# Biodiesel and Pollutant Emissions

Bob McCormick
With: Aaron Williams, John Ireland, Bob Hayes
National Renewable Energy Laboratory
Golden, Colorado

*September 28, 2006*

NREL/PR-540-40752
Presented at the 2006 Texas Biodiesel Conference and Expo held in Austin, Texas on September 27-28, 2006.

## Disclaimer and Government License

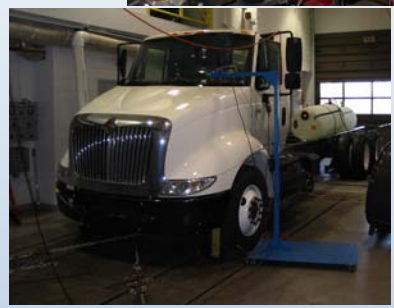
# Results From Three Methods of Testing B20 for $NO_x$ Emissions

*Laboratory*

*Real-World*

- Engine
  - 2 % increase

- Chassis
  - 0% average change



- PEMs
  - No change or decreasing

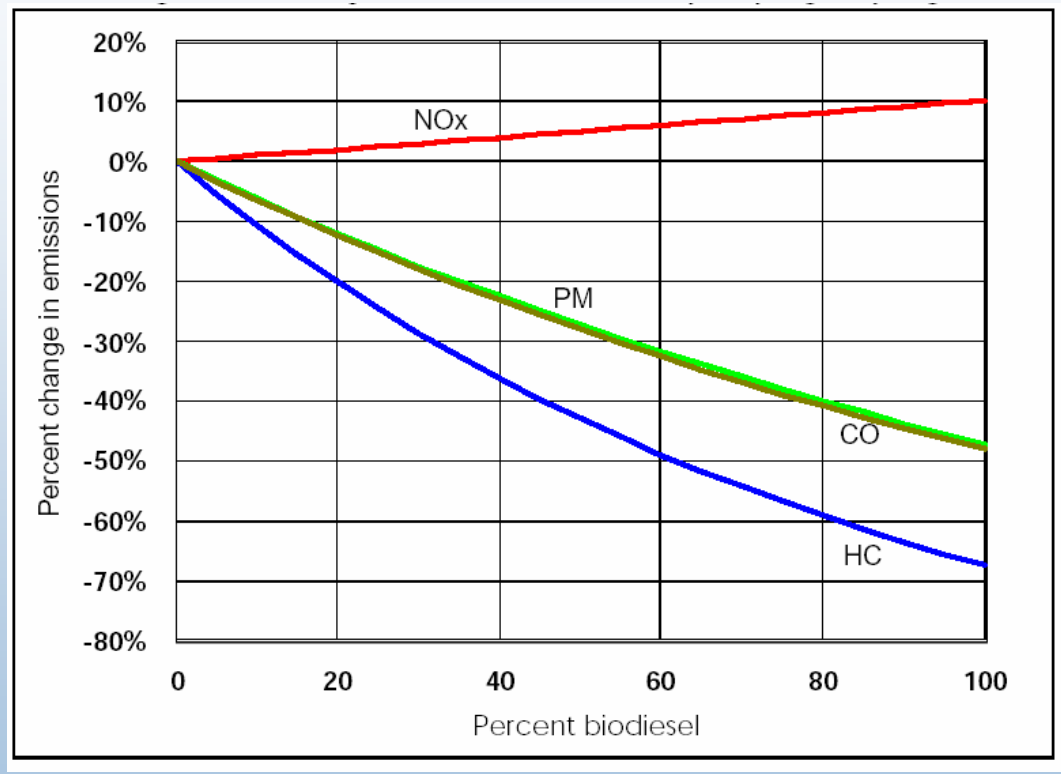
# Engine Dynamometer Testing

- Test used to certify compliance with regulations
- Bare engine is connected to large electric generator
- Operated over a range of speeds and loads
- Emissions are reported in g/bhp-h
  - weight per unit of work done by the engine

# Biodiesel's Effect on Emissions: Engine Compliance Test Results

EPA data compilation:
- data from many studies
- engine models through 1997

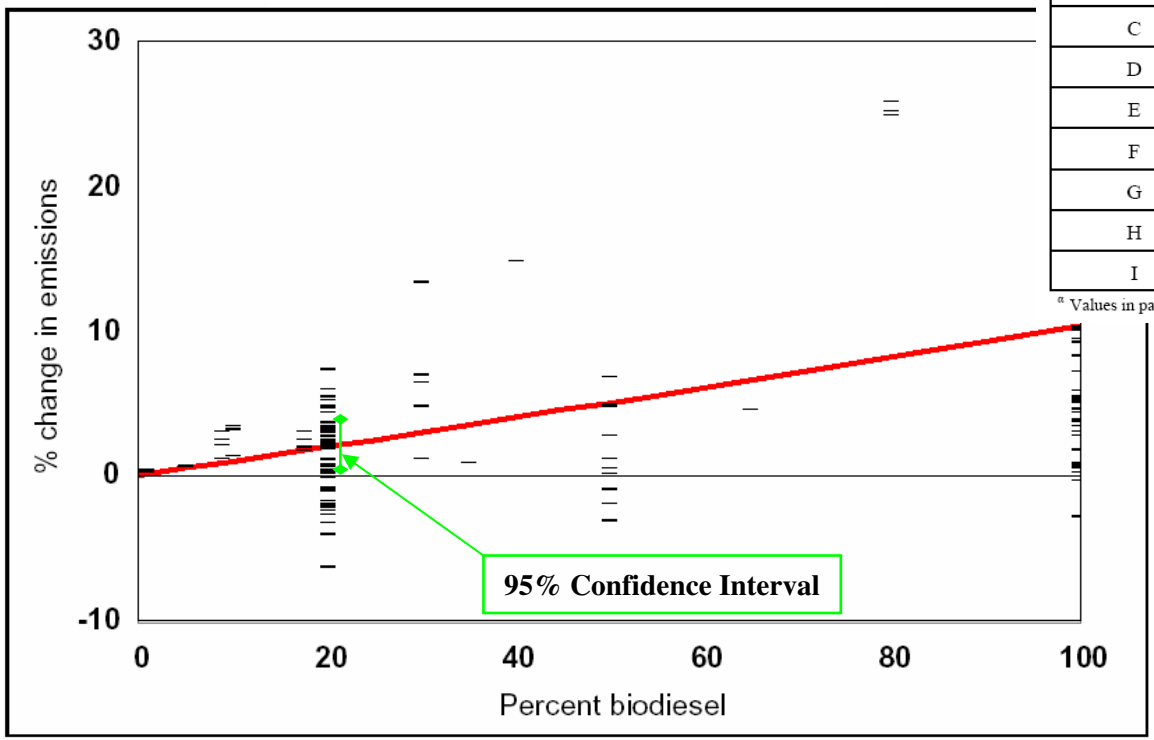
- $NO_x$
  - 2% up for B20
  - 10% up for B100
- PM
  - 12% down for B20
  - 48% down for B100




*EPA420-P-02-001, October 2002*

# Biodiesel's Effect on $NO_x$ Emissions -Engine Data

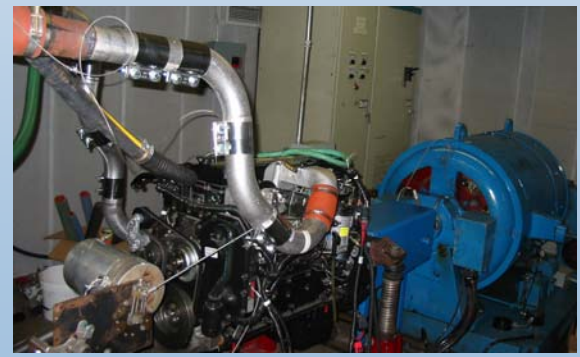
**B20 = +2%, B100 = +10%**




| Standards group | Model years | HD highway engines | NOx observations |
|---|---|---|---|
| B | 2002 - 2006 | 0 | 0 |
| C | 1998 - 2001 | 2 | 14 (2)[α] |
| D | 1994 - 1997 | 10 | 152 (19) |
| E | 1991 - 1993 | 16 | 394 (50) |
| F | 1990 | 3 | 87 (11) |
| G | 1988 - 1989 | 8 | 112 (14) |
| H | 1984 - 1987 | 2 | 16 (2) |
| I | - 1983 | 2 | 10 (1) |

[α] Values in parentheses are percent of total observations

- 43 engines included
- 72% of engines pre-1994
- 95% pre-1997



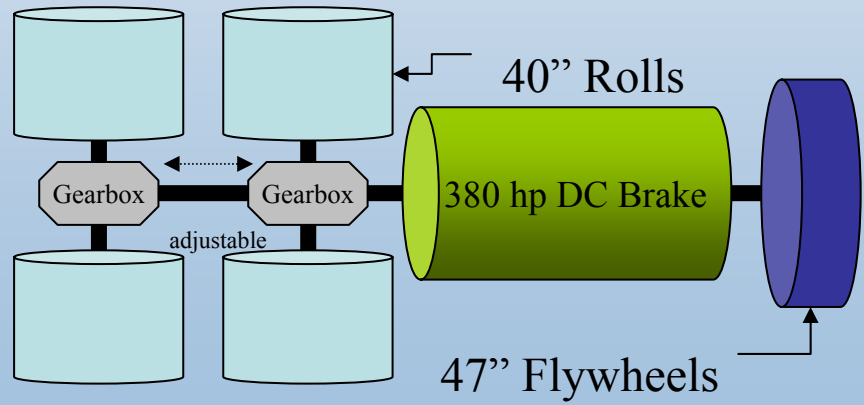
*EPA420-P-02-001, Draft Report, October 2002*

# Emission Benefits of B20

- Broad agreement on reductions on PM reductions
  - 10 to 25% reduction in PM, depending on engine, test cycle, and other factors
- Impact on $NO_x$ emissions less uncertain
  - EPA compilation of published data found B20 causing $NO_x$ to go up ~2%
  - But many studies in the review show $NO_x$ going down
  - Not all newer studies show $NO_x$ going up
- Definitive conclusion for $NO_x$ requires a more representative dataset

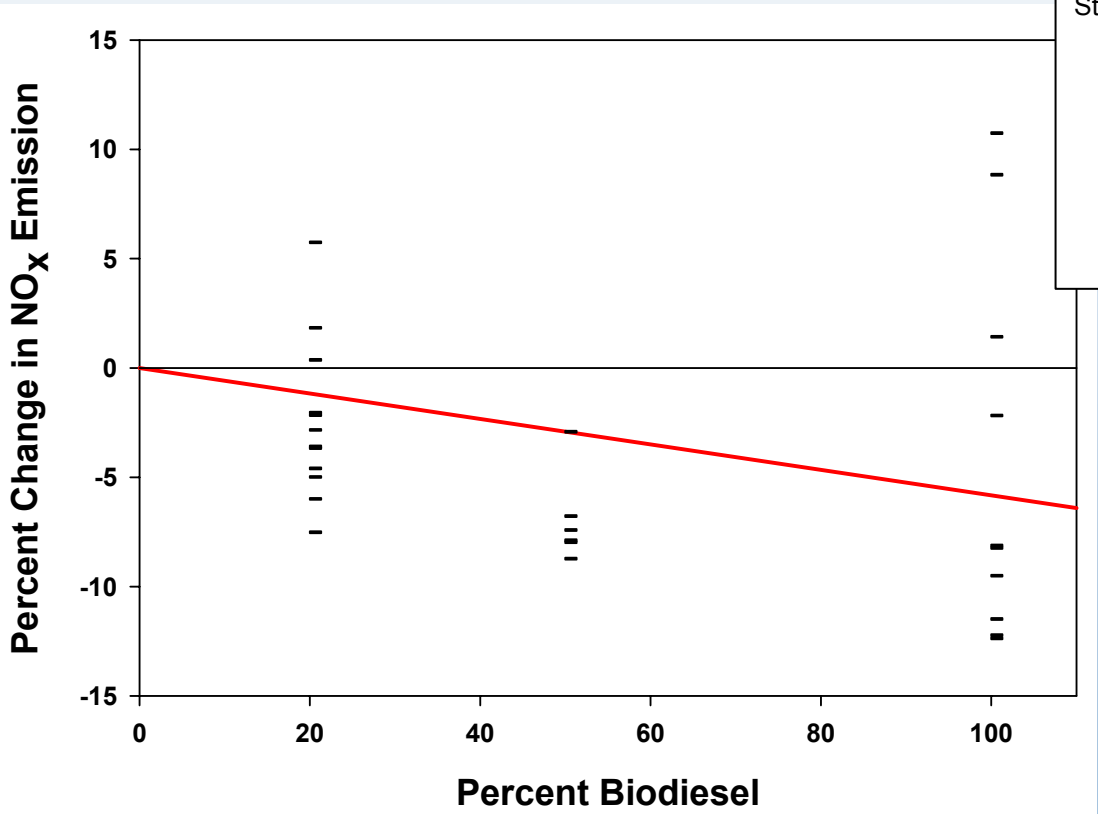
# A Second Way to Measure Emissions

- **Test entire vehicles**
  - More realistic than engine testing
- HD chassis dynamometer
  - 2007 CFR Emissions Measurement Capability
  - 8,000–80,000 lb Range
  - Augmented Braking
  - Grade Simulation
  - Automated Coast-Downs

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

- *EPA compilation also included published vehicle test data*
- *For these vehicles, on average, biodiesel has no impact on $NO_x$*
  - *Slope is not statistically significant (p=0.5)*




| Standards Group | Model Years | #Vehicles |
|---|---|---|
| B | 2002-2006 | |
| C | 1998-2001 | |
| D | 1994-1997 | 6 |
| E | 1991-1993 | |
| F | 1990 | 1 |
| G | 1988-1989 | 2 |
| H | 1984-1987 | 1 |
| I | -1983 | 1 |

8 pickup trucks tested on UDDS
3 transit buses on various cycles

*Data from EPA420-P-02-001, October 2002*

# NREL Vehicle Testing Summary

- **Average change in $NO_x$ for B20 use is 0%**
  - No statistically significant change (less than +/- 0.4%)
  - Versus +2% in EPA analysis
- Magnitude and direction of $NO_x$ impact is cycle dependent
- **Average change in PM for B20 use is -21%**
  - Versus -12% in EPA data compilation

| Vehicle | Engine | | MY | Cycle | NOx % Change | PM % Change |
|---|---|---|---|---|---|---|
| 1 | Cummins ISM | Transit Bus | 2000 | CSHVC | -3.8 | -17.4 |
| 2 | Cummins ISM | Transit Bus | 2000 | CSHVC | -6.2 | -49.3 |
| 3 | Cummins ISM | Transit Bus | 2000 | CSHVC | -4.1 | -22 |
| 4 | Cummins ISM | Class 8 | 2005 | CILCC | 0.0 | -27 |
| 4 | Cummins ISM | Class 8 | 2005 | WVU Interstate | 2.0 | -35 |
| 5 | International Green Diesel | School Bus | 2005 | RUCSBC | 1.5 | 0* |
| 5 | International Green Diesel | School Bus | 2005 | CSHVC | -1.0 | 0* |
| 6 | Cummins ISB | Motorcoach | 2003 | CSHVC | 2.8 | -28.1 |
| 6 | Cummins ISB | Motorcoach | 2003 | UDDS | 3.4 | -30 |
| 7 | DDC S60 | Class 8 | 2000 | CSHVC | 2.1 | -19.4 |
| 7 | DDC S60 | Class 8 | 2000 | WVU Interstate | 3.6 | -26.2 |
| 8 | International 7.6L | School Bus | 2004 | CSHVC | -0.7 | 2.5 |
| 8 | International 7.6 L | School Bus | 2004 | RUCSBC | 6.2 | -24 |

**Vehicle equipped with diesel particle filter*


# A Third Way to Measure Emissions: PEMS

- Portable Emissions Measurement System
  - On-board vehicle
  - Measures emissions during normal operation
- Probably the most real-world emission measurement
- Basis for new EPA inventory model MOVES

# Results of PEMS Studies

- North Carolina:  12 Dump Trucks
  - Measured on NO, not NO+$NO_2$
  - NO was reduced by 10% on average
  - http://www.ncdot.org/doh/preconstruct/tpb/research/download/2004-18FinalReport.pdf
- New Jersey: 3 School Buses
  - $NO_x$ increased in some buses, decreased in others
  - SAE 2005-01-1616
- Texas: 5 School Buses
  - Compare TxLED, B20 (market), B20 (soy)
  - B20 had on effect $NO_x$
  - Texas Transportation Institute at Texas A&M, August 2006

# Biodiesel Effect on $NO_x$

- *$NO_x$ can go up or down depending on engine and test cycle*
  - *This is not well understood quantitatively*
  - *May be a driving cycle effect i.e. engine is operated at different speed a load points on different cycles*
- *Very limited dataset: Neither engine nor vehicle datasets include a representative sample of in-use engines*
  - *Lack of representative sample may also cause the perceived difference between engine and chassis studies*
- *Based on the additional data available today:*
  - *B20 appears to have no significant or consistent impact on $NO_x$ emissions*
- *Reduction in PM and other pollutants is robust*

# Results From Three Methods of Testing B20 for $NO_x$ Emissions

*Laboratory*

*Real-World*

- Engine
  - 2 % increase (EPA review)
  - 0% change (newer studies)
- Chassis
  - 0% change (EPA review)
  - 0% newer (newer studies)
  - 0% change (NREL study)
- PEMs
  - 0% change