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# **Development of High Performance Heavy Duty Engine Oils**

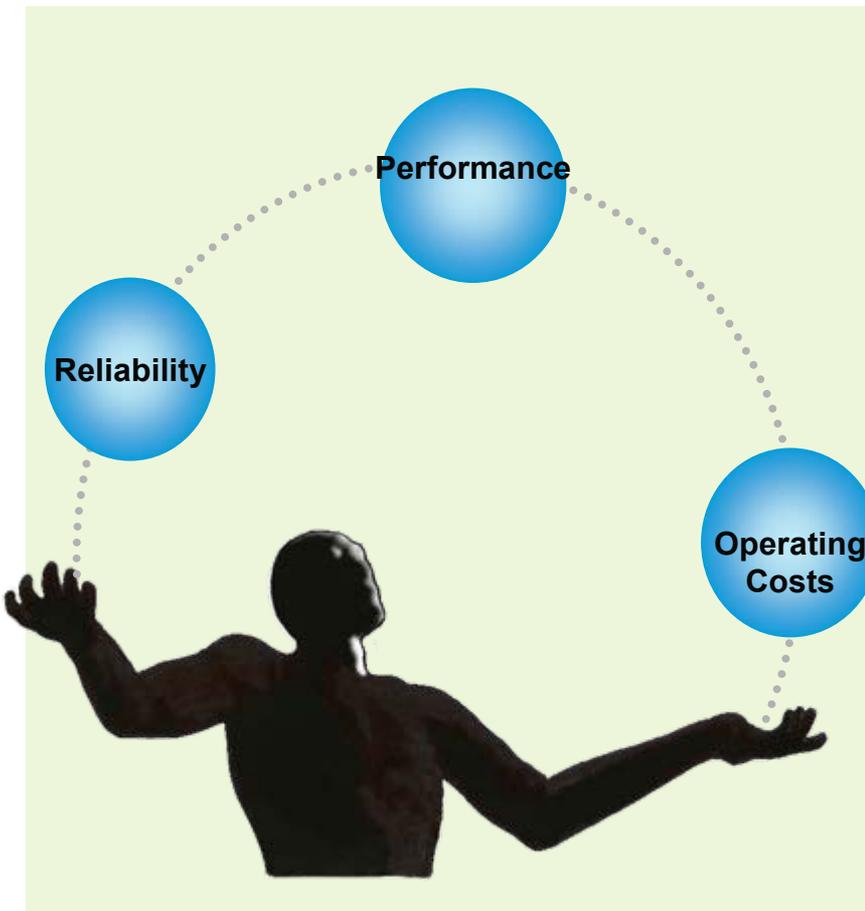
**Frank Lauterwasser  
Chevron Oronite LLC**

**August 6, 2009**

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# Pressures on the OEMs

## Main Drivers for New HD Diesel Engine Technology



The Old Days



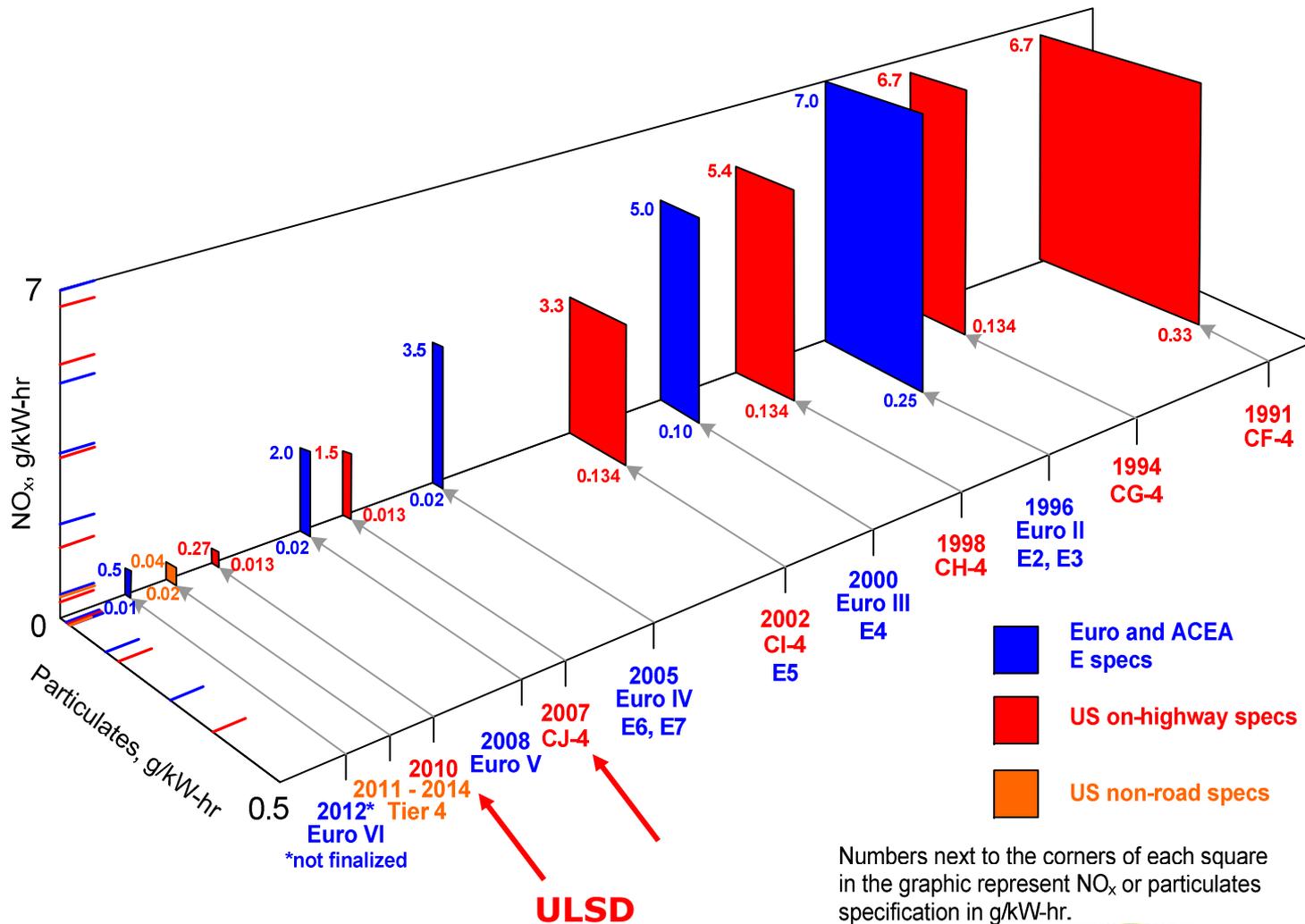
Today

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# Challenge of Emission Compliance

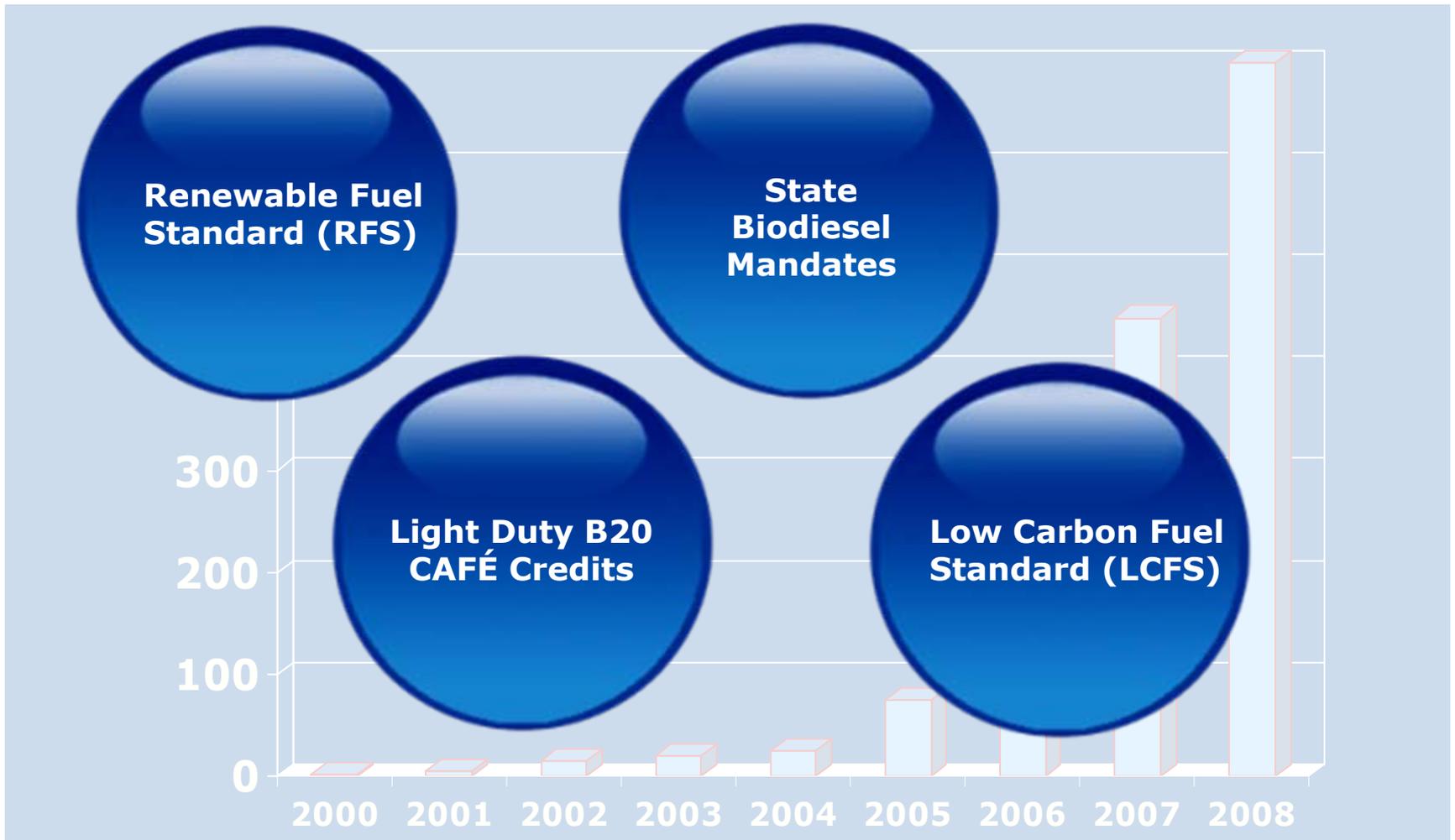


Numbers next to the corners of each square in the graphic represent NO<sub>x</sub> or particulates specification in g/kW-hr.



# Drivers For Increased Biodiesel Use In U.S.

Growth will no longer be based solely on relative economics



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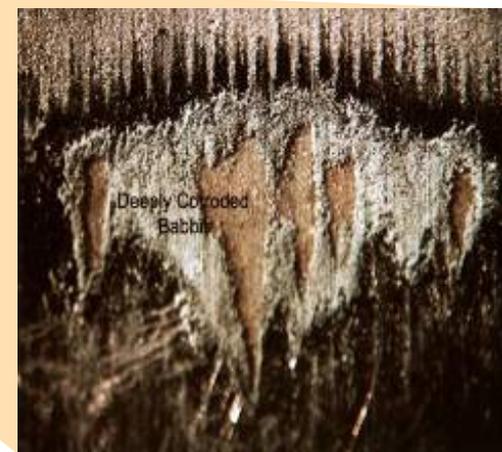
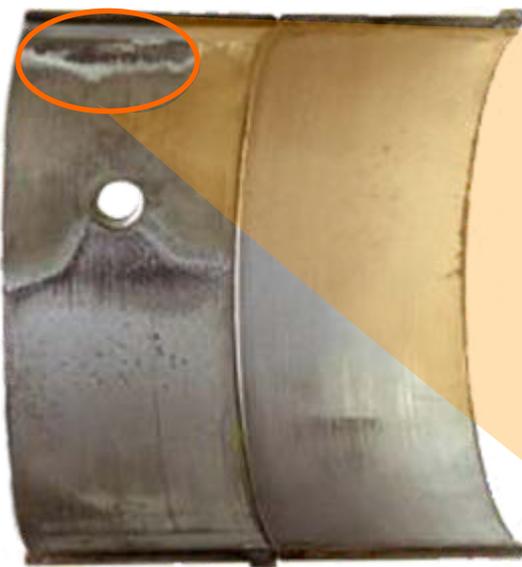


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# Biodiesel Use Can Challenge Conventional Diesel Engine Oils



Engine deposits and lead corrosion

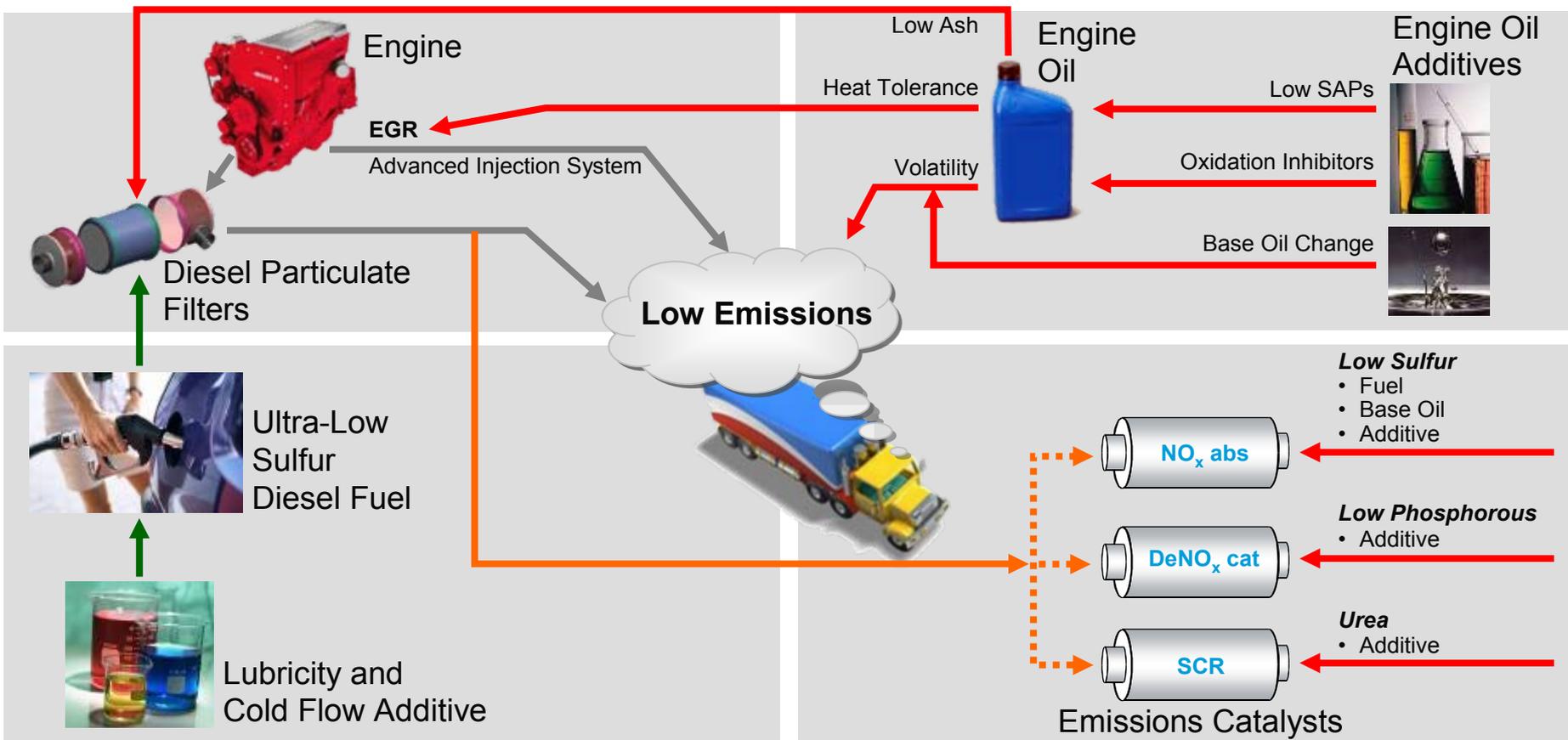


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# Fuels, Lubricants, Additives and After-treatment Changes to Achieve Heavy Duty Emissions Targets



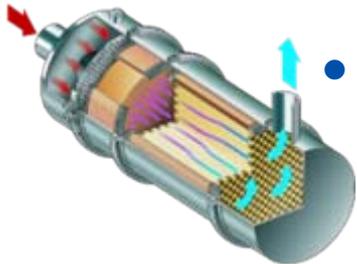
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# API CJ-4: Most Robust Heavy Duty Engine Oil\*

- CJ-4 oils allow the use of EGR, DPF to reach the low emission compliance for 2007
- Low SAPs level to enable the use of after treatment system
  - Low ash level 1.0 for DPF protection
  - Higher stress on the oil due to EGR



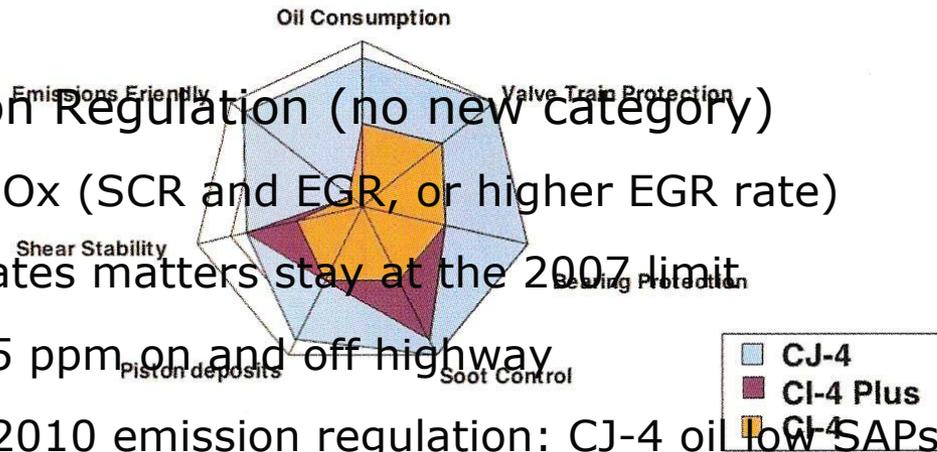
*CJ-4 Performance Upgrade over CI-4/CI-4 Plus*

© Copyright Johnson Matthey Pic 20

- 2010 Emission Regulation (no new category)

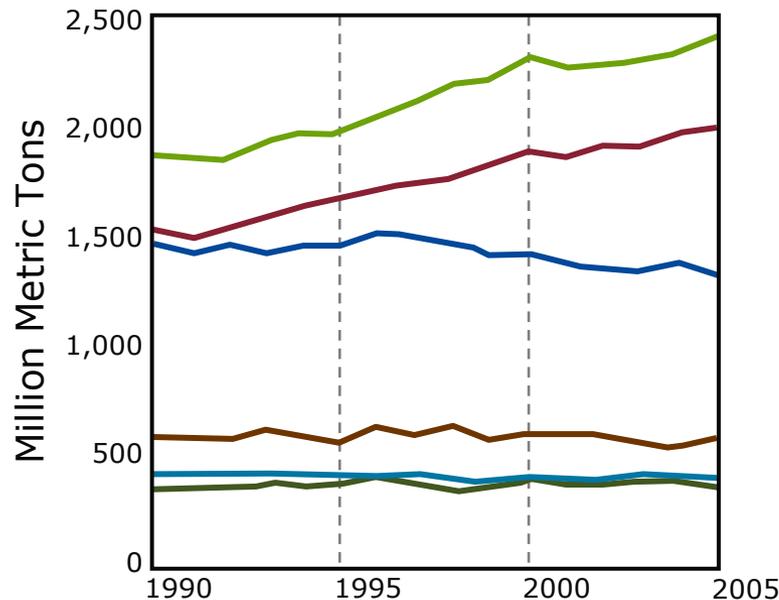
- Lower NOx (SCR and EGR, or higher EGR rate)
- Particulates matters stay at the 2007 limit
- ULSD 15 ppm on and off highway
- Oil for 2010 emission regulation: CJ-4 oil low SAPs (1.0 ash limit)

- ▶ 15W40 and 10W30 (fuel economy) available



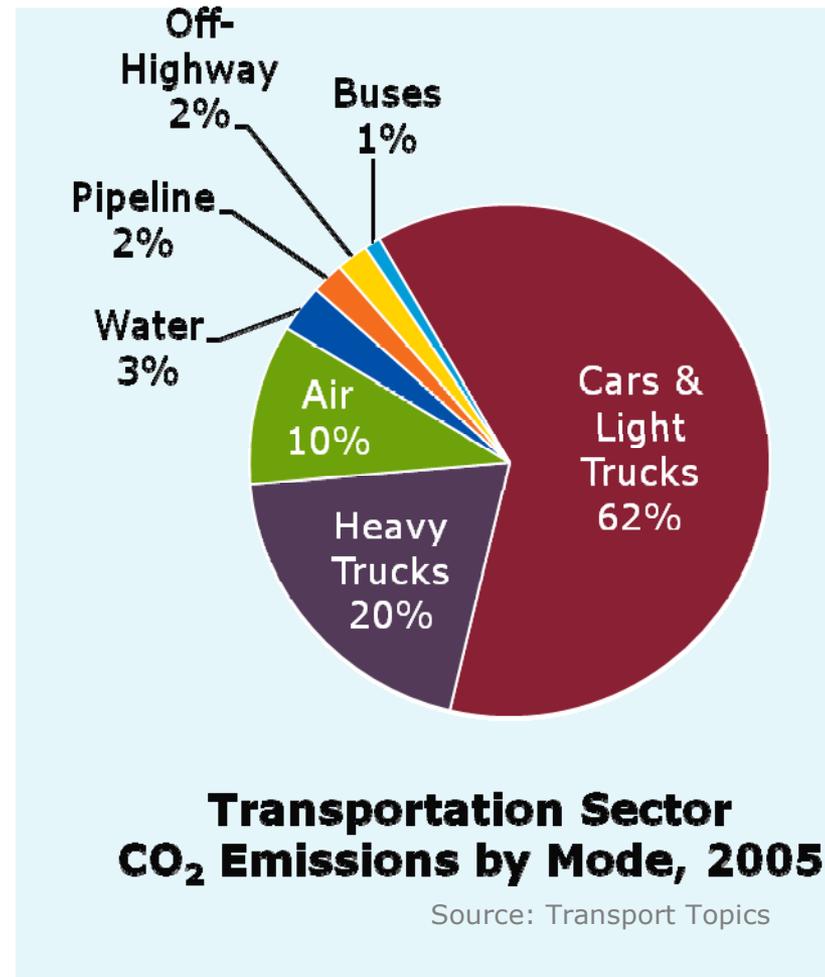
# CO<sub>2</sub> Emissions – Regulations in U.S. Future?

## Greenhouse Gas by U.S. Economic Sector



- Electricity Generation
- Transportation
- Industry
- Agriculture
- Commercial
- Residential

Source: Environmental Protection Agency



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# Active and Pending HD Fuel Economy Regulations

## ■ Japan

- First Truck Fuel Economy Standards in the World
  - ▶ Fully Implemented in 2015
  - ▶ Based on engine dynamometer test
  - ▶ Fuel economy assessed at various operating conditions and parameters

## ■ United States

- Truck Fuel Economy Standards included Energy Independence and Security Act of 2007
  - ▶ Study in progress to establish regulations and criteria– not likely simple mpg, probably ton-miles/gallon or some other measure
  - ▶ Likely to be implemented in 2016/2017
  - ▶ CO<sub>2</sub> emissions regulations may be implemented earlier

## ■ Europe

- ▶ No current Truck Fuel Economy Standard, but CO<sub>2</sub> emissions considered when establishing NO<sub>x</sub> and Particulate Emissions limits in EURO 6





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# The Impact of Biodiesel Use on the Lubrication of Diesel Engines



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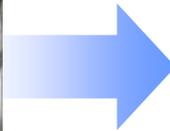
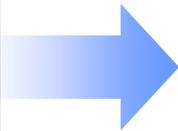
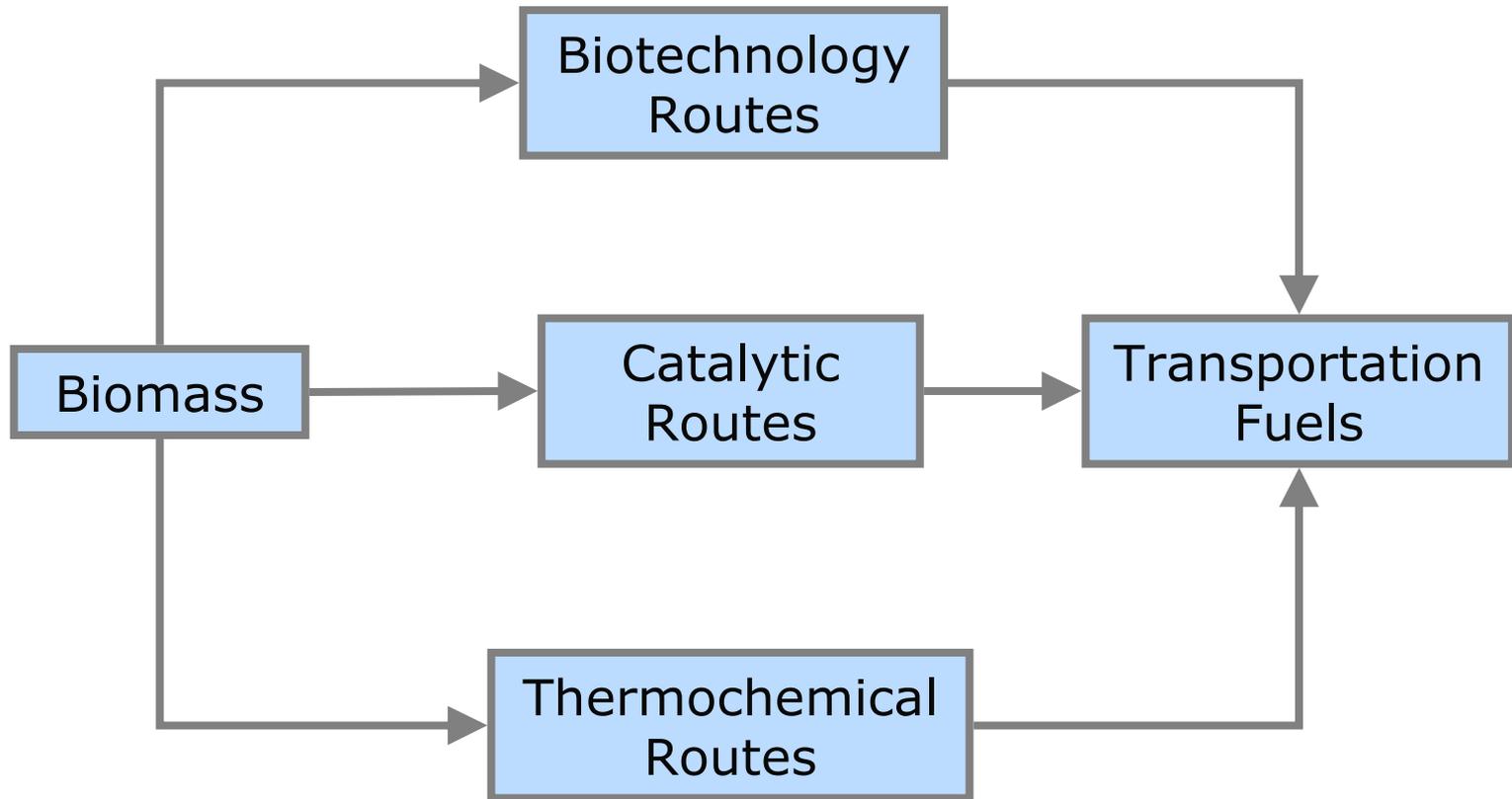
# The Role of Renewables

## Chevron Views

- The world needs all kinds of energy sources – Oil, gas, unconventional and renewables – To meet growing demand in an environmentally sound manner
- Developing infrastructure to produce and distribute new forms of energy such as biofuels on a large scale will be a significant challenge
- Our goal is energy solutions that are practical, innovative and enduring



# Non-Food Biofuels Technology Pathways



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# Biodiesel is a Global Phenomena

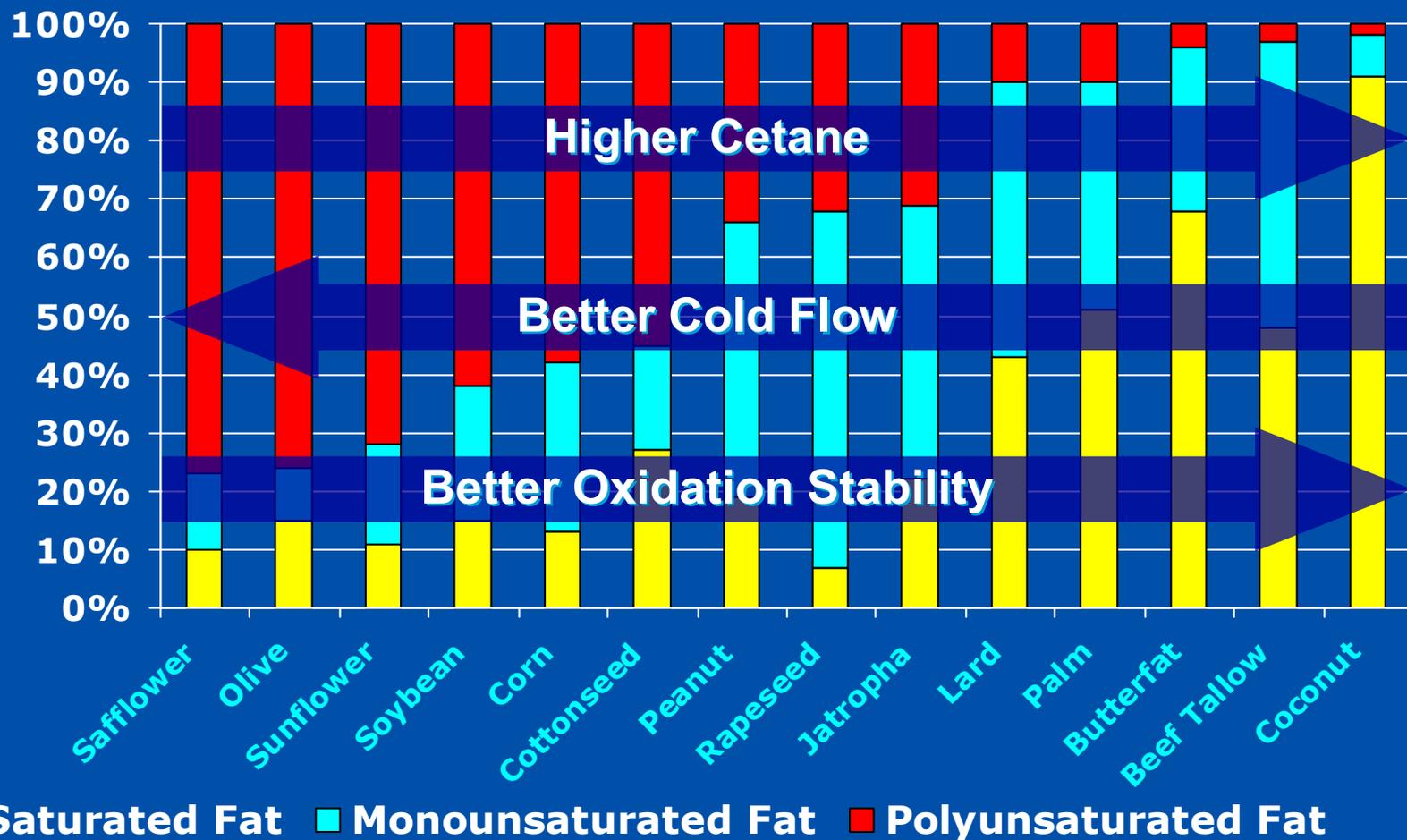


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# Biodiesel Feedstock Properties Impact Performance



Source: NREL



# OEM Biodiesel Issues & Concerns

## Fuel System

- Injector deposits
- Fuel filter plugging
- Injection pump durability
- Materials incompatibility
- Fuel Instability
- Low temperature handling
- May reduce detergency and anti-foam properties of fuel additive packages



## Emissions Systems

- Impact on after-treatment devices and sensors
- Impact on NOx emissions
- Lower BTU content and fuel economy

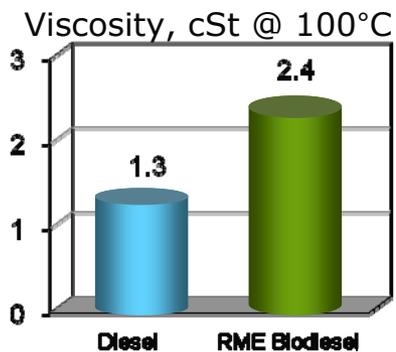
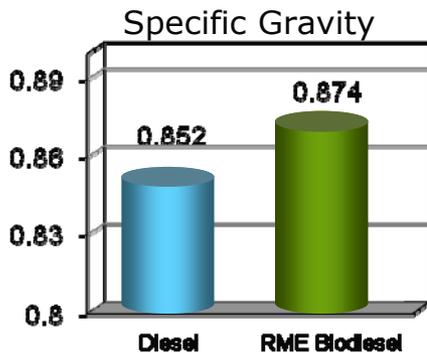
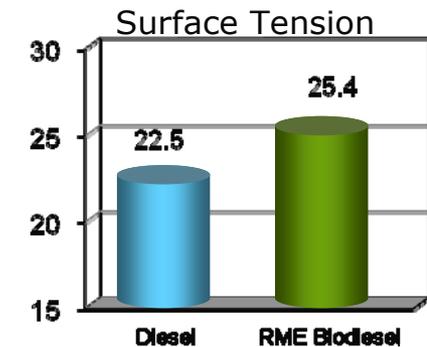


## Lubricant Performance

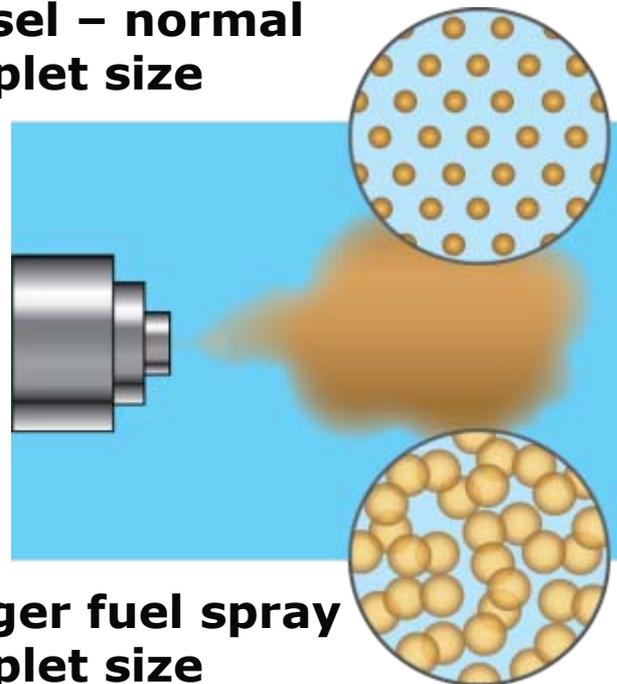
- Fuel dilution
- Corrosion
- Viscosity change
- Oxidation
- Piston Deposits
- Crankcase Deposits



# Crankcase Fuel Dilution With Biodiesel



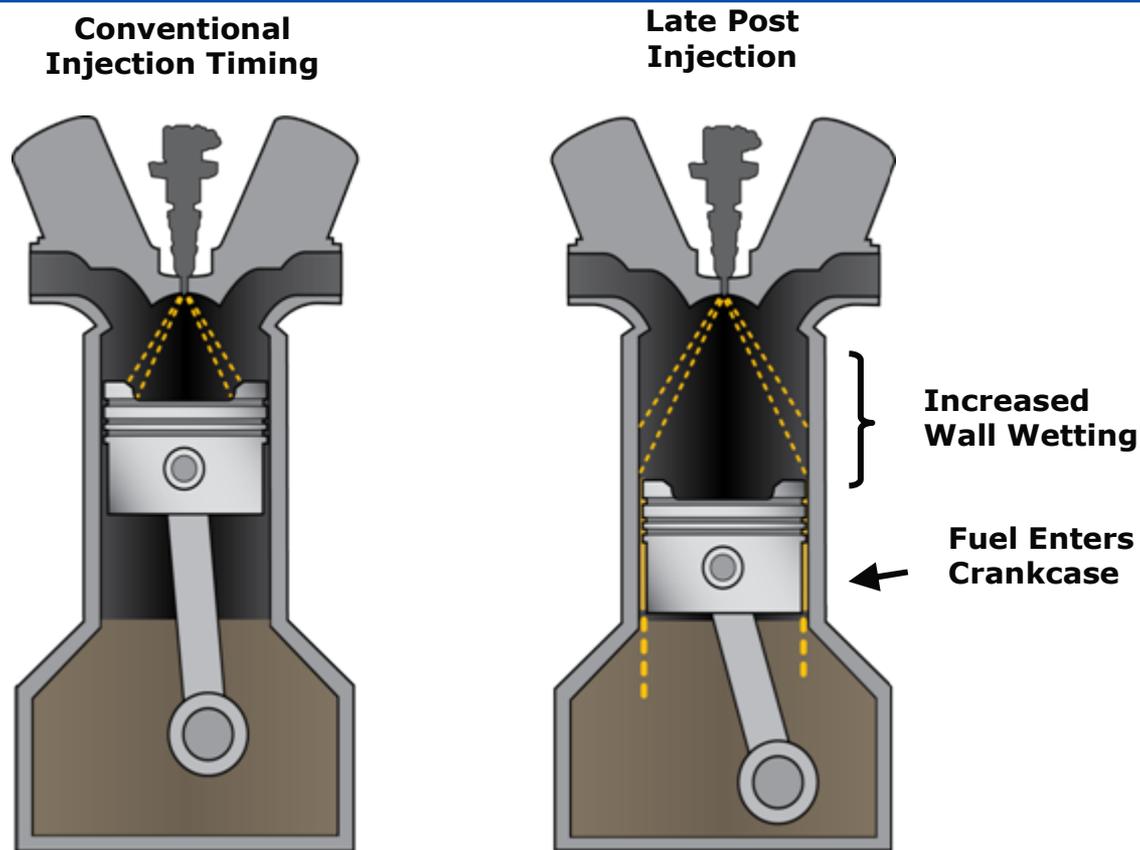
**Diesel – normal droplet size**



**Larger fuel spray droplet size**

*Properties of biodiesel lead to higher levels of fuel dilution*

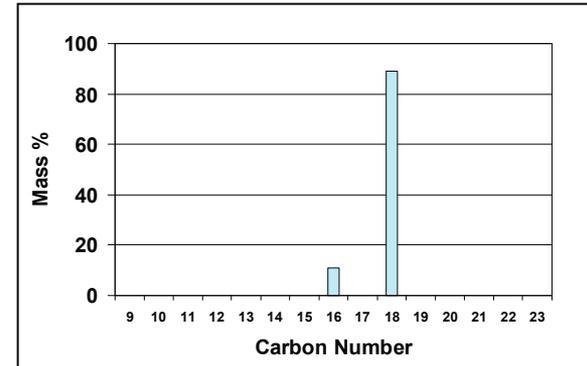
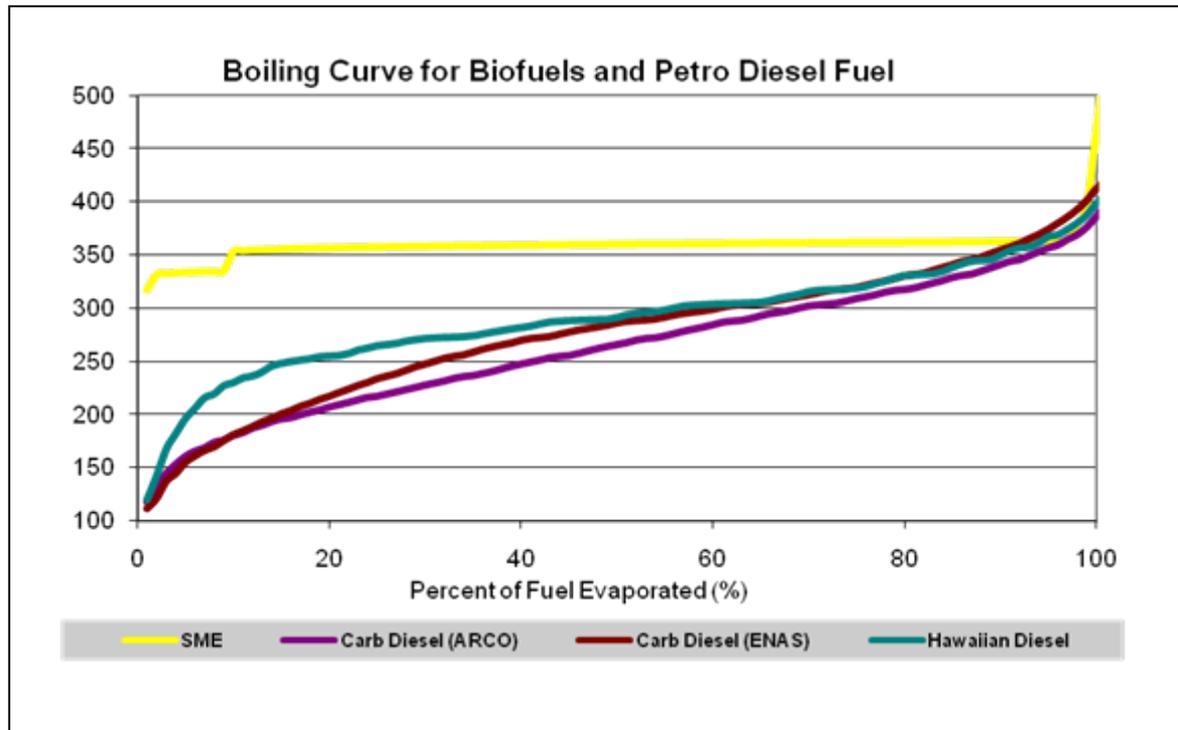
# Late Post-Injection Leads to Higher Levels of Fuel Dilution



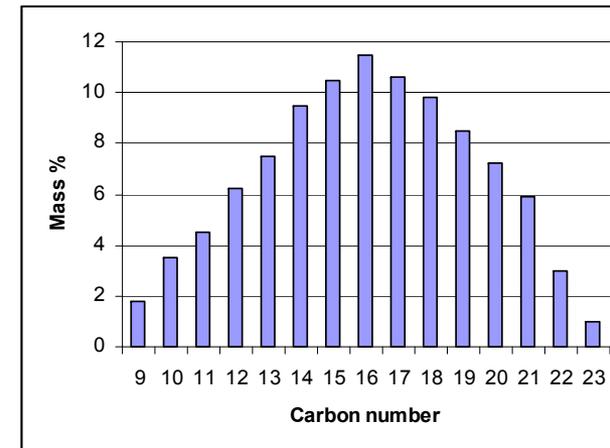
- Some OEMs have reported 15-20% fuel dilution (FAME) at oil drain
- OEMs often reduce drain intervals when biodiesel is used

# Crankcase Fuel Dilution With Biodiesel

**Higher and Narrower boiling range of biodiesel makes it more persistent once it enters the crankcase**



**Soy Methyl Ester**



**Mineral Diesel**

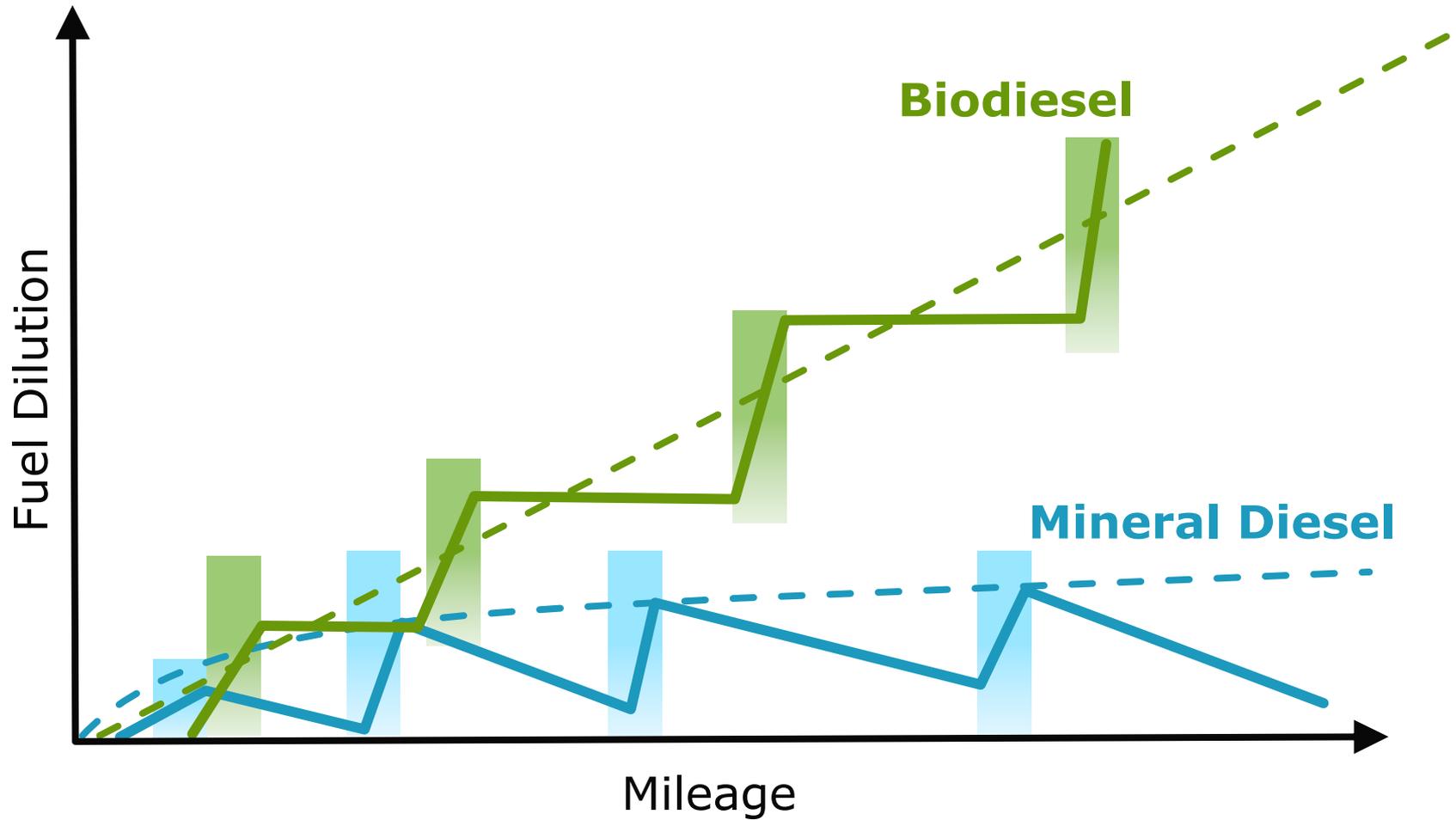
There is a need for a robust analytical method to measure biodiesel content in used engine oils

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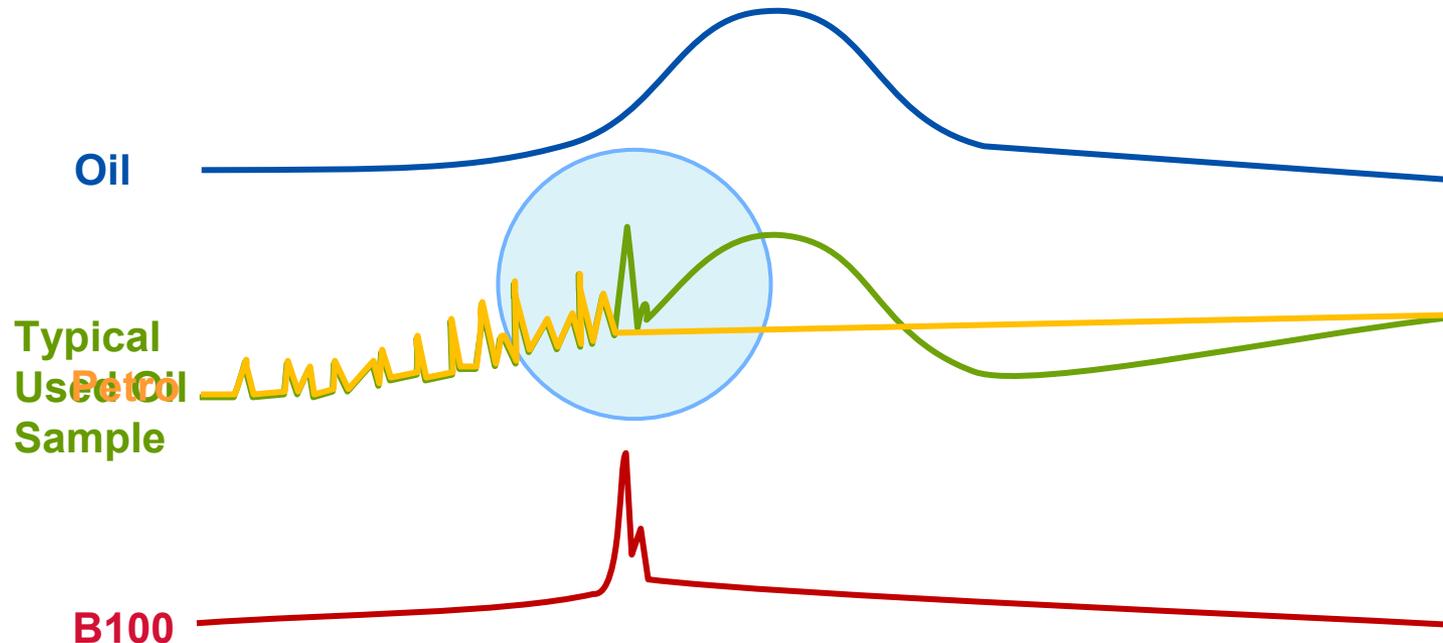
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# Oil Dilution During Particulate Trap Regeneration



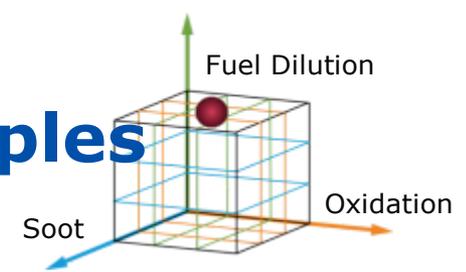
# Biodiesel Fuel Dilution Measurement By GC-FID

- Accurate fuel dilution measurement is important for R&D

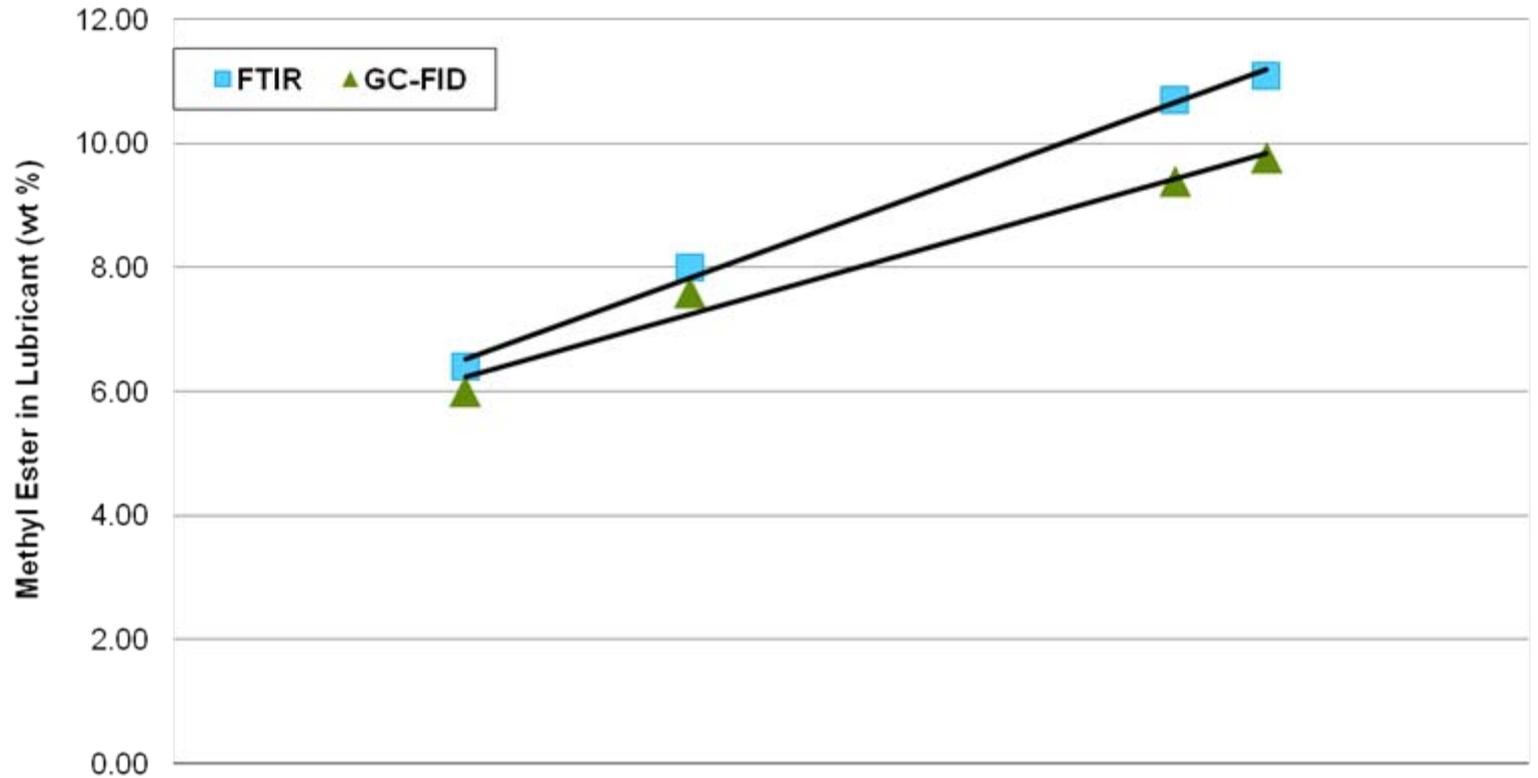


**GC-FID Measurement is Confounded in Used Oil**

# Results From OEM Field Test Samples



Biofuel Dilution for Vehicle Running on B20 SME



Oil Mileage (miles)	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000
Oil Mileage (km)	6,437	8,046	9,656	11,265	12,874	14,484	16,093	17,702	19,312	20,921

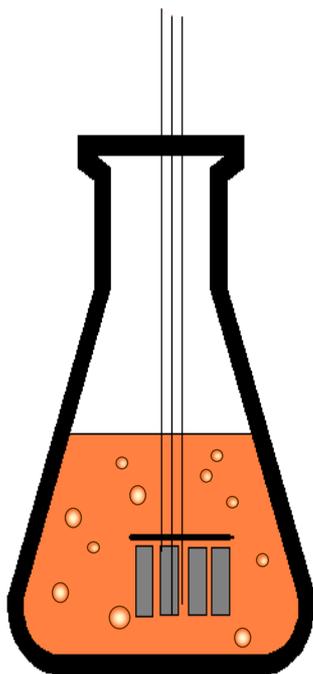
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# Cummins High Temperature Corrosion Bench Test

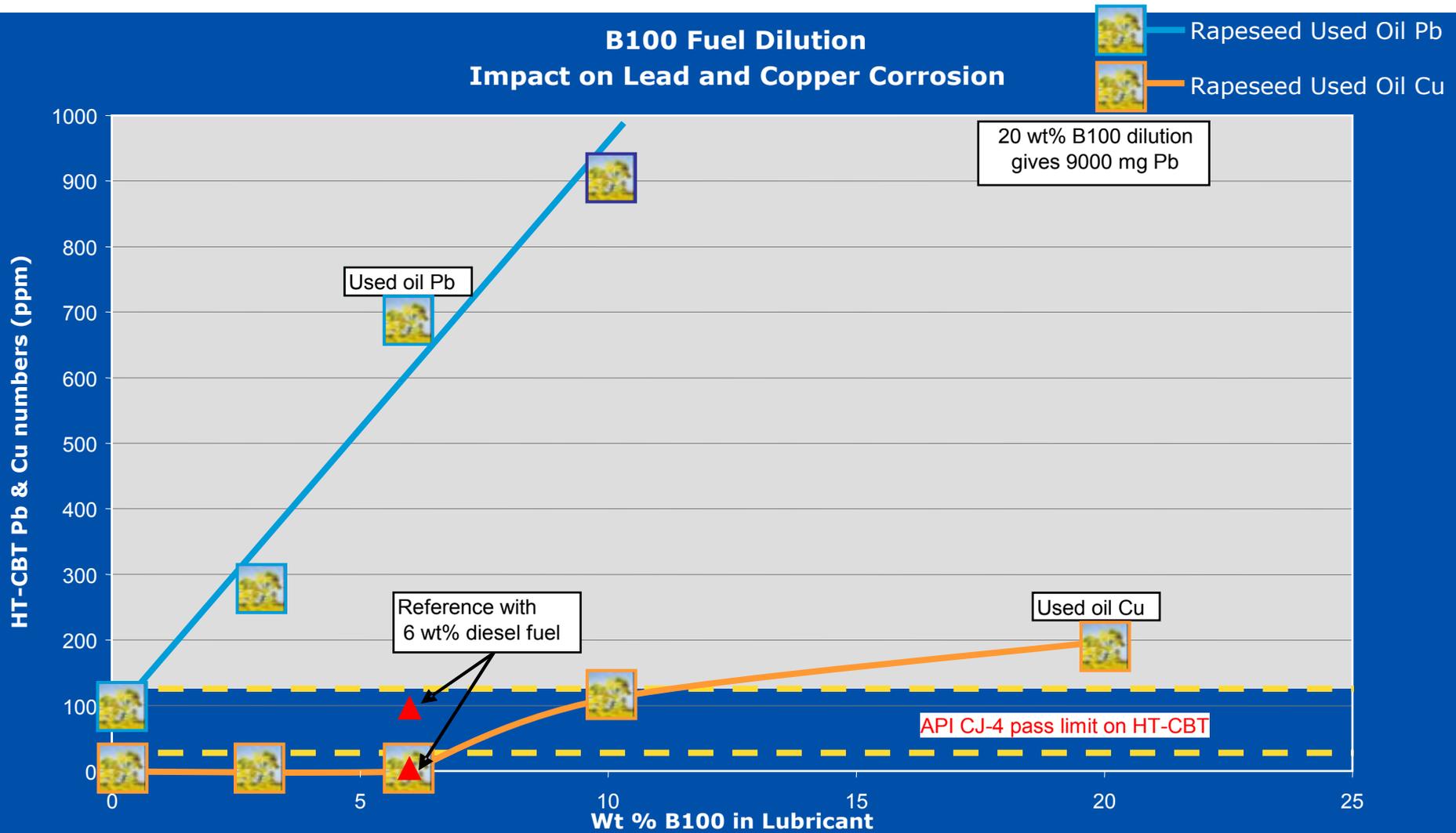
API / ACEA / Cummins Require HTCBT ASTM D6594 for Heavy Duty Diesel Oils



## High Temperature Corrosion Bench Test

- Air bubbling at 10 l/h through 150 ml sample
- No Catalyst
- Temperature 135°C
- 4 metal strips are submerged
  - Copper
  - Lead
  - Tin
  - Phosphor Bronze
- Duration 168h
- EOT oil samples checked for
  - Cu, Pb and Sn Increase
- Copper Strip Rating at EOT

# Lubrication Aspects – Corrosion



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# Mack T-12 Standard Engine Test

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Mack T-12 is a 300-hr test run in Mack E-7E-tech 460-HP engine with high EGR

Test is part of API CJ-4, as well as Mack EO-O specification

- First 100 hr are at rated speed and power
- Last 200 hr are over-fueled at peak torque to maximize wear rates

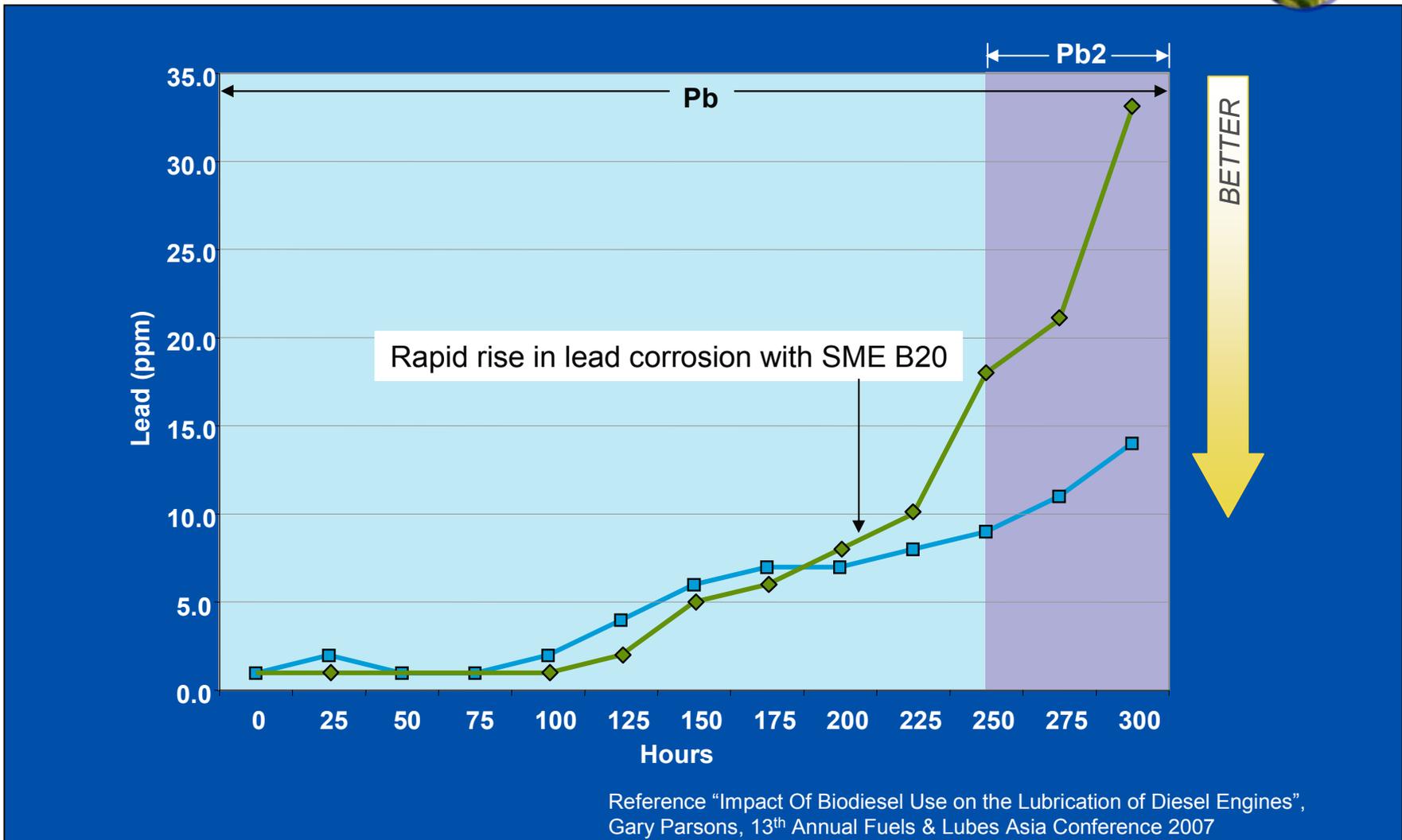
Primary purpose is evaluation of **oxidation, Pb corrosion**, and liner and ring wear resistance



High EGR - 100 Hr  
High EGR - 200 Hr  
15 ppm  
Fuel Sulfur

# Oil Oxidation and Lead Corrosion Identified With Biodiesel Blend Use

■ Mineral Diesel (15 ppm)
 ◆ B20 = Soy

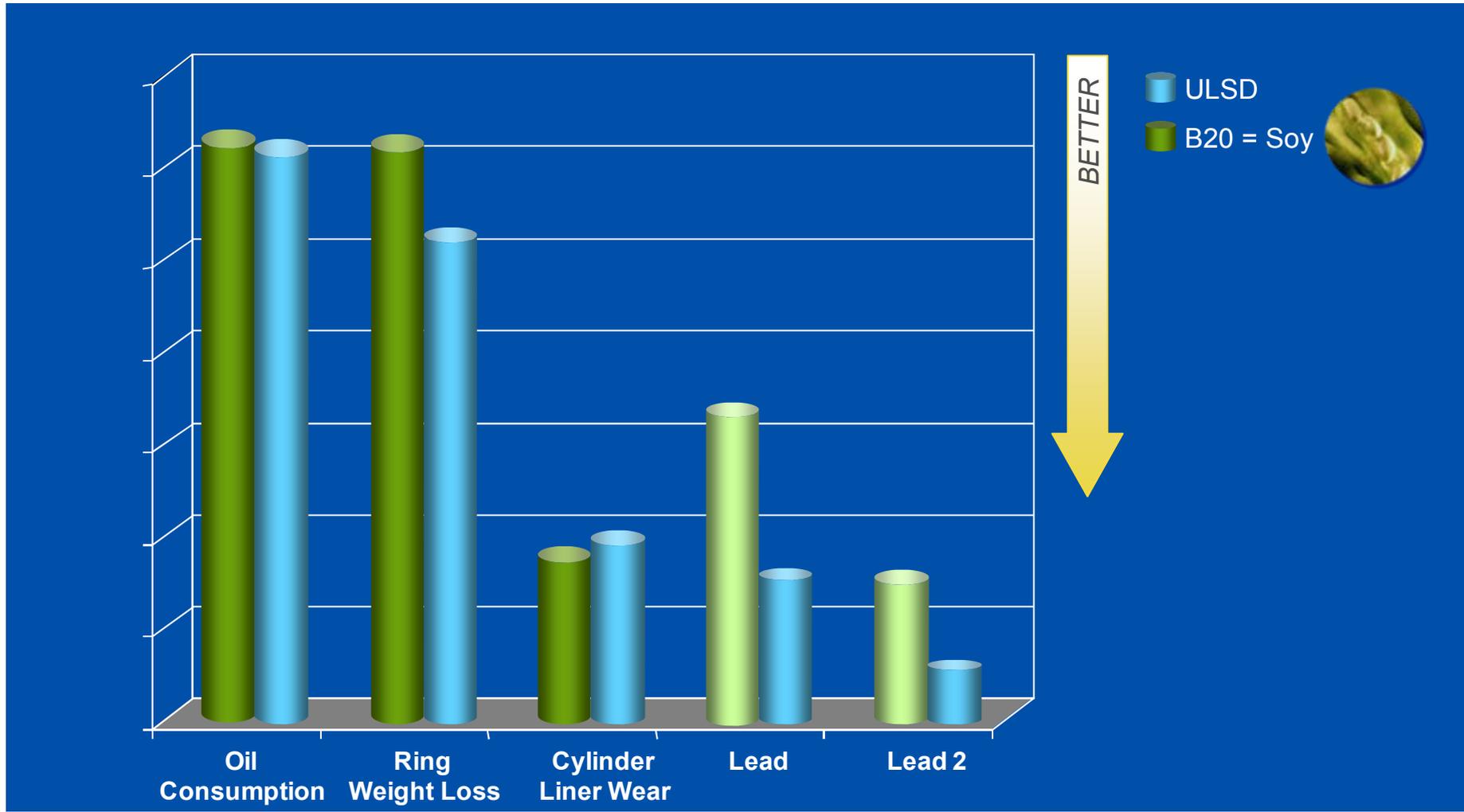


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# Mack T-12 Parameter Comparison API CJ-4 Heavy Duty Engine Oil

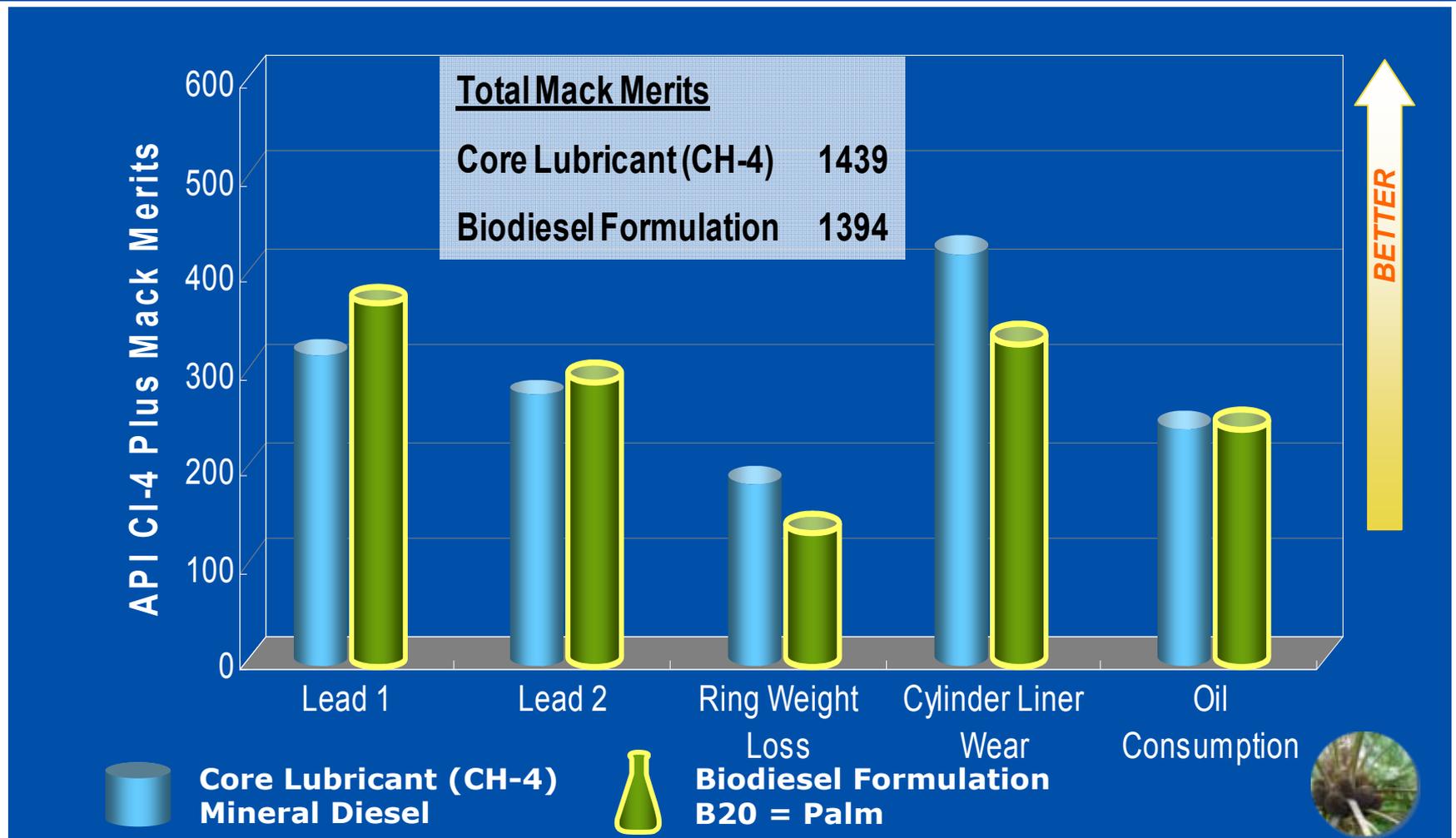


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# Biodiesel Blend Engine Oil Formulation Performance



Excellent Mack T12 Pass on B20 Palm Methyl Ester

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# Summary

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- FAME biodiesel will likely remain a part of the global diesel pool for the coming years
  - Mandates, energy independence, supports local agriculture
  - Low capital investment, low complexity plants
  - New FAME technology being developed
- Use of biodiesel can lead to lubrication issues
  - High and persistent fuel dilution
  - Oil oxidation and bearing corrosion
  - Piston deposits
- Specific methods were developed for biodiesel fuel dilution method
- Specially formulated lubricants can enable safe biodiesel use
  - An Oronite additive booster is available

