

# Biodiesel and Renewable Diesel Research Study

July 8, 2008

California Environmental Protection Agency

---



**Air Resources Board**

# Agenda

- Introduction
- ASTM update
- Definition of biodiesel and renewable diesel
- Update on biodiesel characterization and NOx impact study
  - Fuels
  - Engine/vehicle
  - Test protocol
  - Test schedule
- NOx mitigation strategies
  - Outline of test plan
  - Strategies
- None on-Road
  - TRUs
  - Off-road
- Biodiesel multimedia
  - Update by Dr. McKone
- Open discussion

# Introductions

# ASTM Update

- Roger Gault  
Engine Manufacturers Association

# Definition of Biodiesel and Renewable Diesel

**Non-ester renewable diesel** means a motor vehicle fuel or fuel additive which is all the following:

1. Registered as a motor vehicle fuel or fuel additive under 40 CFR Part 79.
2. Not a mono-alkyl ester.
3. Intended for use in engines that are designed to run on conventional diesel fuel.
4. Derived from nonpetroleum renewable resources (as defined in paragraph (m) of this section).

**Biodiesel (mono-alkyl ester)** means a motor vehicle fuel or fuel additive which is all the following:

1. Registered as a motor vehicle fuel or fuel additive under 40 CFR part 79.
2. A mono-alkyl ester.
3. Meets ASTM D-6751-07, entitled "Standard Specification for Biodiesel Fuel Blendstock (B100) for Middle Distillate Fuels."
4. Intended for use in engines that are designed to run on conventional diesel fuel.
5. Derived from nonpetroleum renewable resources (as defined in paragraph (m) of this section).

References the 2007 Federal Renewable Fuel Standard

- Executive Order S-1-07 Low Carbon Fuel Standard (LCFS)
  - Reduce at least 10 percent of the carbon intensity of California's transportation fuels by 2020.
  - Early action item with a regulation to be adopted and implemented by 2010.
- Executive Order S-06-06, establishing targets for the use and production of biofuels and biopower
  - Includes biodiesel and ethanol.
  - California shall produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050.

- Low Carbon Fuels Standard
  - Biofuels specifications by 2009

# Biodiesel and Renewable Diesel Study

- Biodiesel and renewable diesel emissions evaluation
- Oxides of Nitrogen (NO<sub>x</sub>) formation and mitigation evaluation
- Transportation Refrigeration Units (TRUs)
- Light duty vehicles
- Durability study
- Multi-Media evaluation



# Funded Studies Update

- Biodiesel and Renewable Diesel Research Study
  - Biodiesel and renewable diesel characterization and NOx mitigation study-\$1,689,000
  - Biodiesel and renewable diesel multimedia study-\$400,000
- Other contributors
  - South Coast Air Quality Management District-\$150,000
  - National Biodiesel Board-\$50,000
  - WSPA provided the CARB diesel
  - Innerstate Oil provided transportation, short term storage of fuels, and the facility to blend fuels
  - Neste has provided the renewable diesel and funding
  - NOVA Biofuels
  - Stepan
  - Kodak
  - City of Santa Monica

# On-Road Heavy-Duty Emissions Studies

## Task 1: Biodiesel and Renewable Diesel Emissions Evaluation Study

- Evaluate emissions and health effects
- Evaluate NOx impact

## Task 2: NOx Formation and Mitigation Study

- Investigate the mechanism of NOx formation and evaluate possible NOx mitigation options
  - Changes in fuel specifications-match blending
  - Refinery process
  - Additives

# Updates

# Fuels Update-Specifications

Initial base fuel specifications analysis

- CARB diesel fuel-ASTM D975
- Renewable diesel fuel ASTM D975
- Biodiesel feedstocks-D6751
- Samples from multiple drums were pooled
- All analyses conducted in triplicate
  - Where available, the certificate of analysis will count as one replicate.

# CARB Diesel Fuel Specifications

Property	Measured	Proposed
• Aromatics	18.4%	20%
• Cetane	56	53
• Sulfur	5ppm	<15ppm

# Fuels Update-Biodiesel Specifications

- Meets ASTM D6751
- Animal based biodiesel feedstock Rancimat number was less than 6 hours but still above the minimum 3 hours when all laboratory results are average together
- Both B100 feedstocks were treated with Tenox and all fuel samples were capped in nitrogen

# Fuels Update-Biodiesel Blend Fuel Specifications

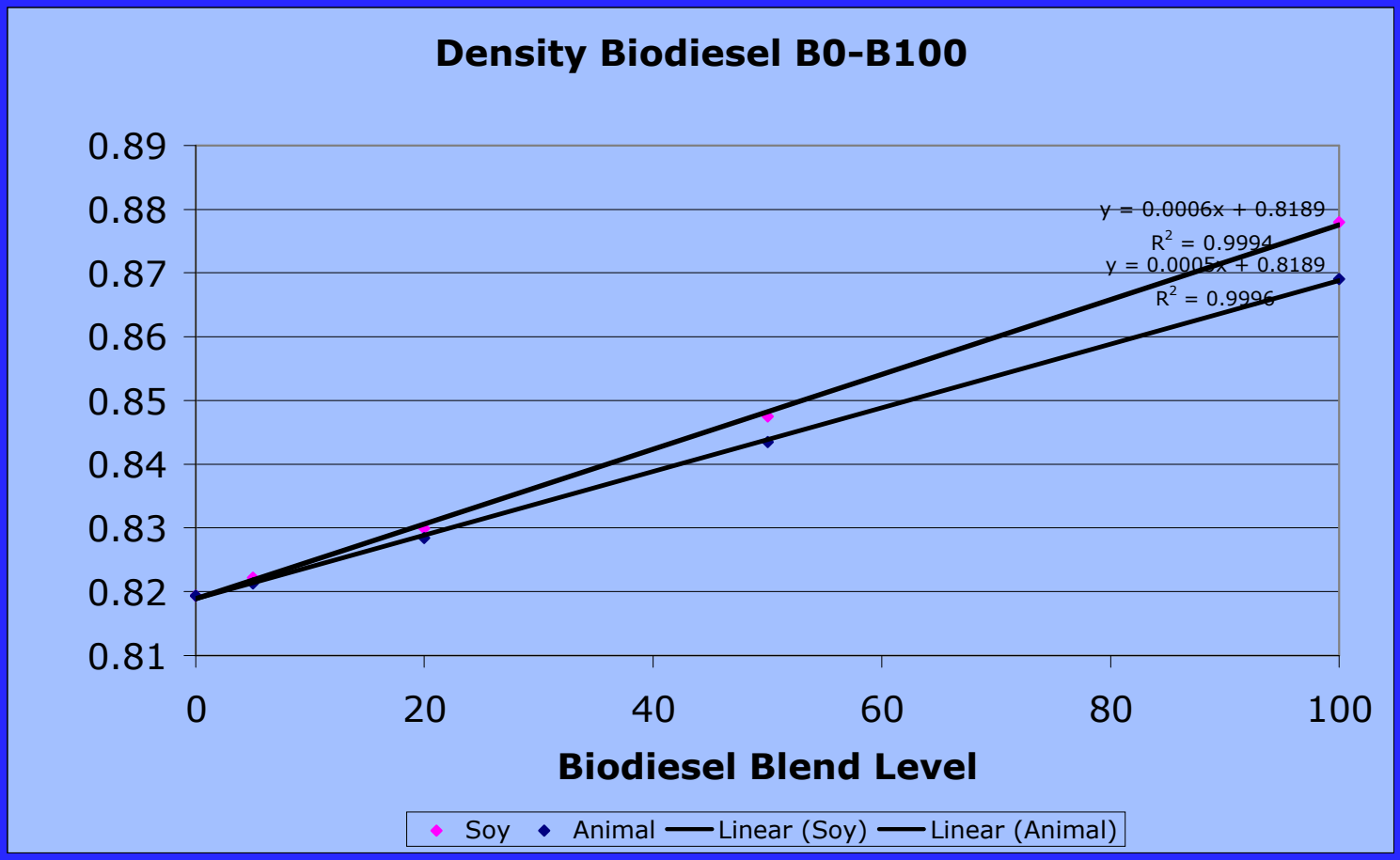
- In the process of being analyzed

# Fuels Update-Biodiesel Blending

- Animal and Soy feedstocks were blended with CARB ULSD to make biodiesel blends B5, B20, B50
- Gravimetric blending
- Fuels were mixed for one hour to ensure fuels were properly mixed
- Blend level check
  - ASTM D7371-07
    - Underestimated blend level
  - API gravity-hydrometer
  - Density



# Biodiesel/Renewable Diesel Study



- Similar linearity and goodness of fit demonstrated with API gravity

# Fuels Update-Renewable Diesel Blends

- Blending will be conducted at CeCERT in July/August

# Fuel Storage Update

- Long term storage
  - Non-temperature controlled storage facility, however the facility is located in Berkeley and near the coast where there is smaller temperature swings
- Remainder of fuel delivered to UCR-CECERT and Stockton test facilities

# Engine Selection

- 2006 Cummins 11 liter ISM
- 2007 Detroit Diesel MBE 4000

# Test Vehicle Update

- Vehicle one
  - Heavy-duty diesel truck equipped with a 2005 Caterpillar C13 engine
- Vehicle two secured for testing
  - Purchasing a heavy-duty diesel truck equipped with a 2007 Detroit Diesel MBE 4000 engine
- Vehicle three
  - Transit bus equipped with a Detroit Diesel 1997 DDCs50 engine and with a Cleaire Longview

# Vehicle Tests

- Weighted towards newer engines/vehicles since less data available
- Includes the three major manufacturer of pre-2008 heavy-duty diesel engine manufacturers
- Includes a vehicle tested with and without a Cleaire Longview, a commonly used after treatment device

# Summary of Final NOx Impact and Biodiesel Emissions Characterization Test Matrix

Engine Tests					
<b>Vehicle type</b>	Truck	Truck			
<b>Model year</b>	2006	2007			
<b>Comments</b>	EGR	2007 Certification			
<b>Engine Man</b>	Cummins	Detroit			
<b>Engine Model</b>	ISM	MBE4000			
<b>Emissions tests</b>	Regulated	Regulated			
Vehicle Tests					
<b>Vehicle type</b>		Truck	Truck	Bus	Bus
<b>Model year</b>		2007	2005	1997-2002	1997-2002
<b>Comments</b>		2007 Certification	ACERT	wo Cleaire Longview	w Clearire Longview
<b>Engine Man</b>		Detroit	Caterpillar	Cummins/Det	Cummins/Det
<b>Engine Model</b>		MBE4000	C13	ISM/DDCs50	ISM/DDCs50
<b>Emissions tests</b>		In-detph for Soy only	In-depth	VOCs & Carbonyls	VOCs & Carbonyls

# Discussion



# Strategies for NOx Mitigation

- Additives
- Match blending
- Renewable/Biodiesel blends

# Strategies for NOx Mitigation (Cont)

- Additives
  - Blend levels

# Strategies for NOx Mitigation (Cont)

- Match blending
  - Approaches
  - Blend levels
  - Properties to control
    - Cetane number
    - Saturation
    - Aromatics

# Strategies for NOx Mitigation (Cont)

- Biodiesel/Renewable diesel blends
  - Blend level
  - Percent biodiesel and renewable diesel
  - Use biodiesel feedstock with highest NOx disbenefit

# NOx Mitigation Study-Test Sequence

Main program																	
Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9	
Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle	Fuel	Cycle
CARD	B	Blend	B	Blend	B	CARD	B	Blend	B	Blend	B	CARD	B	Blend	B	Blend	B
	C		C		C		C		C		C		C		C		C
	B		B		B		B		B		B		B		B		B
	C		C		C		C		C		C		C		C		C
Blend	B	Blend	B	CARD	B	Blend	B	Blend	B	CARD	B	Blend	B	Blend	B	CARD	B
	C		C		C		C		C		C		C		C		C
	B		B		B		B		B		B		B		B		B
	C		C		C		C		C		C		C		C		C

# NOx Mitigation Test Matrix

	2006 Engine	
	FTP	Cycle #2
CARB	6 (3)	6
Blend formulation #1a	6 (3)	6
Blend formulation #1b	6	6
Blend formulation #2a	6 (3)	6
Blend formulation #2b	6	6
Blend formulation #3a	6 (3)	6
Blend formulation #3b	6	6
CARB	6	6
Blend formulation #4a	6	6
Blend formulation #4b	6	6
Blend formulation #5a	6	6
Blend formulation #5b	6	6
Blend formulation #6a	6	6
Blend formulation #6b	6	6
CARB	6	6
<b>Sub total</b>	<b>90</b>	<b>90</b>

# Discussion

## Test Schedule-Emissions Characterization and NOx Impact Tests

- Engine tests
  - Vehicle duty cycle translations
    - Coast down completed
    - Vehicle duty cycle translations
  - Remove engine from 2006 Cummins ISM
  - Pretest: run converted duty cycle on engine dyno
  - Begin engine tests in August
- Vehicle tests
  - Coast downs
  - Pretest in July
  - Main test in the first part of August



# Off-Road Vehicle Test Conducted At Stockton's Emission Test Facility

- Obtained engine dynamometer
- Test John Deere Tier 2 engine

# TRU Study

- TRUs
  - Test B100 on TRU engines
  - Proposed test will be conducted be at the small engine dynamometer facility in El Monte
  - Estimated to be conducted in Summer 2008

# TRU Biodiesel Test Program

- Three engines
- California diesel and two B100 fuels
- Engine dynamometer
- Multiple-mode, steady-state
- NO<sub>x</sub>, HC, CO, PM
- Beginning late July or early August
- Two stages

# First Stage

- One engine
- Two fuels
  - California diesel
  - Soy B100
- Minimum 20 complete tests per fuel
  - CBBC x 10 (Minimum)
  - Eight modes each test
  - Approximately 5 weeks to complete

## Second Stage

- Three engines
- Three fuels
  - California diesel
  - Soy B100
  - Animal B100
- Number tests each fuel TBD
  - CBBC x Number TBD
  - Four modes each test
- Consider biodiesel blends

## Use of Data

- Apply results of emission testing to TRUs with 4-mode weighting
- Try to apply results of emission testing to other applications of same engines by using first stage data to extend the second stage data, as needed, and 8-mode weighting

# Discussion

# Test Schedule

- Goal is to adopt the low carbon fuel standard in December of 2008
  - Requires “critical mass” of biodiesel and renewable research be completed before December 2008
  - Options
    - Completely characterize one engine before starting second engine
    - Increase number of emissions tests per day
      - Require revision to test protocol
      - Pretest will determine if this is a suitable option



# Critical Mass of Data

- On-road
  - Engine tests: NOx impact and NOx mitigation
    - 2006 Cummins ISM
  - Vehicle tests: characterization study
    - 2005 Caterpillar C13
      - Regulated and unregulated emissions except Nitro-PAHs and Ames tests
    - 2007 Detroit Diesel MBE4000
      - Regulated emission
- Non on-road
  - One TRU
  - John Deere off-road engine
- Biodiesel/Renewable Multimedia Evaluation

# Discussion

## Light-Duty Diesel Vehicle Testing

- To be conducted in collaboration with ARB's Research Division Light-Duty Test Program
- Two vehicles (new technology)
  - One passenger car
  - One pick-up truck/SUV/minivan
- Start date late 2008

# Durability Study

- Request for proposal (RFP)
  - Literature search
  - Survey
- CRC advisory role
- RFP will be released later this summer

# Biodiesel Multimedia Assessment

- Principle Investigators
  - Dr. Tom McKone, University CA Berkeley
  - Dr. Tim Ginn University CA Davis
- Biodiesel and renewable diesel
  - Assesses impacts on water, soil, air, human health, and the environment
  - Compared to CARB diesel
  - Evaluation includes a range of feedstocks, blend levels, and additives

# Biodiesel Multimedia Assessment Protocol

- Draft Multimedia Guidance Document
  - Tier one: Establishes the risk assessment elements and issues (scope of work)
  - Tier two: Development of the experimental design
  - Tier three: Multimedia risk assessment submittal, review, and recommendation
- Goal to present Draft Tier one at the next advisory group meeting

# Biodiesel Multimedia Update

- Dr. Tom McKone

# Biodiesel and Renewable Research Study Schedule

Engine tests													
NOx impact	Eng 2005			Eng 2007									
Phase one mitigation													
Phase two mitigation													
Vehicle on-road chassis tests	Veh 2005		Veh 2007		Veh w/w/oRet		Veh 2006						
UCD Analysis	2005				2007								
MLD	2005		2007		Veh w/								
Off-road Stockton	Test												
TRUs El Monte	TRU-1		TRU-2										
Final Report													
Light Duty													
Multimedia													
Tier one													
Tier two	Tier II												
Tier three			Tier III										
Peer Review													
EPC													
Biodiesel Durability													
	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09



# **Biodiesel and Renewable Diesel Advisory Group**

- Next meeting in September 2008

# EPA/CARB Diesel Study

<http://www.arb.ca.gov/fuels/diesel/dieselcomp/dieselcomp.htm>

Draft test plan