

# Biodiesel as a Fuel Retrofit to Improve Air Quality

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# Biodiesel Overview

- A diesel displacement fuel made from plant oils, animal tallow or recycled cooking oils through a chemical process to remove glycerin and yield methyl or ethyl esters optimized for combustion
- Renewable, agriculturally produced alternative fuel to displace imported petroleum; similar price
- Biodiesel itself is non-toxic, non-flammable and non-volatile, making it safer to handle & store
- Biodiesel contains little sulfur and no aromatics
- When blended with petroleum diesel or burned as a pure fuel, biodiesel can significantly reduce diesel engine exhaust PM, CO, HC, S & toxics

# Biodiesel is produced from fats and oils to make a clean burning fuel

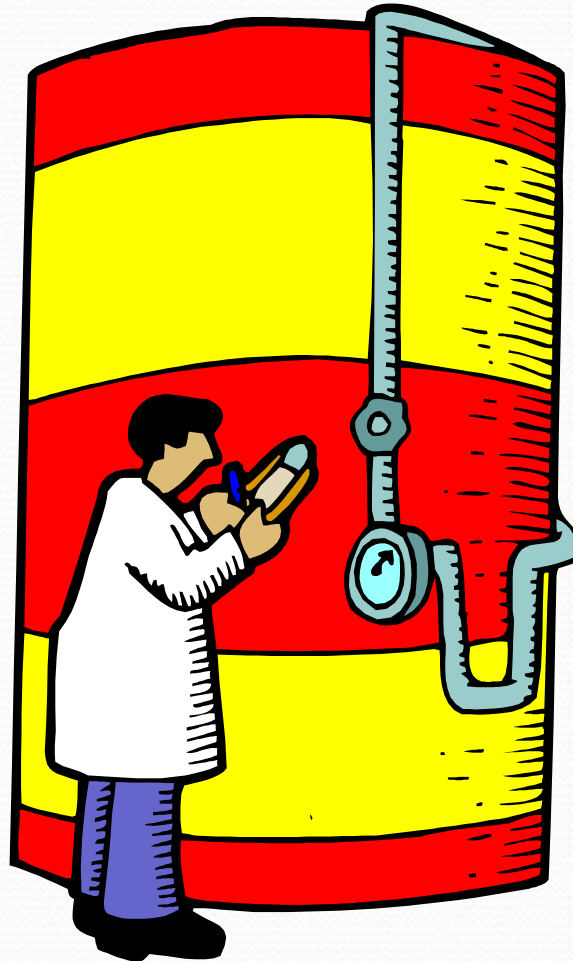
- Biodiesel is produced from a variety of vegetable oil, animal fat or recycled cooking oil/grease Feedstock
- Biodiesel is NOT raw oil, it is modified by a chemical process so the fuel can be used in any diesel engine
- Process of ‘transesterification’ clips three fatty acid chains (C14 to C20) off the Triglycerides (fats & oils) to lower viscosity and remove the glycerin
- Reaction requires an acid or base catalyst and alcohol, usually methanol, to generate ‘alkyl esters’
- Purified methyl esters = Biodiesel made to ASTM spec

# The Biodiesel Reaction

+ Catalyst (hydroxide)

Combining

**Vegetable Oil or  
Animal Fat  
(100 lbs.)**  
+  
**Methanol  
(10 lbs.)**



Yields

**Biodiesel  
(100 lbs.)**  
+  
**Glycerin  
(10 lbs.)**

# Biodiesel Feedstock and Reagents

## Oil/fat (triglycerides)

Soybean, Canola  
Mustard, Rapeseed  
Sunflower, Safflower  
Cottonseed

## *Tropical* Crop Oils:

African palm, Coconut,  
Jatropha, Castor bean

Jojoba & local crops

Beef tallow, pork lard,  
chicken fat, other fats

Recycled cooking oil, brown grease, trap grease

## Alcohol

Methanol (most common)  
Ethanol (rare)

## Catalyst (base)

Sodium hydroxide or  
Potassium hydroxide

# ASTM D6751 Biodiesel

## Specs

<b>Property</b>	<b>ASTM Method</b>	<b>Limits</b>	<b>Units</b>
Flash Point	D93	130 min.	Deg C
Water-Sediment	D2709	0.050 max.	% vol.
K. Viscosity, 40 C	D445	1.9 - 6.0	mm <sup>2</sup> /sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur S 15 Grade	D5453	15 max	ppm
Copper Corrosion	D130	No. 3 max.	
Cetane	D613	47	min.
Cloud Point	D2500	Report	Deg C
Carbon Residue	D4530	0.050 max.	% mass
Acid Number	D664	0.80 max.	mg KOH/g
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorus Content	D 4951	0.001 max.	% mass
Distillation Temp 90% Recovered	D 1160	360 max.	Deg C

# ASTM D6751 Testing

## Highlights

- Acid number – for aged, oxidized fuel
- Flashpoint – for residual methanol
- Water & sediment – fuel fouling, deposits plus moisture in fuel accelerates oxidation
- Sulfated ash – for residual catalyst
- Bound glycerin – for incomplete conversion (mono, di and triglyceride residues in fuel)
- Free glycerin – inadequate fuel polishing
- ASTM updates now include specs for  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$  & oxidation stability

# Fuel Quality Control: A Mindset at 3 Levels from Plant to Fleet

- Production at the plant: feed stock to fuel
  - BQ 9000 or other rigorous QA program
  - ASTM 6751 specs and NBB certification
- Distribution, storage and handling
  - BQ 9000 or other rigorous QA program
  - Protocols, documentation, monitoring
- Consumer/fleet storage, dispensing & use
  - Protocols, documentation, monitoring



# Fuel Quality can Deteriorate

- ASTM spec fuel that is improperly stored, transported and handled can be ruined
- Observed distribution problems include:
  - Storage tanks contaminated with water or old fuel (diesel or biodiesel); bacterial growth
  - Trucks not clean; carry over residues to fuel
  - Improper techniques for blending and fueling
  - Aged fuel – oxidized, precipitates, sediments
  - Mixed batches of fuel from various suppliers
  - ULSD occasionally out of spec too

# Good Distribution Practices

- Clean dry storage tanks, rigorous maintenance and testing programs
- Inspection of each transport truck prior to loading; prior fuel only diesel or biodiesel
- Certificate of Analysis for batch delivered
- Proper blending, not just splash blending
- Filtration of fuel to at least 5 microns
- Protocols to prevent contamination
- Paper trails from supplier to consumer
- Samples of B100 for consumer



2004

Biomass

# BIODIESEL

## Handling and Use Guidelines



DOE/GO-102004-1999  
Revised November 2004



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable.



[www.biodiesel.org](http://www.biodiesel.org)

# Biodiesel is usually blended with ULSD to facilitate use & lower cost

- Low blends (B2-B5) to restore lubricity to ULSD
- B20 (20%): EPA Alt Fuel used by government & military fleets without any engine modifications
  - B20 is lowest blend that achieves significant emissions improvements for diesel exhaust
  - B20 used in CA fleets since 1999 (UC Davis) then Berkeley and other cities, counties, parks and private sector fleets all over the country
- B50 limited use; achieves >25% PM reduction

# Pure (B99/B100) Biodiesel Fuel in Niche markets and applications

- Maximize environmental, health and air quality benefits of pure biodiesel in specialty applications
- Marine vessels, tour & recreational boats (since 1993)
- National parks, theme parks and tour vehicles
- Private vehicles and small fleets – Retail fuel stations
- Municipal fleets (e.g., Berkeley 2003-2005)
- School buses and vans for transporting the elderly
- Mining industry; Construction equipment near hospitals , water reservoirs & other sensitive areas

# Biodiesel Performance – B20



**BIODIESEL RETURNS  
ENVIRONMENTAL BENEFITS  
WITHOUT  
SACRIFICING OPERATING  
PERFORMANCE**

- B20 has Similar Performance to Petrodiesel:
  - Torque
  - Horsepower 98%
  - Mileage -2%
  - Range – 2%
- BTU Content
  - (120,000 vs. 126,000 BTU/gal for B100)
- Cold Flow
  - (3-5 °F > for soy-based B20)

# Biodiesel and Health Effects

- Reduces Particulate Emissions
  - B20 lowers PM 16-18% B100 lowers PM 47-55%
- Reduces targeted compounds thought to cause cancer: Poly Aromatic Hydrocarbons (PAHs)
- Significantly reduces the mutagenicity of exhaust (in both gaseous & particulate phases)
- Tier 1 Mutagenicity studies at UC Davis testing biodiesel exhaust PM on bacteria
- Tier 2 Inhalation studies on lab rats exposed to biodiesel engine exhaust for weeks— no mortality even at high dose; minor pathology in a few rats

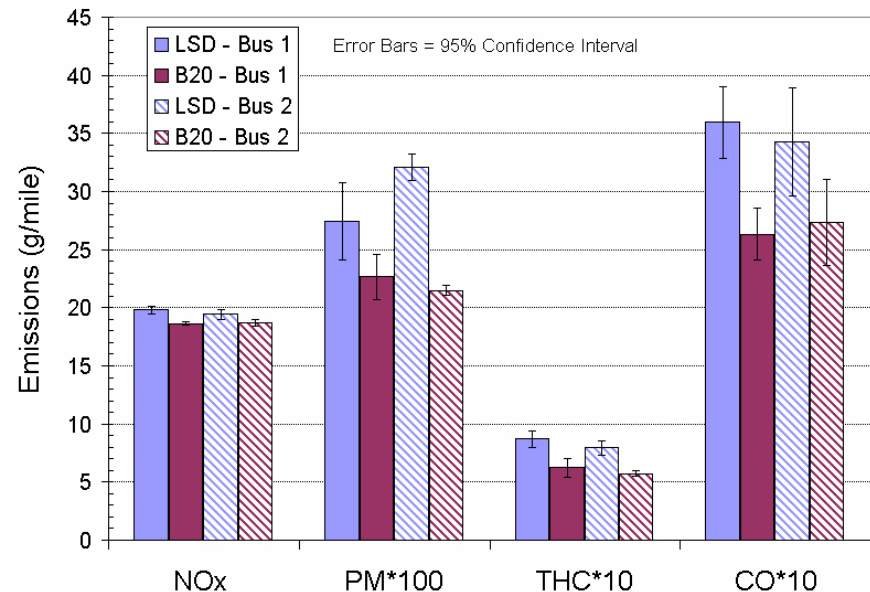
# Cleaner Emissions per Early NREL & EPA Studies

<b>Emission Type</b>	<b>B100</b>	<b>B20</b>
Unburned Hydrocarbons (HC)	-56-67%	-11-20%
Carbon Monoxide (CO)	-43-48%	-12-18%
Particulate Matter (PM)	-47-55%	-16-18%
Air Toxics & Mutagenicity	-60-90%	-12-20%
Oxides of Nitrogen (NO <sub>x</sub> ) (per EPA Draft Report 2002)	+6-10%	+1.2-2%

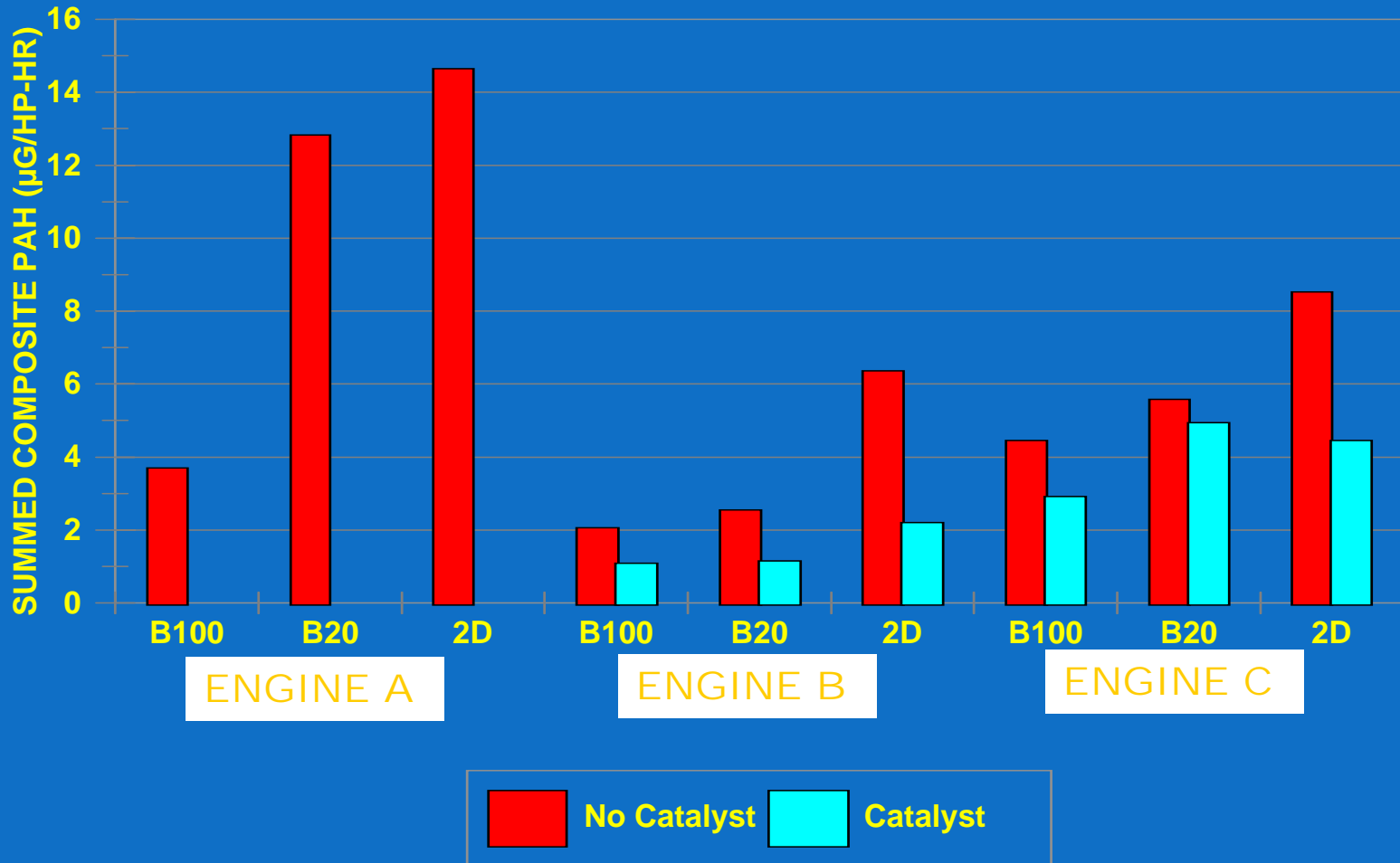


# Biodiesel Bus Chassis Dynamometer Testing

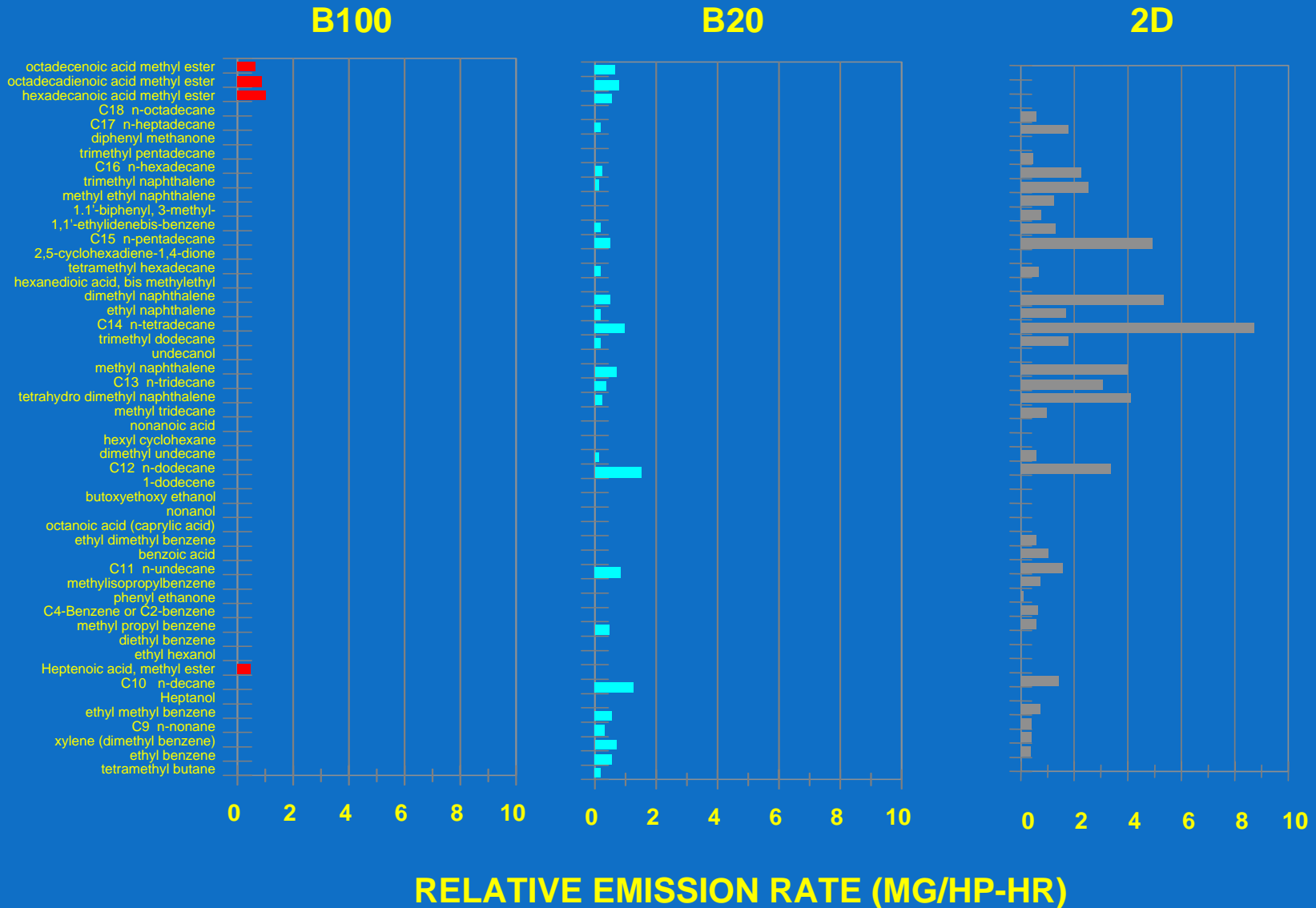
- B20 vs. conventional diesel fuel
- 2 in-use buses tested (40,000 lb GVWR)
- City Suburban Heavy Vehicle Cycle (CSHVC) at 35,000 lb inertia
- Cummins ISM 2000 Engine – No EGR
- Fuel economy reduction  $\approx 3\%$
- Emission reductions (g/mile basis)
  - **PM  $\approx 18\%$**
  - **HC  $\approx 29\%$**
  - **CO  $\approx 24\%$**
  - **NO<sub>x</sub>  $\approx 4\%$**
  - **statistical confidence > 99%**



# Poly Aromatic Hydrocarbon Emissions



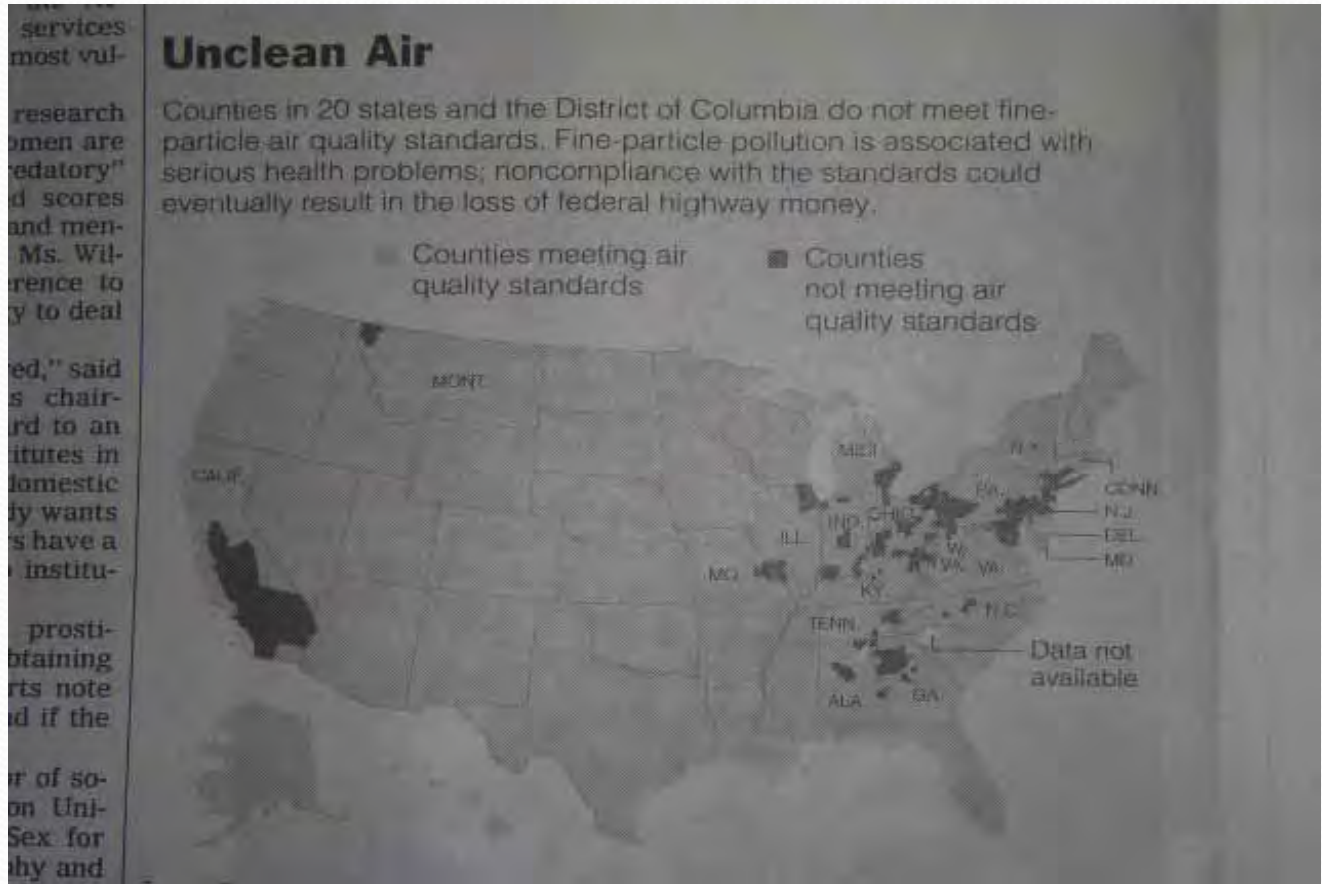
# HEAVY HC SPECIATION – EPA BASE N14 ENGINE



RELATIVE EMISSION RATE (MG/HP-HR)

# 225 US counties do not meet federal fine particle EPA air quality standards (20 states)

In the East, it is coal power plants... In the West, we have engine exhaust



California dwarfs other states

N.Y. Times  
Dec 18'04

# Pros and Cons...first the good news

- Biodiesel is a renewable, domestic fuel produced from the agriculture sector or from recycled feedstock
- Biodiesel is a non-toxic, non-volatile, non-flammable fuel with performance properties similar to ULSD
- Biodiesel can be blended with ULSD or used as neat fuel in any diesel engine with little or no modification
- Biodiesel offsets lubricity issues associated with ULSD
- Biodiesel reduces emissions of CO, HC, PM & toxics
- Biodiesel can function as a 'Fuel Retrofit' to immediately reduce PM and toxics associated with older diesel engines – in urban areas or Central Valley

# Further pros...

- Biodiesel is an EPA Alt Fuel and government fleets receive EPA credits for using B20 in diesel vehicles
- Biodiesel is a highly refined product with strict ASTM specifications that should ensure fuel quality
- Biodiesel uses petroleum distribution infrastructure
- Biodiesel blends can improve performance of PM traps
- Several states now mandate low blends or B20 blend
- Feedstock diversity and agricultural economic benefits
- Easy to use, drop in fuel for agriculture, construction and other off road applications
- One solution for lowering emissions from older trucks

# And the cons...not insurmountable

- Cost – B99 about 50 cents/gallon higher than ULSD but in recent past, it was same price as diesel fuel; B20 is close
- Availability – Limited retail pumps, especially in CA, although readily available via bulk distribution
- Regulatory issues – Biodiesel is still not recognized by CA as an Alternative Diesel Fuel; more research in CA
- NOx emissions still a concern for higher blends & B99 but these can be reduced with additives and after-treatment
- Cold flow problems with some feedstock/high blends
- Storage and distribution can affect fuel quality
- Research data missing for newer engines & after-treatment
- Warranty concerns in new engines for blends over B20
- Lack of understanding by public, agencies & fleets

# Future Biodiesel Opportunities

- Use biodiesel in higher blends (B50 or higher) to reduce PM and air toxics from older diesel engines
- Incentivize use of higher blends to reduce diesel exhaust associated with older trucks operating at
  - School buses, transit buses, garbage & recycling trucks
  - Ports (Oakland, Long Beach, Los Angeles, Tacoma)
  - Borders (with Mexico and Canada)
  - Congested inner city trucking distribution centers – E.J.
  - Agricultural sector (Central Valley)
- Develop regional biodiesel feedstock industries, from recycled oil-grease, to tallow and new oil seed crops



# Growing Biodiesel Feedstock in Western States

## Canola and Mustard oil seed crops

- Canola can be a rotation crop for wheat farmers in Eastern Washington, Oregon, Idaho, NV; currently grown for oil seed in Idaho and Colorado
- High oil yield strains yield 100-150 gallons of biodiesel per acre (double the yield of soy)
- Mustard can be dry farmed – wide climate distribution
- Plant debris contributes nitrogen to soil
- Glucosinolate in mustard plant and meal is an organic fungicide, pesticide & herbicide - reduces costs for farmer and provides additional incentives
- Suitable for distressed land not in crop production: Grow Energy in CA without competing with Food