Biodiesel R&D at NREL

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Acknowledgement

- USDOE
  - FreedomCAR and Vehicle Technologies
- National Biodiesel Board
- Cummins Engine Company

DOE/NREL Research Priorities

- Determined in consultation with industry:
  - Biodiesel 2007-2010 Work Group
  - NBB B20 Fleet Evaluation Team
  - ASTM Biodiesel Task Force and Stability Working Group
  - Annual Biodiesel Technical Workshop (held by NBB)
  - CRC AVFL Committee
- Represents substantial in-kind industry contribution

Research Priority Setting

Based on voting at annual Biodiesel Technical Workshop (Jan 2005)

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Ongoing projects in these areas

Recently has become a much higher priority

Fuel Quality and Stability

Biodiesel Quality Surveys

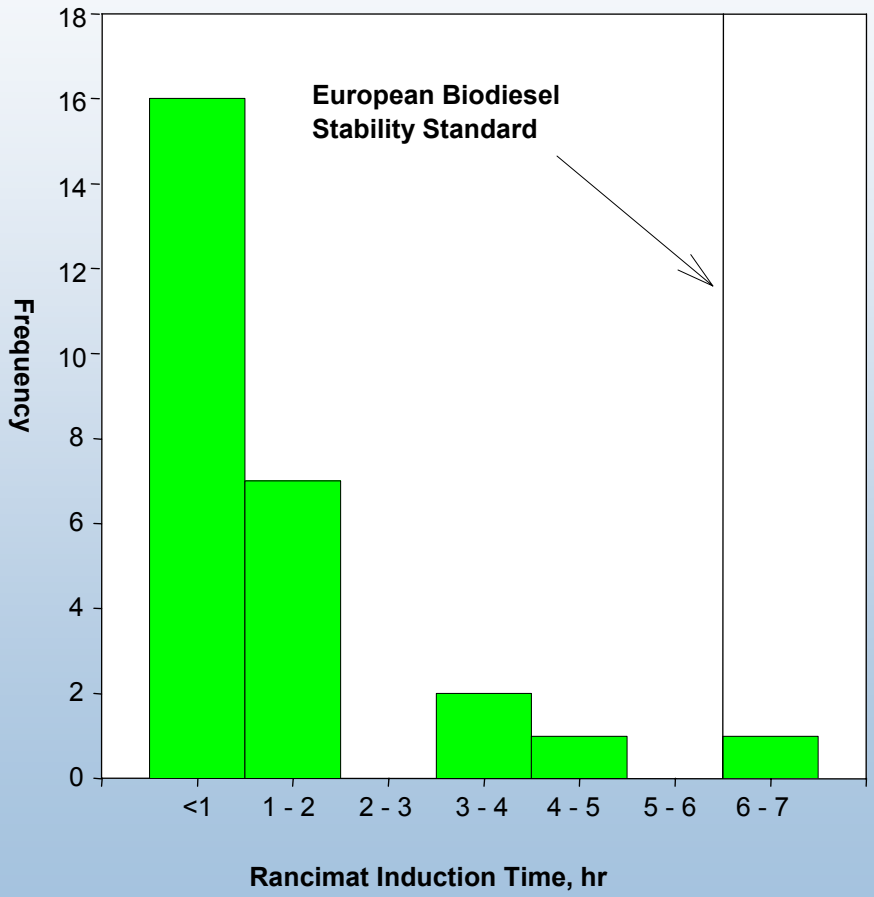
B100 and B20 Quality Surveys Conducted in 2004

- 85% or more of samples meeting D6751
- Significant issue identified with blending of B20
- Report available for download: *http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/38836.pdf*

New B100 Survey Ongoing

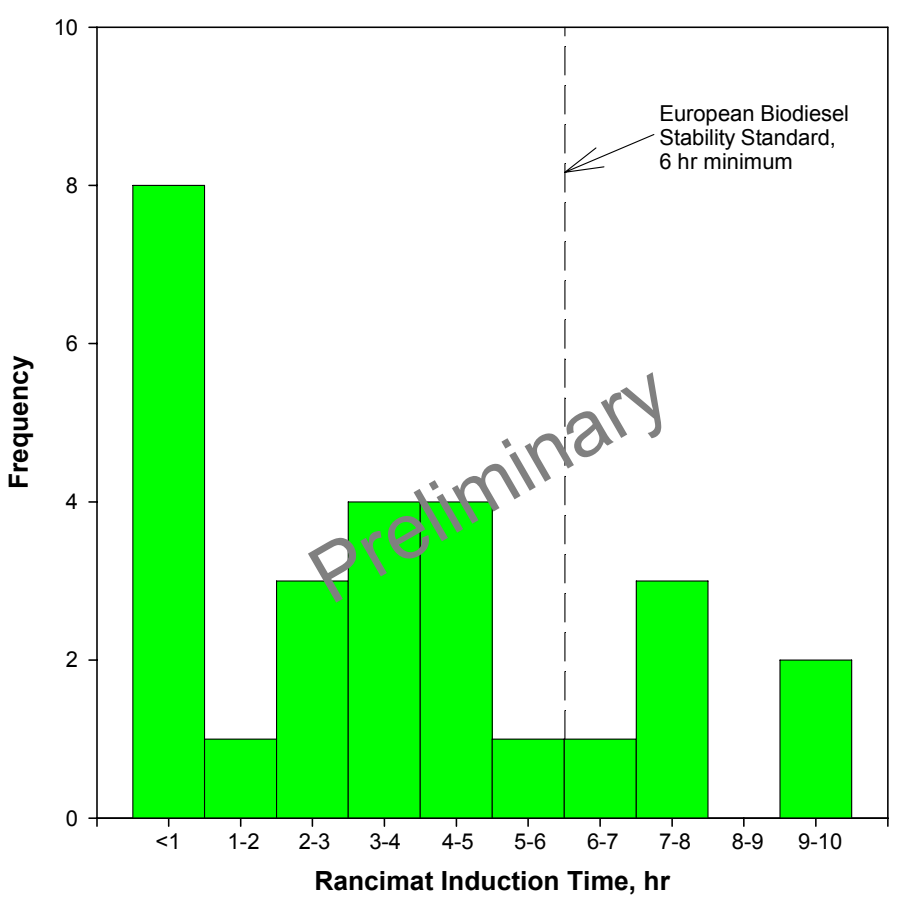
New B20 Survey to be Initiated Shortly

2004 B100 Quality Survey Stability Results



- Rancimat test,EN14112 (110°C, air)
- Measures **induction time** for volatile acid formation – may be related to time for start of deposit formation
- **Tests run several months after sample collection –may not be representative**

2006 Quality Survey Stability Results



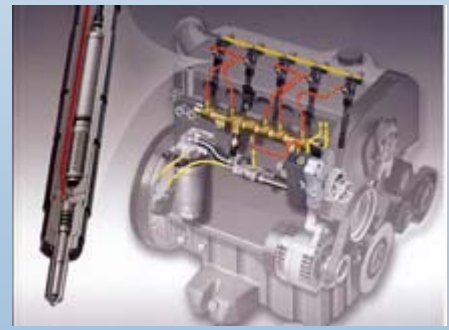
- Tests conducted on fresh biodiesel samples
- Indicate much broader range of stability
  - Many samples meeting EU specification
  - One third of samples less than 1 hr
- Low stability still an issue for some biodiesel

Oxidation Stability R&D Plan

- General consensus on the need for ASTM specifications on stability:
  - In B100 spec (D6751)
  - In stand-alone B20 spec
  - In D975 for 5% biodiesel blends?
- The main R&D need is to relate stability test results to more real world scenarios

Ageing Scenarios

1. In storage and handling
   - Applies to B100 and blends
2. In vehicle fuel tank
   - Recirculation at low fuel level
   - Applies to biodiesel blends only
3. Ageing in high-temperature engine fuel system
   - Deposit formation from unstable or pre-aged fuel
   - Applied to biodiesel blends only



Expected Results

- Determine if accelerated tests are predictive of scenario simulation results
- Determine if stability of B100 is predictive of stability of B5 and/or B20 blends
  - Anticipate that adequately stable B100 produces stable B5
- If things work out, propose stability test and limit for B100
  - Will ensure stability of B100 during storage and handling
  - Will ensure stability of B5
- Propose separate stability requirement for B20

Long-Term Durability Impacts:

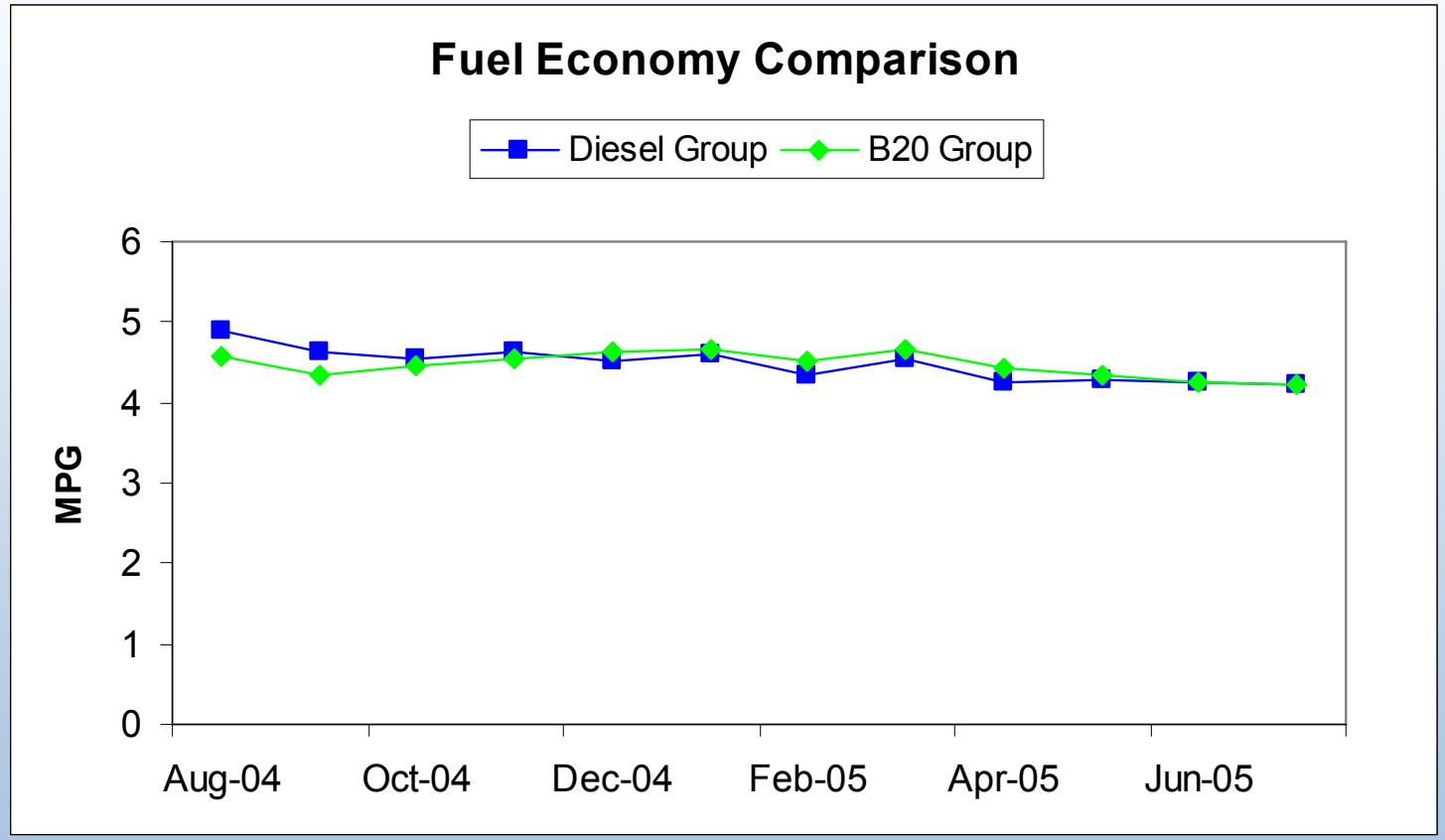
Quantitative Fleet Evaluation

Boulder, Colorado, B20 Fleet Evaluation

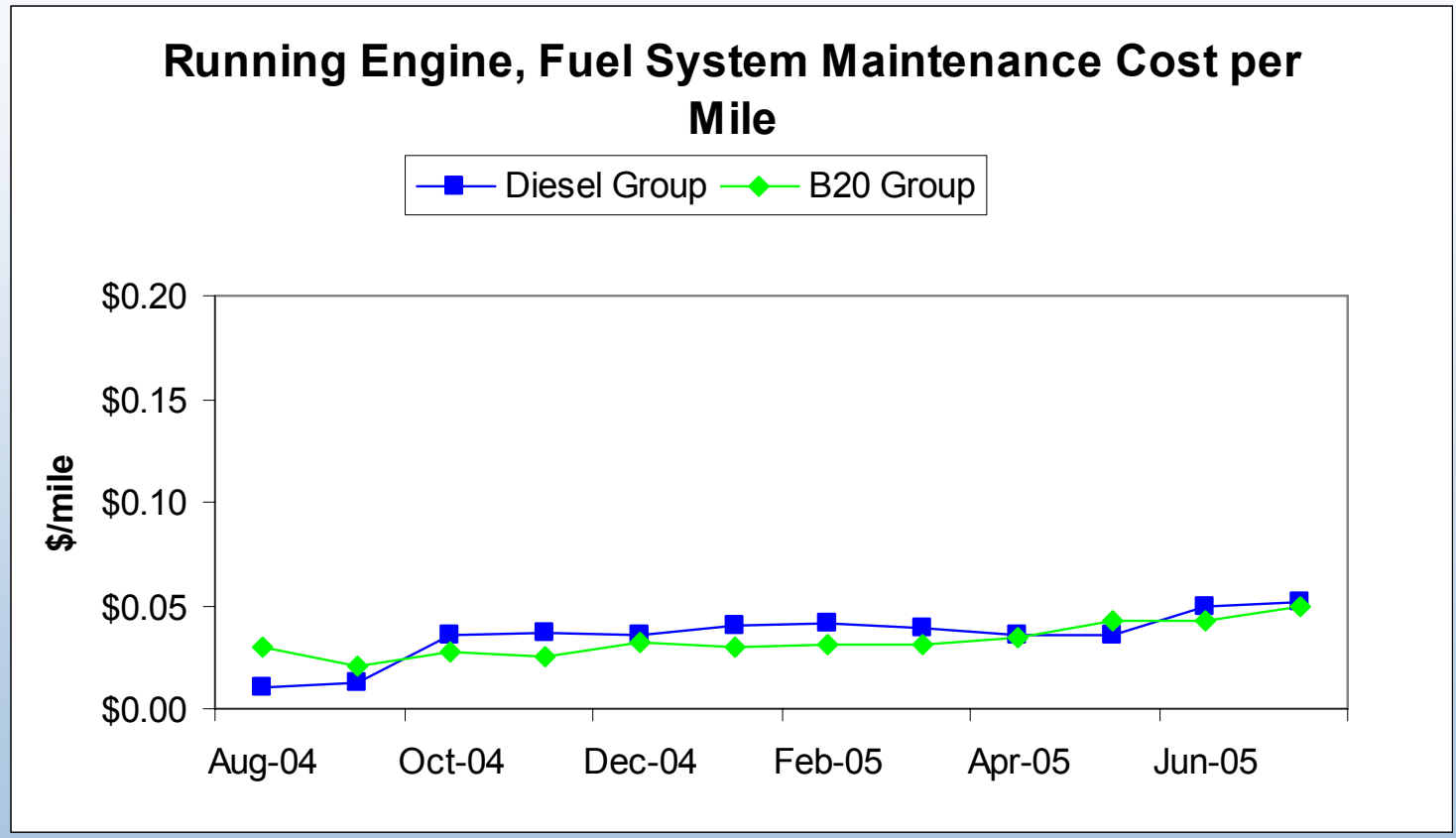
- *Comparative Operating Costs*
- 9 mechanically identical buses
  - 2000 Orion V; Cummins ISM
  - 5 operated on B20, 4 on diesel
  - identical duty cycle, Boulder Skip Route
- Documenting mileage accumulation, fuel use, maintenance costs
- Future tests to document impact on lubricant, wear of engine components

http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/38364.pdf

Fuel Economy

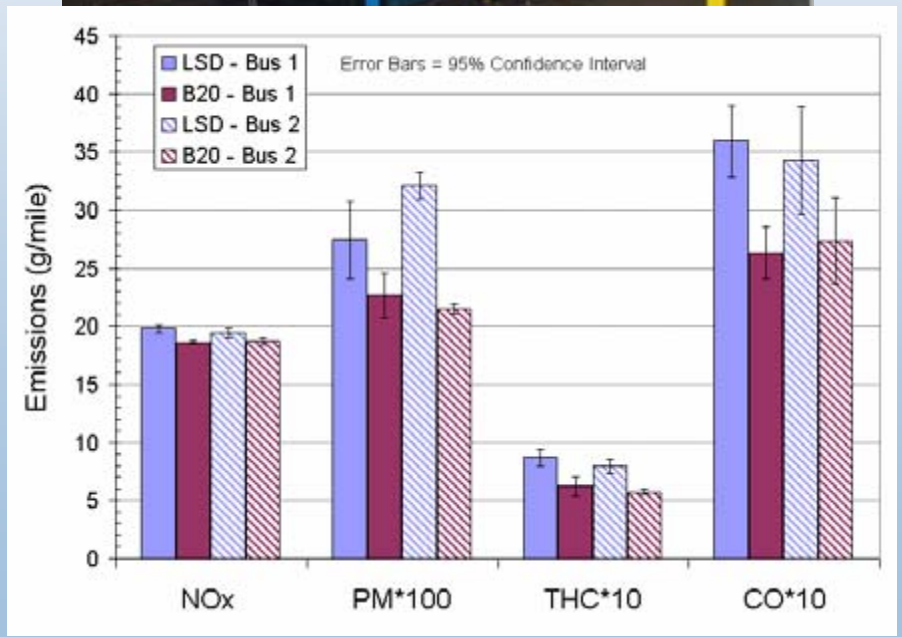


Maintenance Costs



Biodiesel Bus Chassis Dynamometer Testing

- B20 vs. conventional diesel fuel
- 2 in-use buses tested (40,000 lb GVWR)
- City Suburban Heavy Vehicle Cycle (CSHVC) at 35,000 lb inertia
- Cummins ISM 2000 Engine – No EGR
- Fuel economy reduction ≈ 3%
- Emission reductions (g/mile basis)
  - PM ≈ 18%
  - HC ≈ 29%
  - CO ≈ 24%
  - NO_x ≈ 4%
  - statistical confidence > 99%
- Repeated with biodiesel from 2 suppliers

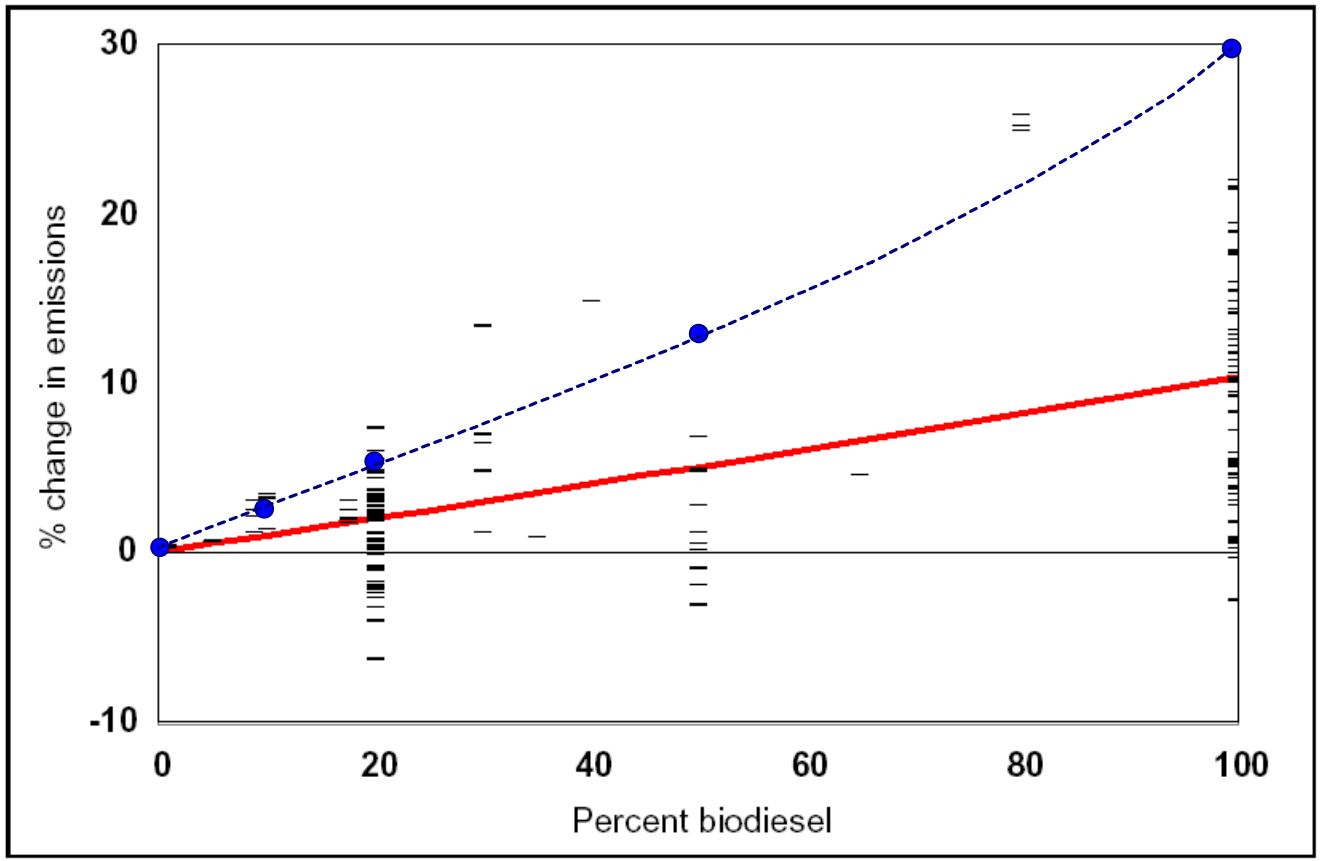


Impact on NO_x Emissions

Biodiesel's Effect on NO_x Emissions -Engine Data

Typical Older Engines (thru 1997): **B20 = +2%, B100 = +10%**

Newer Engines (2004 compliant): **B20 = +4%, B100 = +30%**

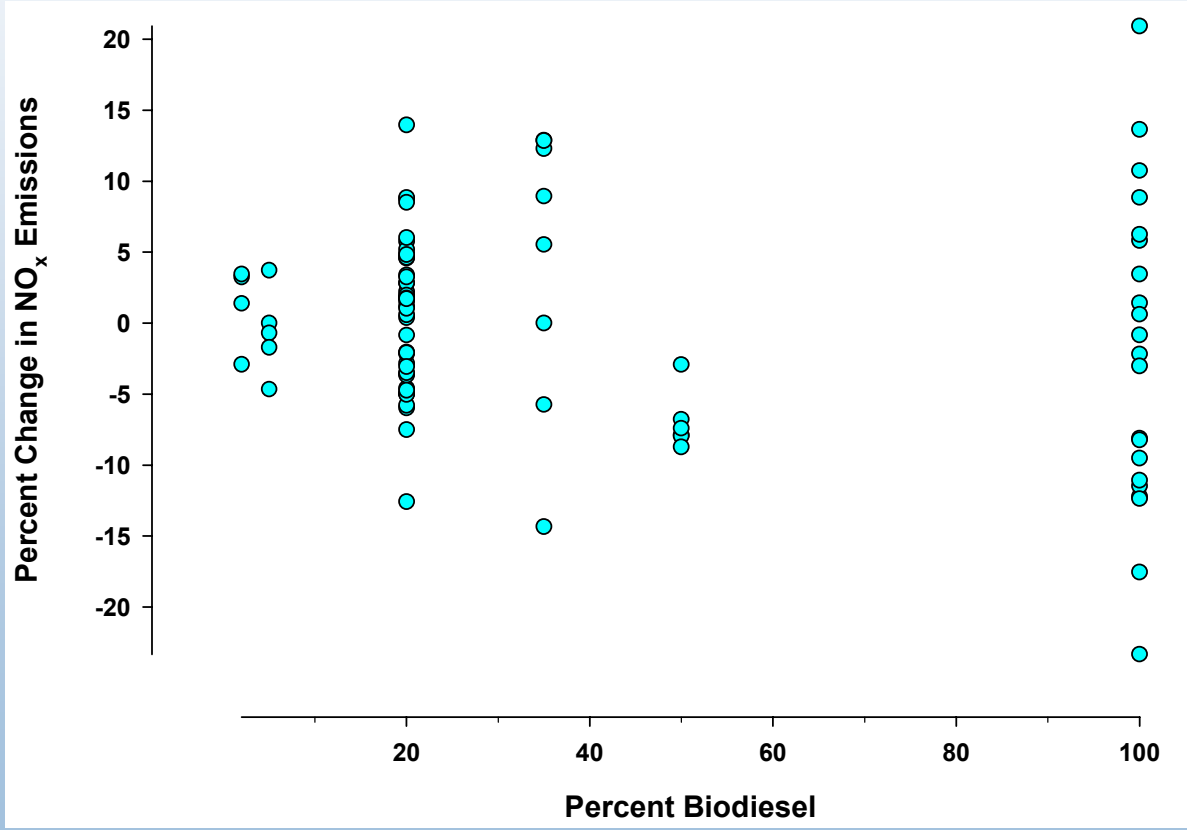


Analysis for Pre-1998 Engines from EPA420-P-02-001, October 2002

Analysis for newer engines, McCormick, et al., http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/37508.pdf

Biodiesel's Effect on NO_x Emissions -Vehicle (Chassis) Data

- *No consistent effect of biodiesel on NO_x*
- *NO_x emission changes are caused by test cycle and engine technology differences*



Data from EPA report plus additional chassis data in public domain

Bottom Line on Biodiesel and NO_x

There are insufficient data, and insufficiently representative data, to draw any conclusions regarding the average effect of biodiesel on NOx emissions, even directionally

Testing of additional vehicles and engines is ongoing

Biodiesel and Engine Technology of 2007 and Beyond

2007 OEM Project

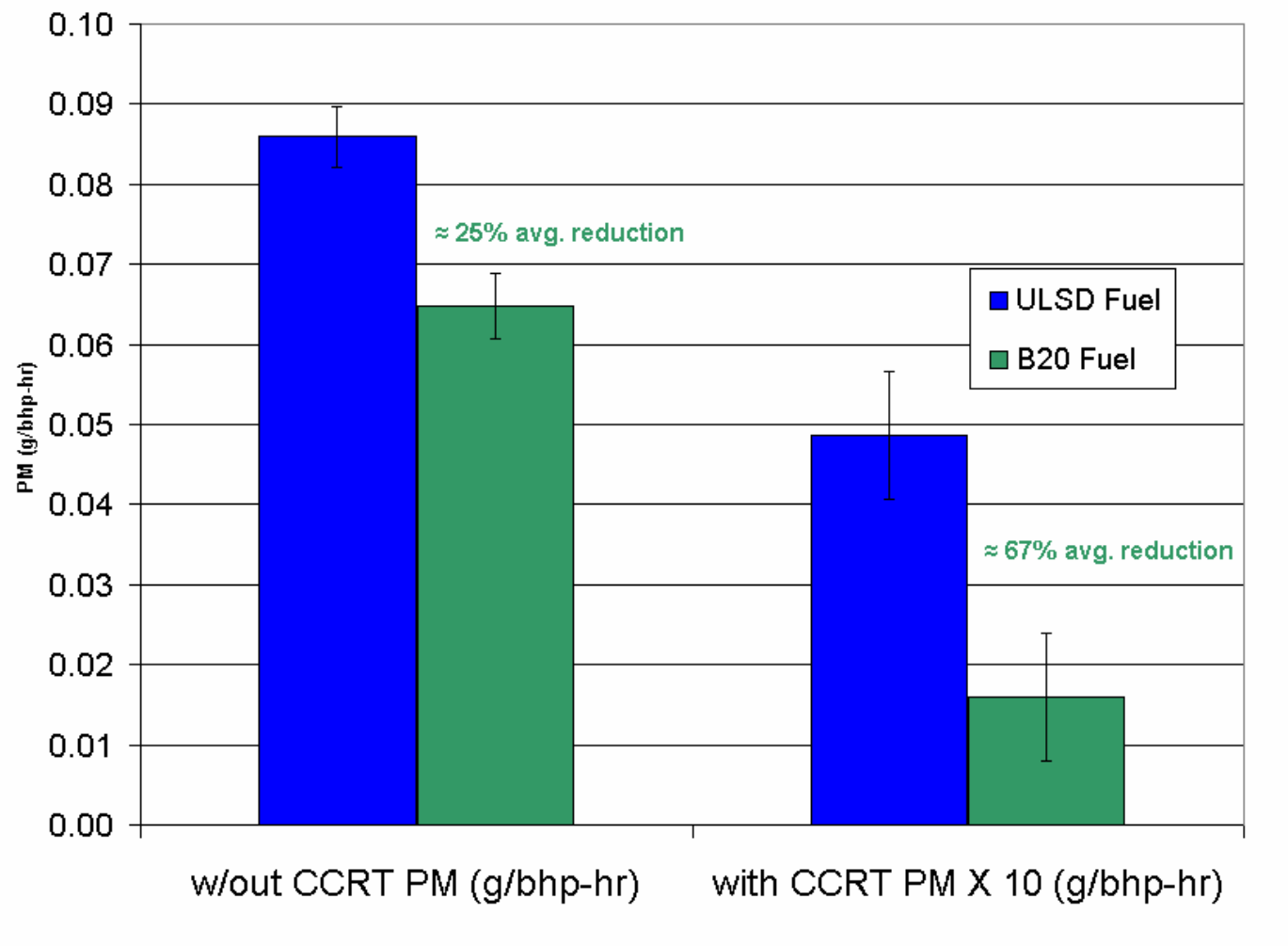
- **Project Goal:** Investigate the impact of B20 and lower on 2007 and later fuel system, engine, and emission control technology

- Major tasks:
  - Performance and Emission Control System durability in advanced vehicles (multiple platforms)
    - Diesel Particle Filters
    - NO_x Selective Catalytic Reduction (Urea)
    - Lean-NO_x Traps
  - Fuel Injection Equipment Simulation
  - Fleet Evaluation

- Significant funding from NBB, DOE, and in-kind resources from stakeholder industries
  - Manufacturers of Emission Controls Association (MECA)

Diesel Particle Filter Performance

- Heavy-duty FTP (engine dynamometer)
- 2002 Cummins ISB (EGR) with continuously regenerated DPF



Closing Remarks

- Biodiesel is a significant sustainable energy resource for the United States
- Poor understanding of oxidation stability is limiting development of ASTM specifications for blends
  - *Being addressed in ongoing study*
- Interim results show no difference in operating costs or engine wear for use of petrodiesel versus B20
  - *Much more in-use data are required to fully understand B20 impacts*
- There are not sufficient data to say if B20 blends cause NO_x, on average, to go up or down
  - *Additional vehicle testing data are being acquired*
- Indications are that as little as 5% biodiesel increases the reactivity of PM in a DPF
- Major research need is testing of biodiesel in post-2006 engines