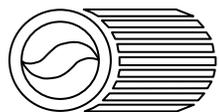


# **Biofuels Research Study**

**August 30, 2007**

**California Environmental Protection Agency**

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**Air Resources Board**

# Introductions

# Agenda

- Background
- ASTM activities
- Biofuels research studies
- Multi-Media evaluation
- In-kind contributions
- Advisory group discussion
- Presentation by others
- Open discussion
- Schedule of meetings

## Background

- 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 adopted by the first quarter of 2009
  - Biofuels research study is needed

# ASTM Update

- Steve Howell will provide update

# **Biofuels Research Study**

- Biofuels emissions evaluation
- NO<sub>x</sub> formation and mitigation evaluation
- Multi-Media evaluation

# **Funded Research**

- Initial biodiesel study-\$100,000 (SCAQMD \$50,000 additional)
- Biofuels characterization and NOx mitigation study
  - Biofuels characterization and Phase one of NOx mitigation study-\$1,280,000
  - Phase two of the NOx mitigation study-\$409,000 Upgrade to ARB dynamometer
- Biofuels multimedia study-\$400,000
- Total cost **\$2,189,000**

# **Duration of Contracts and Grants**

- Initial biodiesel characterization study: 6/06-6/08
- Biofuels characterization and NOx mitigation study: 6/07-6/09
- Biofuels multimedia: 6/07-6/09

# **Biofuels Emissions Characterization and NOx Mitigation Research**

“Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California- Biodiesel Characterization and NOx Formation and Mitigation Study”

Principal Investigators: Thomas D. Durbin (UCR) and J. Wayne Miller (UCR)

University California Riverside-CE-CERT

University California Davis

# **Scope of Work**

## **Task 1: Biofuels 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

# **Expanded Scope**

- Increase emphasis on renewable diesel fuels
- Light-duty vehicles

# **Proposed Test Elements**

- CARB diesel fuel
- US EPA diesel fuel
  - Comparison of US EPA diesel fuel and CARB diesel fuel is needed to compare results with future EPA studies.
- Biodiesel and biodiesel blends
  - B5, B20, B50, B100
- Renewable diesel
  - R5, R20

## **Proposed Test Elements (cont)**

- Two biodiesel feeds-soy and a second feedstock to be determined
- Two engines
- Three on-road vehicles and two off-road vehicles/engines
- Emissions: criteria, toxics, biological testing

# **Test Schedule**

- CeCERT engine dynamometer testing
  - Start Fall 2007
- ARB Heavy-Duty Test Facility at Los Angeles (MTA)
  - Start Spring 2008 initial work on chassis followed by Phase 2 NOx mitigation study conducted on the MTA engine dynamometer
- Stockton-off-road
  - Start in 2008

# **Pretest Preparation**

- Biofuels advisory group input
- Obtain vehicles/engines
- Fuel selection and procurement
- Delivery, storage, and fuel analysis
- Implement QA/QC
- Set up infrastructure
- Finalize test protocol

## **Estimated Fuel Requirements for Both Biofuels Characterization and NOx Mitigation Studies**

- Total volume of fuel 15,000 gallons (2x)
  - CARB diesel fuel: 7500 gallons
  - Biodiesel B100: 3600 gallons
  - US EPA diesel fuel: 150 gallons
  - Renewable diesel: 1000 gallons
  - Additional fuel for NOx mitigation study: 2750 gallons

# **Fuel Issues**

- Fuel specifications
- Batches
- Blending
- Analysis of fuels
  - Methods
  - Laboratory to conduct analyses
  - Frequency of measurements
- Storage
  - Condition requirements
  - Location

# CARB Diesel

- Commercial fuel with specifications similar to average CARB diesel fuel
  - 53 cetane
  - 5 ppm sulfur
  - 20 percent aromatics

## **CARB Diesel (cont)**

- One batch of fuel for the entire test
- Analysis of fuels
  - ASTM D975
  - 3-4 Laboratories to conduct analyses
  - Complete specifications conducted at the beginning of test
  - Stability tests conducted at regular intervals
- Storage facility and conditions

# **Discussion**

# **Proposed Biodiesel Fuels**

- **Feedstock one: Soy based**
  - Feedstock two: Animal grease, recycled grease (yellow grease), palm oil, animal fat, or market blend
    - Selection based on range of feedstock properties such as cetane and saturation or production
- **Four blend levels: B100, B50, B20, B5**
  - Added B5 blend level to test matrix

# **Biodiesel Feedstocks**

- Feedstock specifications must meet-D6751
- Analysis of fuels
  - Intervals, replicates, and number of laboratories conducting the analysis
- Batches of fuel
  - Related to number of stability of B100
- Storage
  - Storage facility
  - Conditions

# **Biodiesel Blends**

- Fuel specifications
  - Specified methods from D6751 and D975
- Analysis of fuels
  - Intervals, replicates, and number of laboratories conducting the analysis
- Batches of fuel
  - Related to number of stability of B100

## Biodiesel Blends (cont)

- Blending
  - Conducted at CE-CERT or other facility
  - Method for blending large batch
  - Blend level fraction measurement:  
EN140078  $\pm$  2 vol %
- Storage
  - Location
  - Conditions: temperature, humidity, anti-oxidant, nitrogen blanket,
  - Storage life

# **Discussion**

# **Renewable Diesel**

- Market primarily low blends
- Proposed test matrix
  - R5
  - R20
- Batch, analysis of fuels, storage facility and conditions same as CARB diesel
- Fuel specifications

# **Discussion**

# Engine Selection Considerations

- Emissions for PM and NOx
  - Predominantly from heavy-duty diesel engines including both heavy-heavy and medium-heavy duty diesel engines
  - Medium-duty diesel engines
  - Light-duty expected to play a greater role in the future

# Biofuels Research Study

## NOx and PM Emissions from On-Road Heavy-Heavy-Duty Diesel Engines by Model Year Groups

Table 1: Contribution (%) of HHD to total on-road diesel fleet, Calendar Year: 2007

MdlYr	Pop	VMT	NOx	PM10
pre-1991	6	5	9	28
1991-1993	2	3	6	7
1994-2001	11	26	45	33
2002-2006	4	16	14	16
2007	1	4	2	0
AllMYr	24	54	76	85

Table 2: Contribution (%) of HHD to total on-road diesel fleet, Calendar Year: 2012

MdlYr	Pop	VMT	NOx	PM10
pre-1994	4	3	8	19
1994-2001	9	14	37	31
2002-2006	5	13	18	26
2007-2009	3	12	9	3
2010-2012	4	15	3	3
AllMYr	26	57	74	82

Table 3: Contribution (%) of HHD to total on-road diesel fleet, Calendar Year: 2017

MdlYr	Pop	VMT	NOx	PM10
pre-1994	2	1	3	8
1994-2001	6	6	25	22
2002-2006	4	7	16	27
2007-2009	3	8	11	5
2010-2017	13	41	17	15
AllMYr	28	62	72	77

# Engine Dynamometer Limitations

- Engine dynamometer
  - Max load rating of 1575 ft-lb and 600 hp

# **Proposed Test Engines**

- Two Engines will be tested with a possibility of limited testing on a third engine
- Engine horsepower rating
  - 400-500 hp is the middle range
  - Cannot exceed 600 hp and 1575 torque due to engine dynamometer limitations
- Engine selection based on market share
  - Caterpillar, Cummins, Detroit Diesel
- Propose:
  - 2002-2004 engine
  - 2007 engine
  - 1994-2001 engine
- Discussion

## **Linking Engine and Chassis Dynamometer Emission Tests Results**

- In the US EPA biodiesel test program and using their test methodology found a good correlation between chassis and engine dynamometer tests
- Test an engine on a chassis dynamometer and then test the same engine on a engine dynamometer using the same test cycle
- Two of the test cycles will be used on both engine and chassis tests

# Test Vehicles

- Selection of vehicles
  - The pool of vehicles and engines tested will cover the range of diesel engines in California
  - Mix of heavy-duty and medium duty
- Three on-road vehicles
  - One vehicle will be tested with and without an diesel particulate filter

# Possible Biodiesel NOx Impact

- Biodiesel under certain conditions increase NOx
- Evaluate NOx as compare to average test cycle load (US EPA)
- Evaluate NOx as compared to blend level

# US EPA Biodiesel NOx Evaluation

- Average load of cycles
- Select cycles with a range of loads
- Considered appropriate load cycles
- Allows for a comparison of chassis with engine

# Test Cycle Criteria

- Representative of California
- Representative of vehicle operation
- Select three test cycles
  - Cover a range of average loads
  - HHDTs high average load
  - FTP or UDDS medium average load
  - Low UDDS low average load
- Discussion

# NOx Evaluation

- Evaluate a range of blend levels
  - Allow for a comparison of NOx increase as related to blend level
  - Six test replicates
  - Allows for comparison with other regulated and unregulated pollutants

# Toxics Testing

- PAHs Collect on filters and sorbant media:  
GC/MS
- Nitro-PAHs Collect on filters and sorbant  
media GC/NCI-MS
- Unsaturated carbonyls
  - Sampling: Bisulfite mist chamber
  - Analysis: Derivatize with  
pentafluorohydroxylamine analysis GC/NCI-MS

## Toxics Testing (cont)

- 1,3-butadiene: Tedlar bags/GC FID
- VOCs: Tedlar bags/GC/FID
- Carbonyls DNPH cartridges/HPLC
- Elements: Filter/TBD
- Ions: Filter/Ion chromatography

# Others Species

- NO<sub>2</sub>: Tedlar bags/FTIR
- EC/OC: Filters
- Ultrafines
  - particle number, size distribution, real-time mass measurement and possibly surface area and morphology

# Biological Tests

- Salmonella/microsome microsuspension assay: mutagenicity
  - TA98, TA100 (filter/sorbant)
  - TA102, TA104 (selected samples)
- Comet assay: Chromosomal damage (DNA strand breaks) (filter)

## Biological Tests (cont)

- Human lung and macrophage assays  
Oxidative stress and inflammation
  - Inflammatory cytokines: IL-8 and TNF (tumor necrosis factor)
  - Prostaglandin synthase COX-2
  - Heme oxygenase-1: HO-1
  - C reactive protein: indicator of cardiovascular stress
- Collect samples on filters

# NOx Mitigation Studies

- Evaluate mitigation of NOx increase
  - Changes in fuel specifications-Match blending
  - Additives
  - Refinery process
- Discussed in detail in subsequent Biofuels advisory meeting

# **Biofuels Multi-Media Assessment**

- Title: Biofuels Multimedia Assessment
- Principle Investigators
  - Tom McKone, Public Health-Environmental Health Sciences, University California at Berkeley
  - Tim Ginn, Civil & Environmental Engineering, University California at Davis

# **Multi-Media Assessment**

- Evaluate impact of biodiesel, biodiesel blends, and renewable diesel relative to CARB ULSD fuel
- Consider feedstocks common to California

# **Cost Breakdown of Multi-Media Assessment**

- Total cost \$399,994
- Alternative Fuel Incentive Program funds
  - UCB: \$30,000
  - UCD: \$69,994
- Funds from ARB monies
  - \$300,000

# Multi-Media Assessment Kick-off Meeting

- Selection of feedstocks
- Incorporate renewable diesel fuels

# Impact on Light Duty Vehicles

- Light duty diesel vehicles are expected to play an increasingly important role in California
- Need to obtain information on the emissions impact of light duty diesel vehicles
- Need industry support

# Biodiesel Durability Study

- Need to determine satisfactory performance and durability in in-use vehicles
- Need industry support

# In Kind Contributions

- Fuels
  - CARB diesel fuel
  - US EPA diesel fuel
  - Biodiesel and biodiesel blends
  - Renewable diesel
  - Storage
  - Fuel analysis
- Engines
- Vehicles
- Other

# Biofuels Advisory Group

- Purpose/objective
- Schedule monthly meetings
- Meetings held in Sacramento and El Monte

# Presentation by Others

# Open Discussion