (MMTCO ₂ e)	Percent GHG Emissions Reduction
Low Carbon Vehicles	22	53%
Super UL carbon Vehicles	1	2%
Fuel Economy Improvements	19	45%
Total Reductions	42	100%

GHG Reduction potential



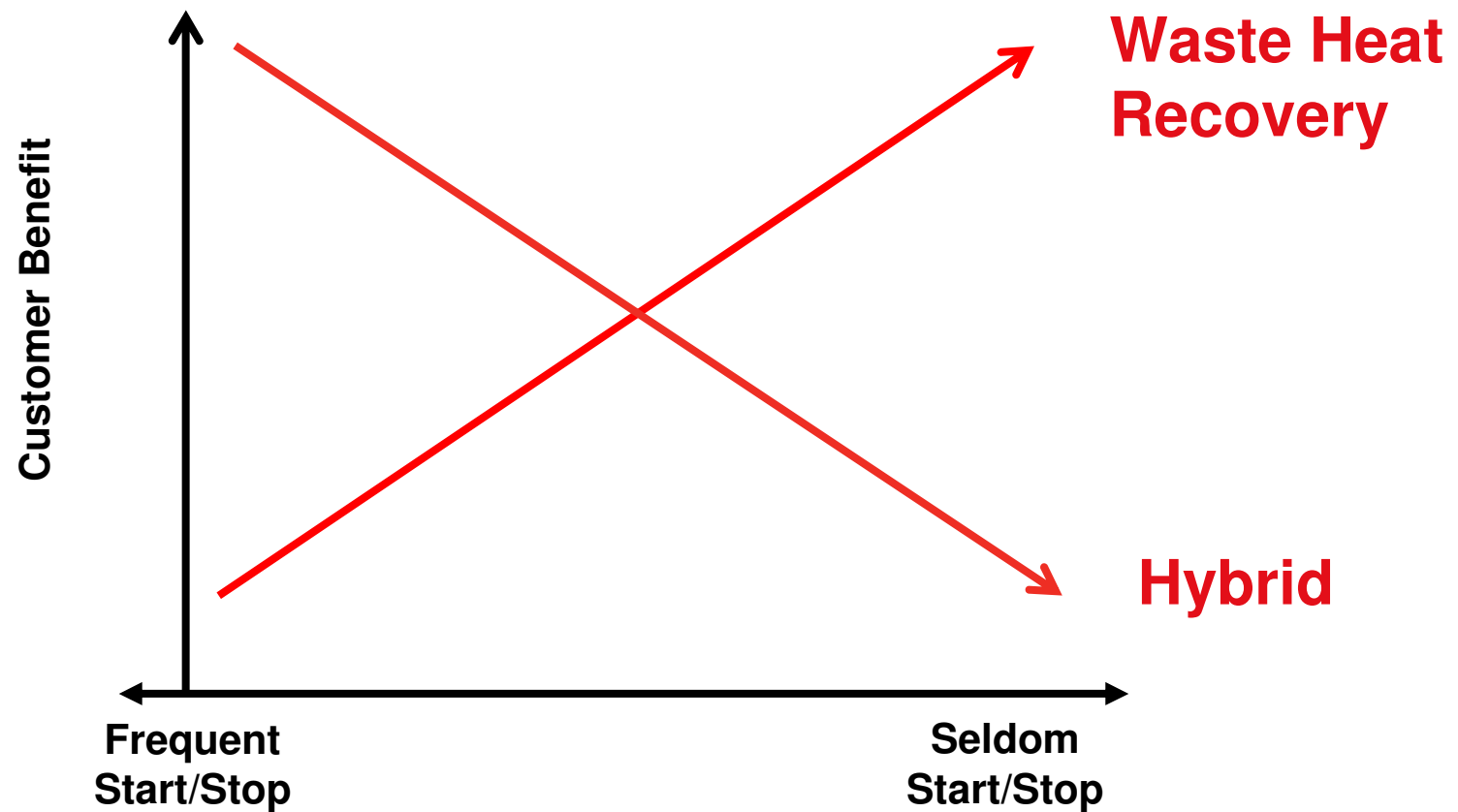
- Low carbon fuels
 - E85 lowers GHG more significantly
 - Natural gas engines experience
 - Fuel change practical
- Engine down size
 - Reduce engine fuel consumption
 - Integrate with engine electrification
 - Reduce criteria pollutants and GHG
- Hybridize
 - Energy recovery
 - Technologies /products available
 - Product cost is an impediment for commercial vehicles

E85 Engine Attributes Relative to Diesel



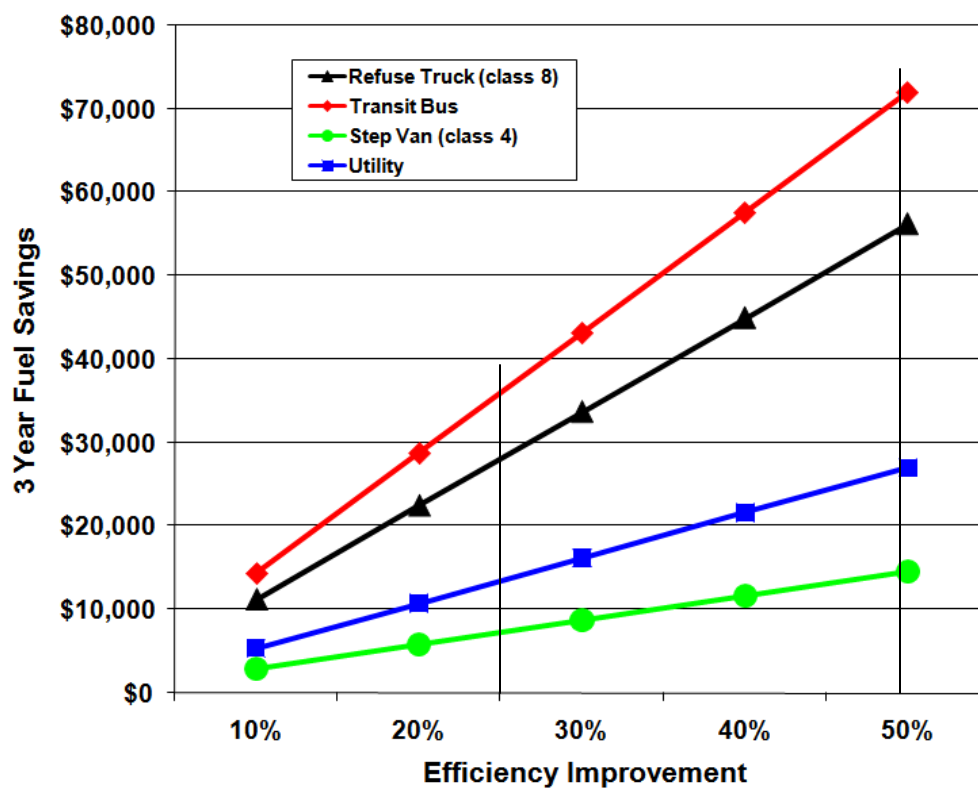
- Diesel-equivalent peak torque and brake thermal efficiency
- Lower GHG - as much as 60%
- Engine system less costly & easy to package
- Higher power density potential – lower cylinder pressure requirements than diesel
- Down sized diesel engine maintains diesel-like robustness

Waste Heat Recovery vs. Hybrid





Hybrid Fuel Savings vs Efficiency Improvements



Significant Benefit of Engine Centric Power Train



Ethanol Engine/Hybrid Potential

- Demonstrate a combined engine / hybrid 80% reduction in petroleum based fuels over a drive cycle
- Demonstrate a combined engine / hybrid 70% reduction in CO2 emissions over a drive cycle
- Demonstrate a combined engine / hybrid 36% reduction in energy use over a drive cycle



Potential Markets

E85 Engine Integrated with Hybrid System
(Hybrid System could also be integrated with a Natural Gas or Clean Diesel Engine)

- Vocational Trucks
 - Bucket
 - Dump
- Other applications
 - Pick up & delivery
 - Shuttle bus

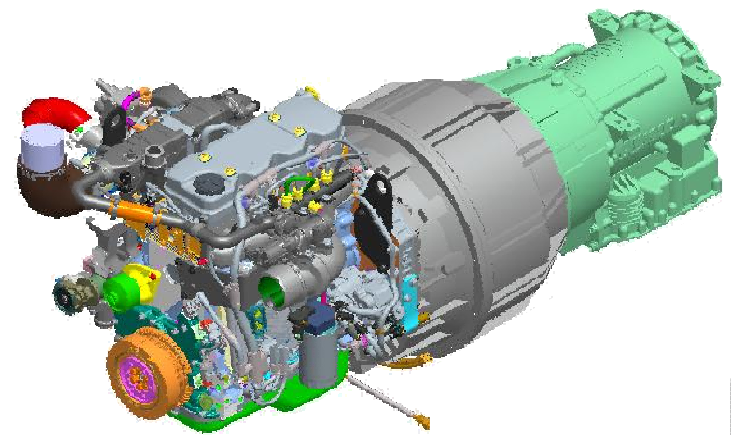
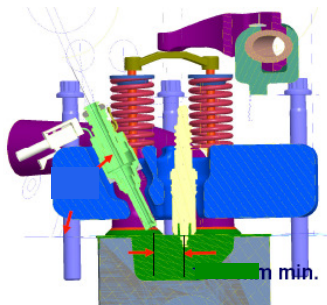


- Based on the relationships of Cummins and its California Distributors, we believe the following sectors will have an interest in participating in a prototype demonstration: beverage delivery; municipal government, public and private utilities, irrigation districts, and transit fleets.

Next Steps



- CMI Natural Gas engines are ready now for a demonstration project in a hybrid vehicle
 - CMI is interested in integrating a hybrid power train with a CMI natural gas engine
- CMI is interested in developing diesel engines for ethanol fuel
 - Greater GHG reduction than natural gas
 - Improved hybrid technology
 - Appropriate for CNG



Summary



- Low carbon fuel combustion technologies available for medium and heavy duty engines
- Engine down size
 - Reduce engine fuel consumption
 - Integrate with engine electrification
 - Reduce criteria pollutants and GHG
- Hybridize
 - Energy recovery
 - Technologies /products available-improved systems on the horizon
- CMI strongly positioned to support Natural Gas and Ethanol demonstration projects in a hybrid vehicle