

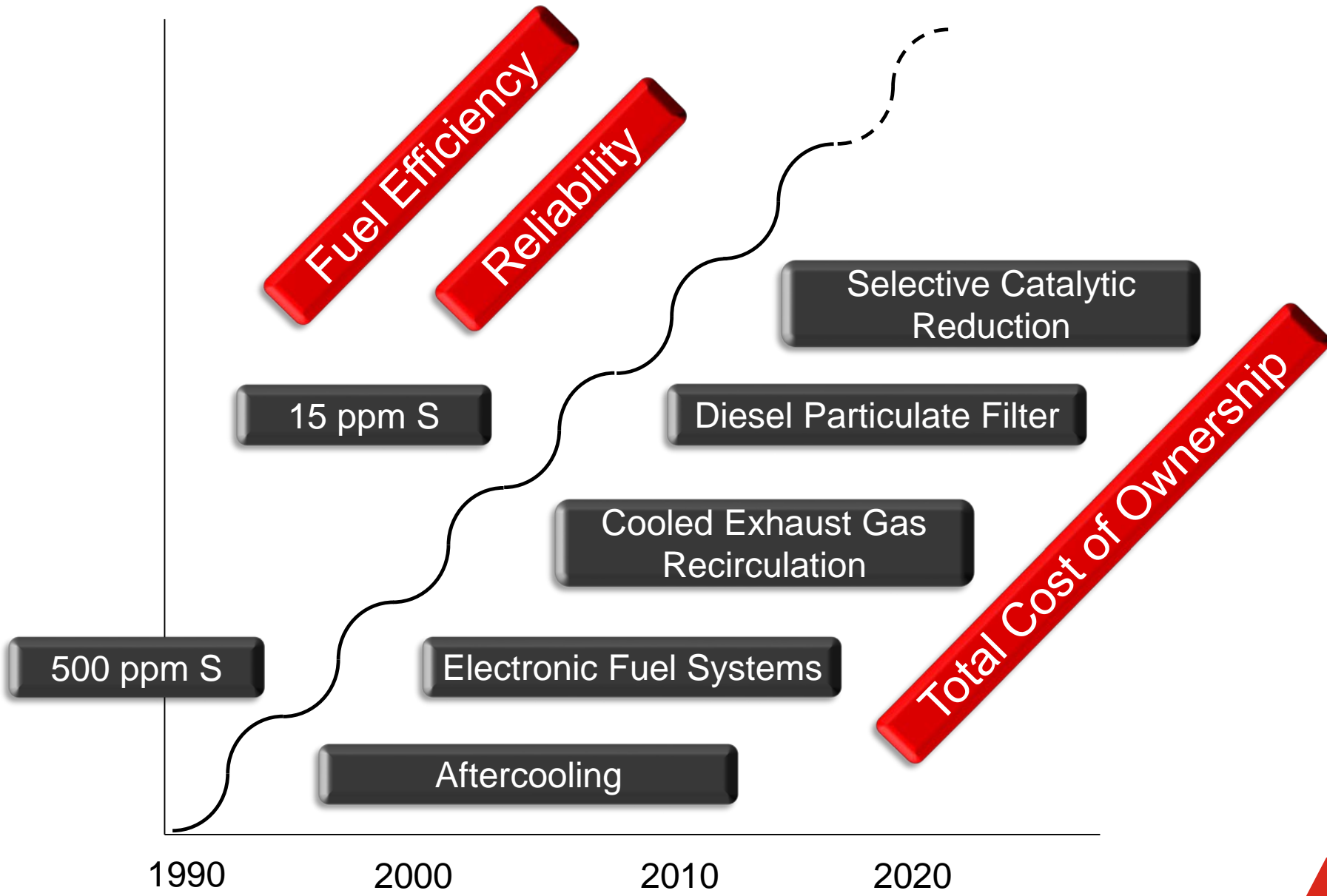
Enabling Technologies - Diesel through hybrid

David Dunnuck

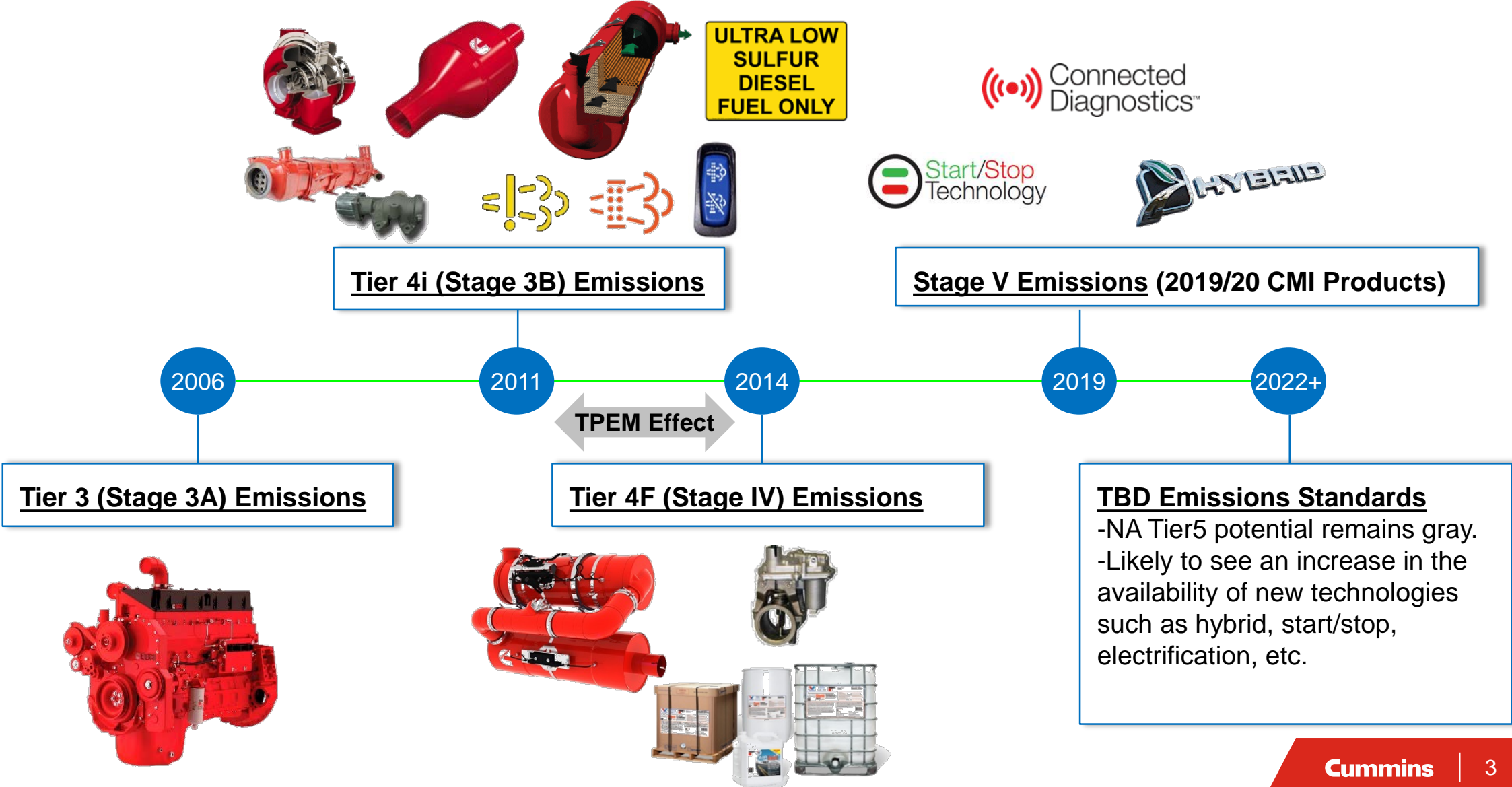
Executive Director – CES Research
and Engineering

January 2019

Evolution of Diesel Technology

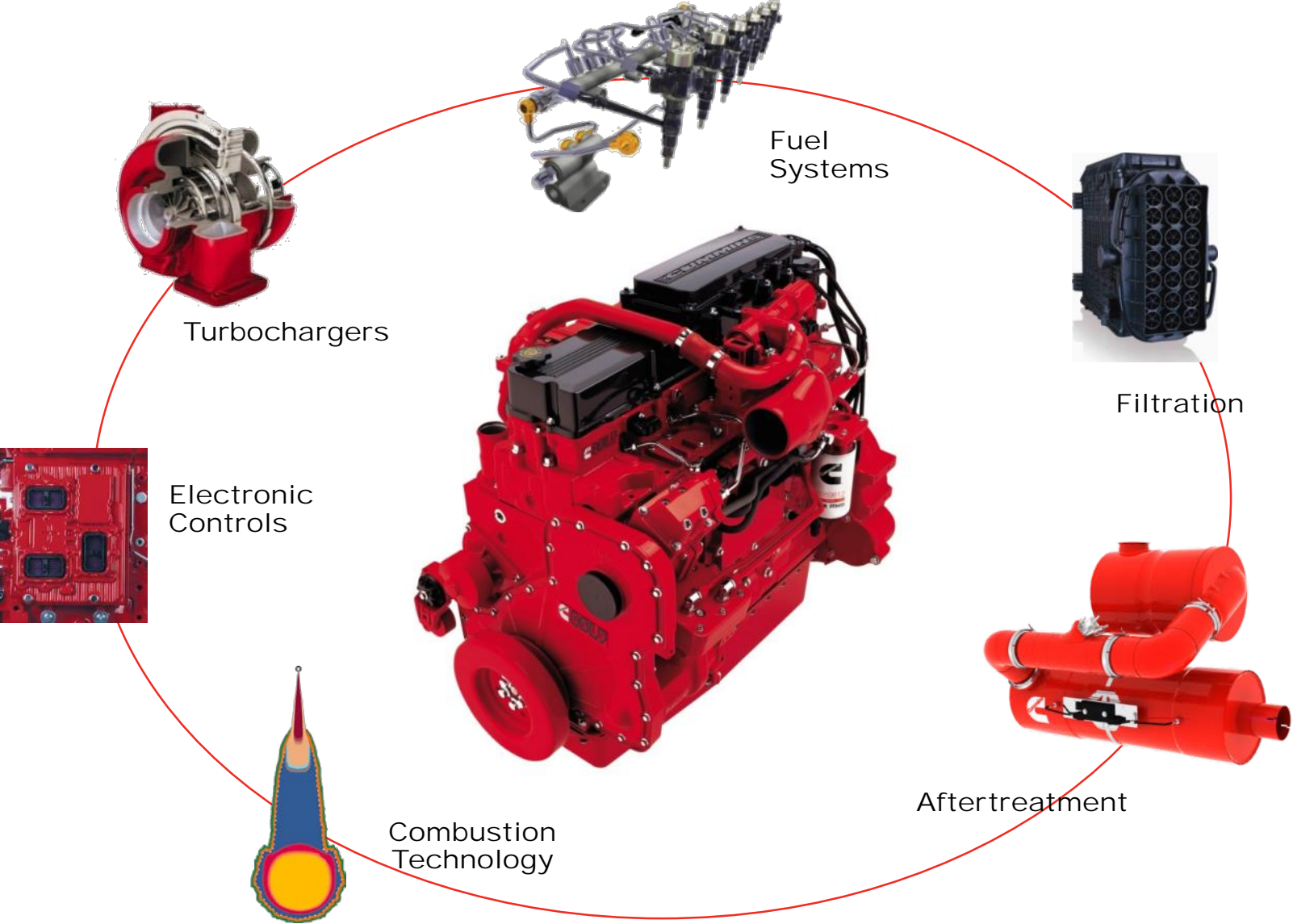


Technology Introduction - Recent Tiers



System Integration

Cummins design, build & integrate the complete Tier 4 system from air-intake to exhaust



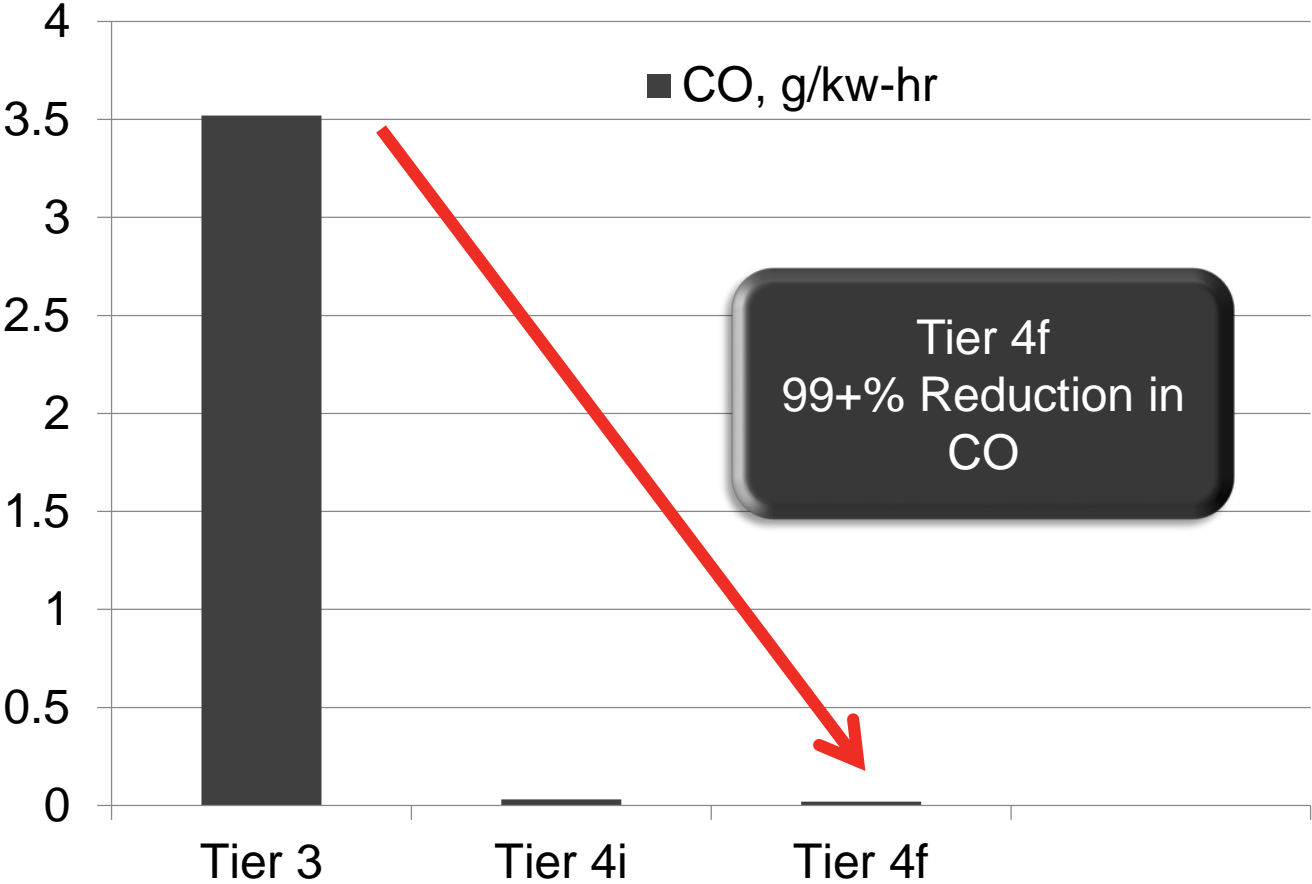
The Right Technology Matters



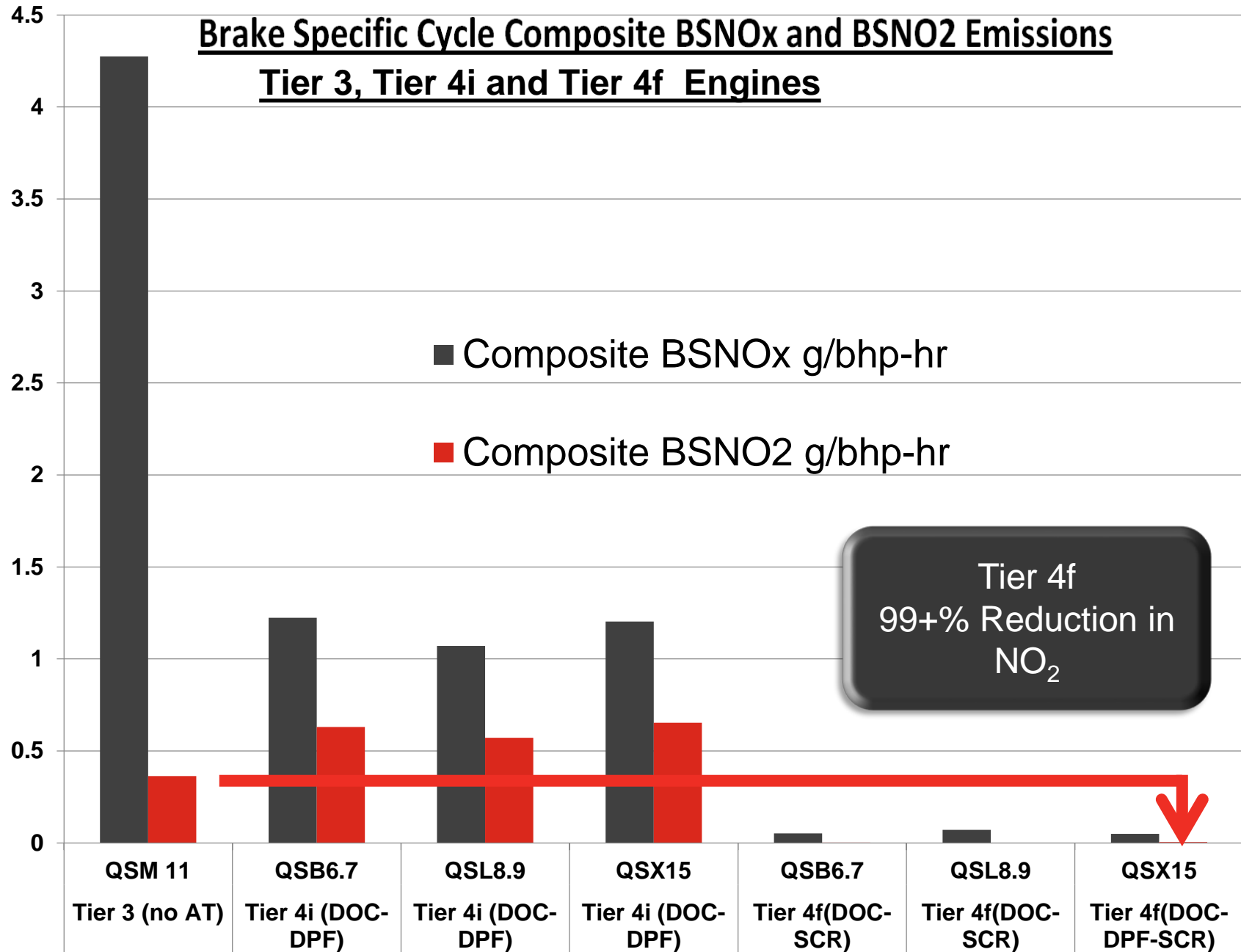
- Fit technology to market application

Application	First Date	In-Cylinder Only	Cooled EGR/VGT	NOx Adsorber	SCR	PM Aftertreatment
Tier 3 / EU Stage IIIA	2005	●				
EPA Tier 2 > 751 hp	2006	●				
Euro 4 On-Highway	2006				●	
EPA 07 On-Highway	2007		●			●
EPA 07/10 Pickup Truck	2007		●	●		●
Euro 5 On-Highway	2009				●	
EPA 10 On-Highway	2010		●		●	●
Tier 4 Interim / Stage IIIB	174-751 hp	2011	●			●
	75-173 hp	2012				
Tier 4 Final / Stage IV	174-751 hp	2014	●		●	
	75-173 hp	2015				
Stage V	2019				●	●
Tier 4 Final	2020					

Carbon Monoxide Emissions



Brake Specific Cycle Composite BSNOx and BSNO2 Emissions
Tier 3, Tier 4i and Tier 4f Engines



Characteristics of New vs. Old Diesel PM

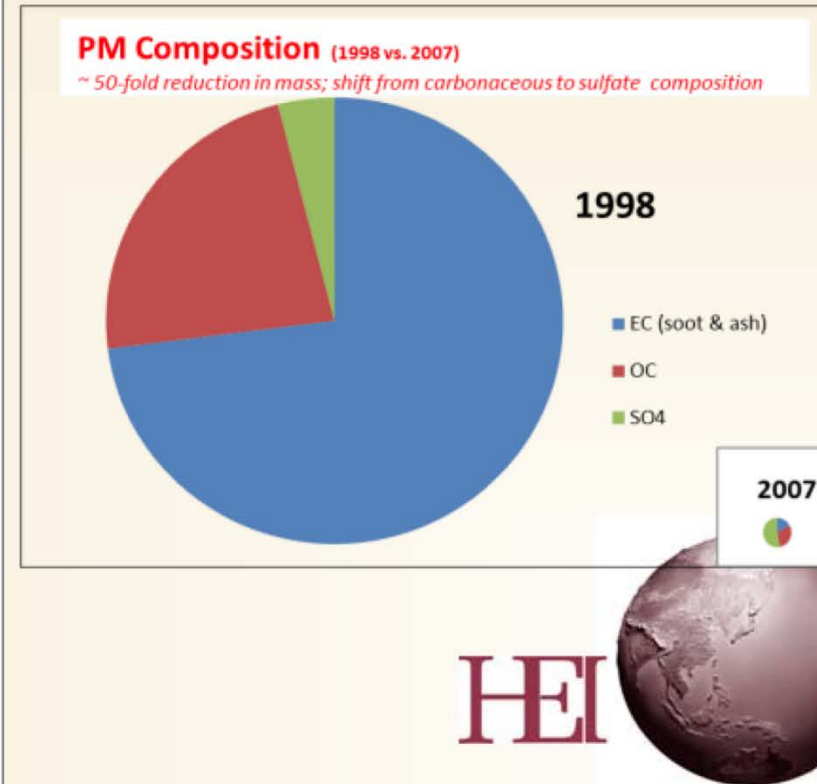
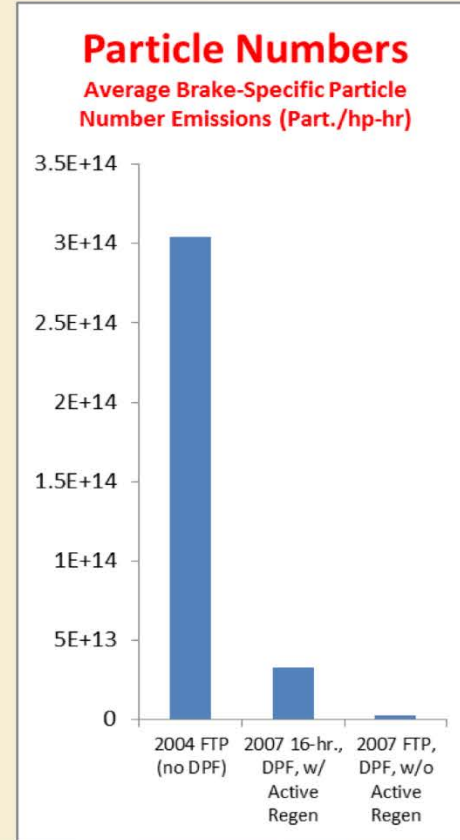
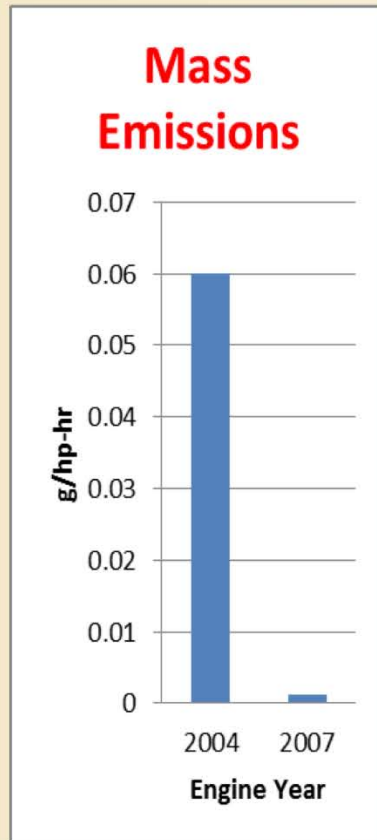
HEI ACES Results Compared to earlier Testing:

Dramatic Reductions

98% reduction in mass

90% - 99% reduction in Ultrafine Particles

Substantial reduction in carbon particles

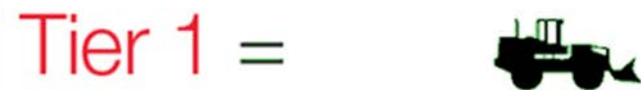
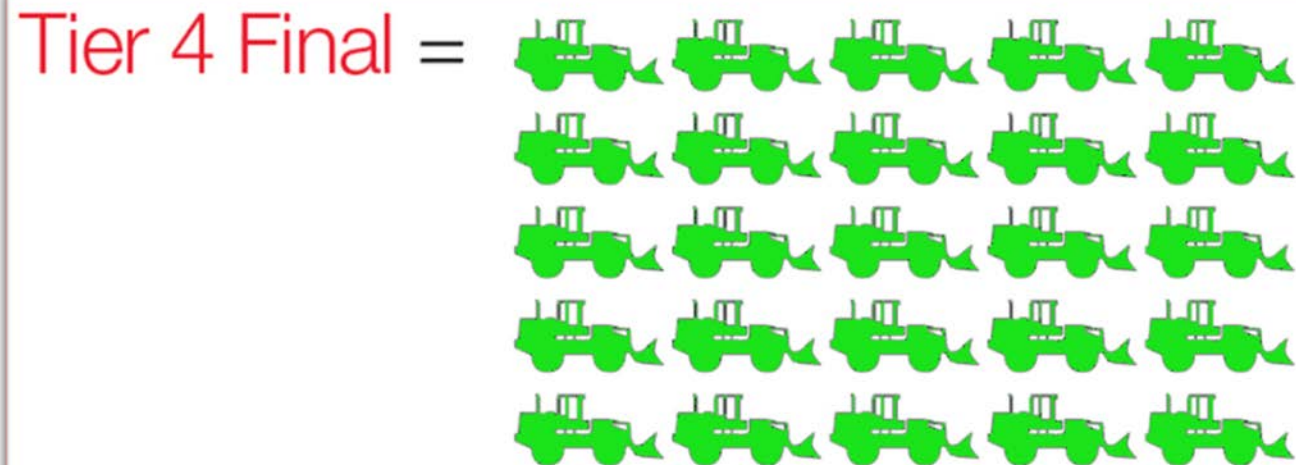


(Khale, *Air & Waste Manag. Asso.*, 2011)

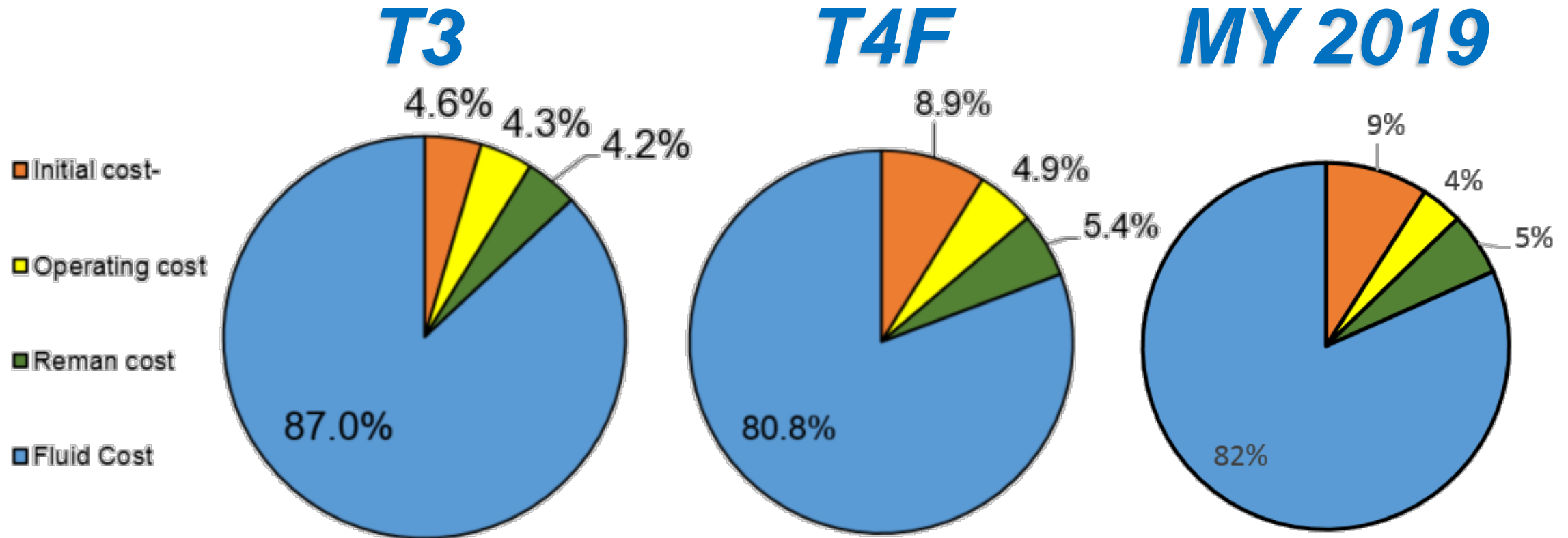
(Courtesy of HEI Report, 2015)

Meeting 'Near-Zero' Emissions

Emissions from 25 Tier 4 Final machines equivalent to just one Tier 1 machine!



Operating TCO Comparison: 6.7L

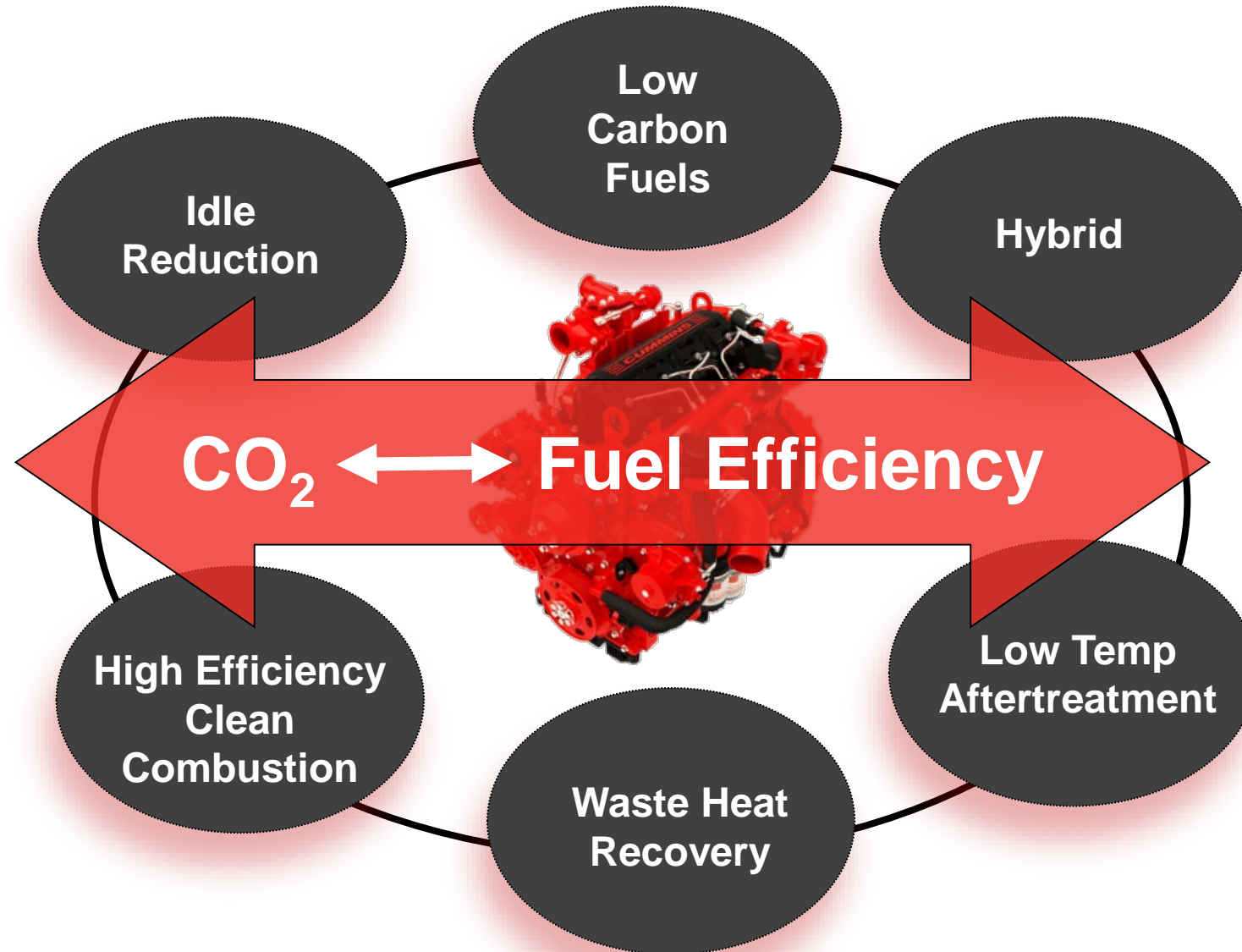


Total Cost	1	0.93	0.91
Maint Cost	1	1.08	.78

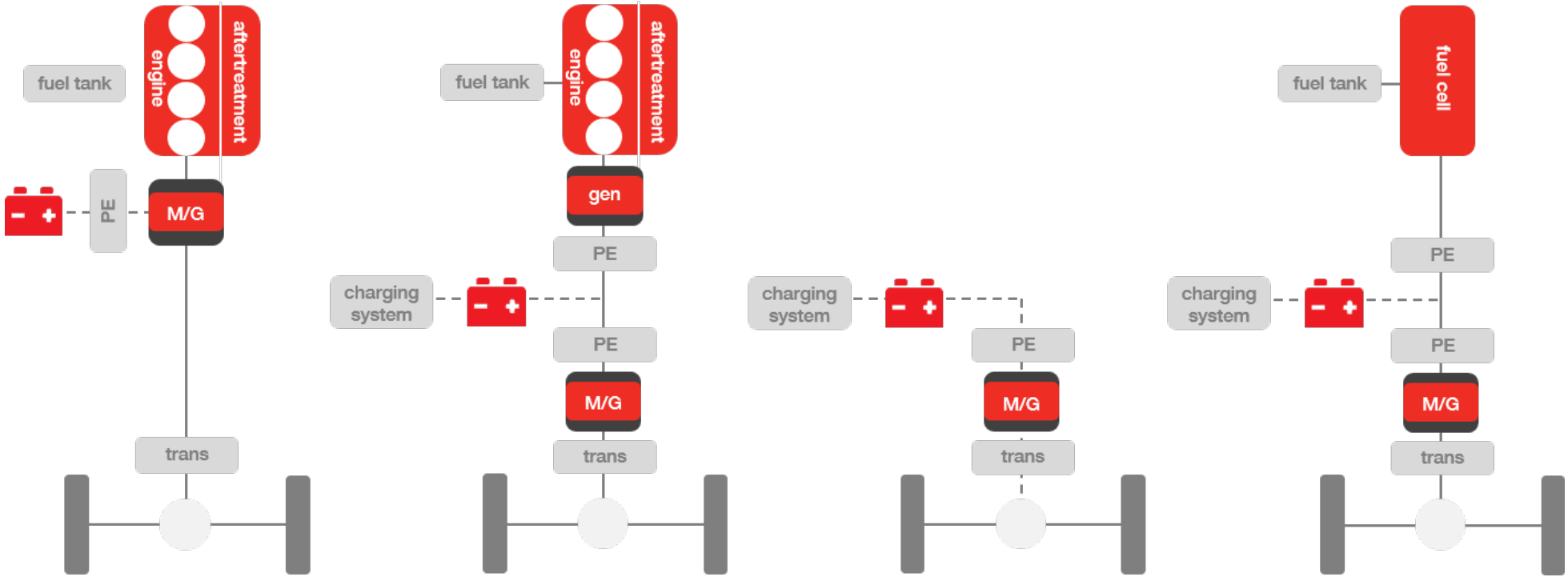
**TCO savings realized with newer products is highly duty cycle dependent.*

**Regional diesel & DEF pricing have direct affects on the above.*

Reducing CO₂



POWERTRAIN OF CHOICE



IC Engine

Hybrid
(Range Extended)
2020

Battery
Electric
2019

Fuel Cell
Electric

Alternate Energy

electrification • natural gas •
gasoline • others

Super Power Solution

Intelligent Data Systems

connected systems •
controls • intelligent
transportation

Powertrain Integration

transmission • axles • brakes

Super Engine System

» Cummins is committed to being a diverse powertrain supplier across our regions and markets.

» We are in a period of transformative change within the industry. With change comes opportunity.

The future includes:

» Internal combustion powertrain fueled by conventional and non-conventional fuels.

Electric powertrain as pure EV, range extended EV and hybrid.

Connected solutions to drive the demands of digital business.

energy diversity is **KEY**



Q+A

