

EMISSION IMPLICATIONS OF BIODIESEL FUEL

**Presented to
Biodiesel Forum and Technology Roundtable
South Coast Air Quality Management District Headquarters
November 7, 2006**



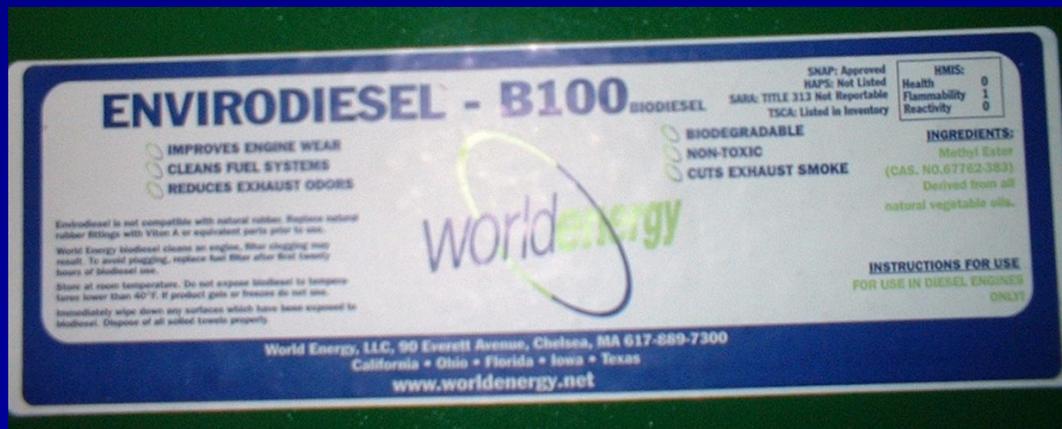
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Overview

- **What is biodiesel?**
- **Why is biodiesel interesting now?**
- **Effect of biodiesel use on diesel engines**
- **Effect of biodiesel use on diesel engine emissions**
 - Heavy duty transient cycle
 - Other heavy-duty test data
 - Light-duty vehicle data
 - Effect of feedstock composition on emissions
 - Synergy with catalytic aftertreatment systems
- **Other environmental effects of biodiesel**
- **Implications for emissions inventory and control strategies**
- **Conclusions**

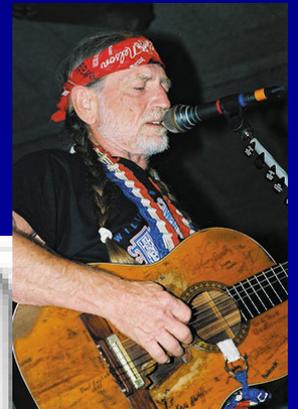
What is Biodiesel?

- **Alkyl esters of long-chain fatty acids derived from biological sources**
 - usually methyl ester (from methanol), sometimes ethyl ester (from ethanol) or isopropyl ester (from isopropanol)
 - fatty acids derived from vegetable or animal fats/oils
- **Liquid with physical and chemical properties compatible with diesel fuel**
 - Miscible in blends
 - Performance similar to diesel in engines
- **Potentially “renewable” fuel for diesel engines**



Why is Biodiesel Interesting Now?

- **Economics**
 - Petroleum diesel prices approaching those for biodiesel
 - Reduced oil demand => lower prices
- **Energy security / diversification / decentralization**
 - Domestic diesel fuel extender
 - Production is economic on modest scale
- **Global warming**
 - NREL estimates 78 to 81% reduction in “well to wheels” CO₂
- **EPACT**
 - Biodiesel use can offset part of AFV purchase mandate
 - Credits toward renewable fuels standard compliance
- **Environment**
 - Air benefits and disbenefits
 - Water, soil, hazwaste benefits
- **Willie Nelson**



Biodiesel Production and Feedstocks

- **Biodiesel production**

- common oils/fats are triglycerides - three fatty acids bonded to a glycerin
- react oils/fats with alcohol in the presence of a catalyst
 - breaks triglyceride bond, releasing glycerol
 - substitutes alkyl group



- **Feedstock can be any common vegetable oil or fat**

- Soy oil
- Mustard seed oil
- “Yellow grease”
- Tallow
- Rapeseed (Canola) oil
- Lard
- Grease trap waste

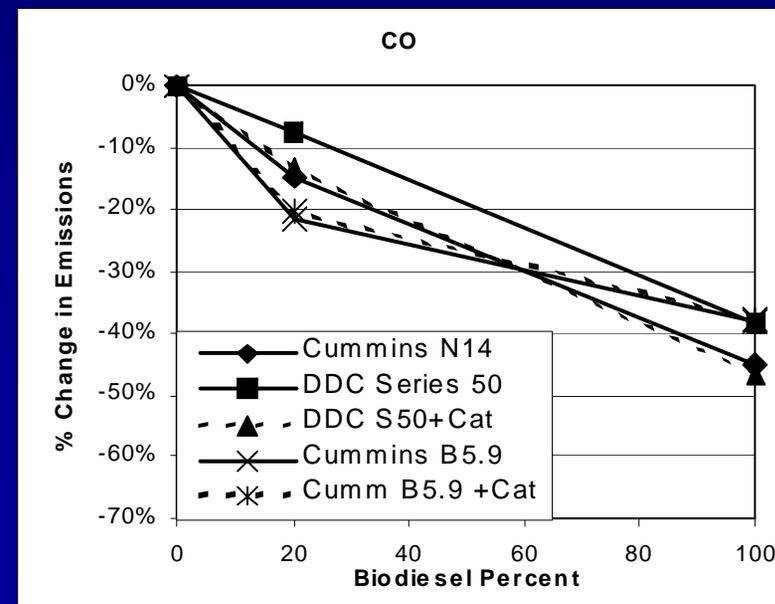
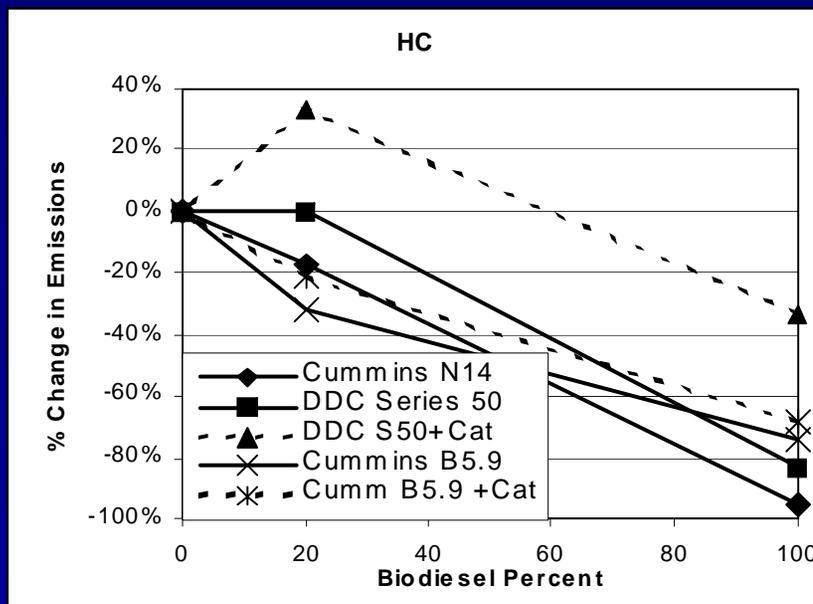
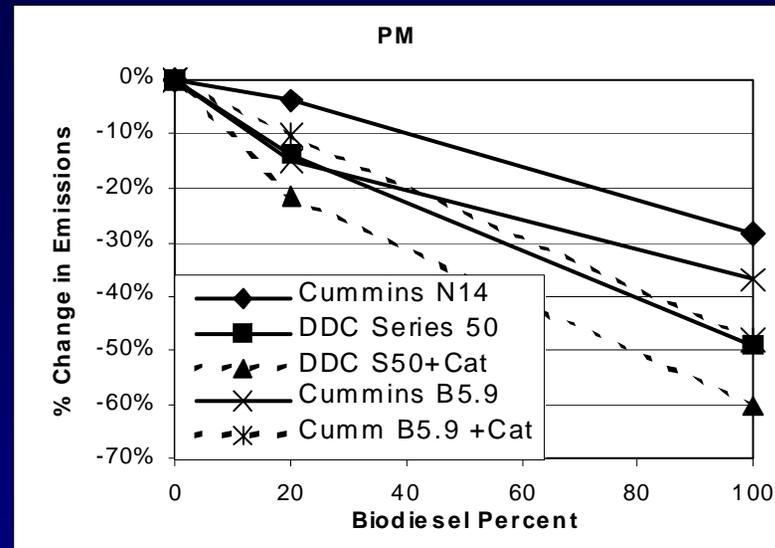
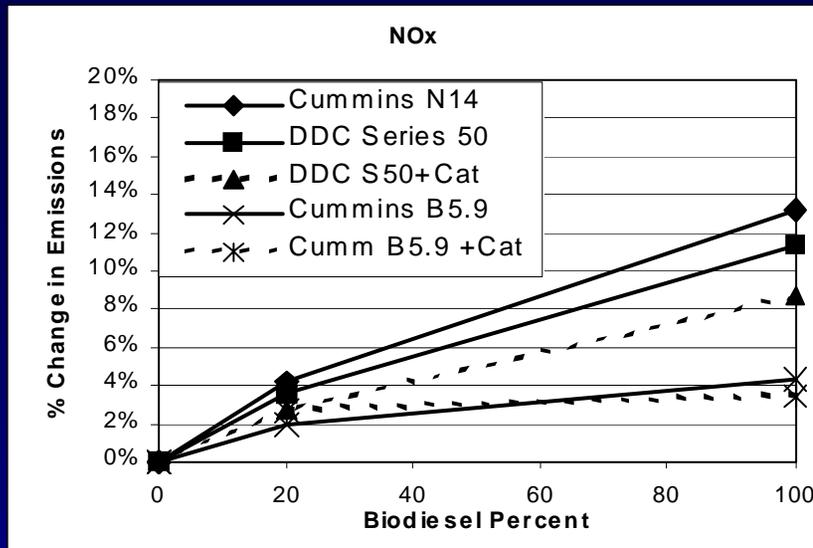
Effect of Biodiesel Use on Diesel Engines

- **Most diesel engines can use up to 100% biodiesel without modification**
- **Engine manufacturer acceptance - to varying degrees**
 - Consensus that up to B5 is OK for general use
 - Test programs using B20 show minimal problems
 - U.S. manufacturers won't void engine warranty because of biodiesel use, but won't cover damage due to biodiesel
- **Little long-term use data on B100**
- **Known problems**
 - B100 attacks natural rubber fuel lines and seals
 - Fuel gelling/filter plugging at low ambient temperature
 - depends on saturated fatty acid content
 - May need to shorten oil change intervals due to fuel dilution
 - Oxidation stability / bacterial growth / deposit formation
 - Filter plugging due to loosening of deposits on first use

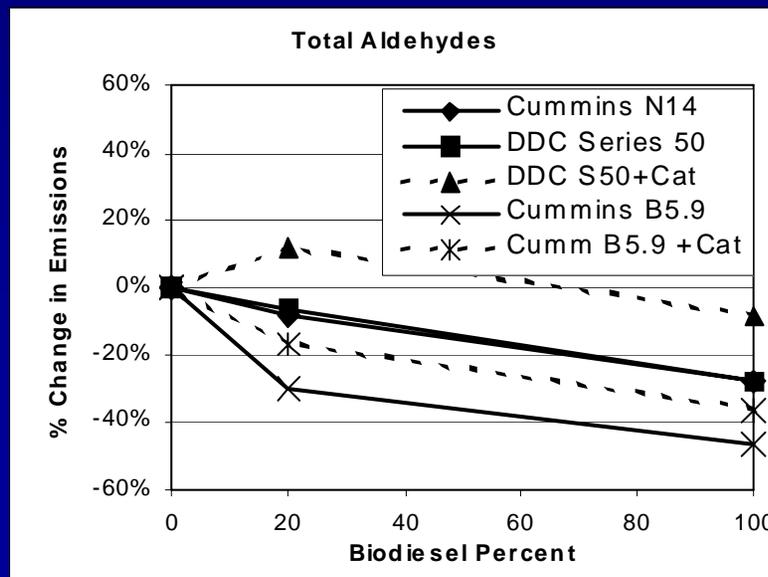
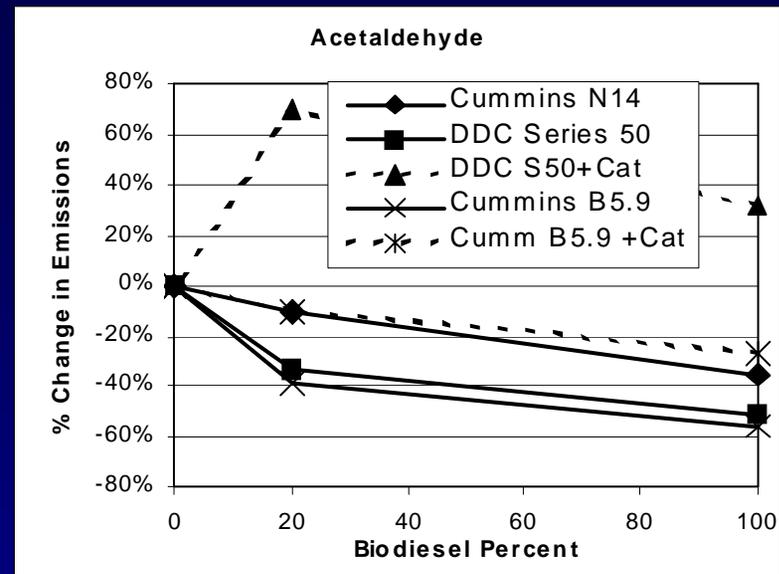
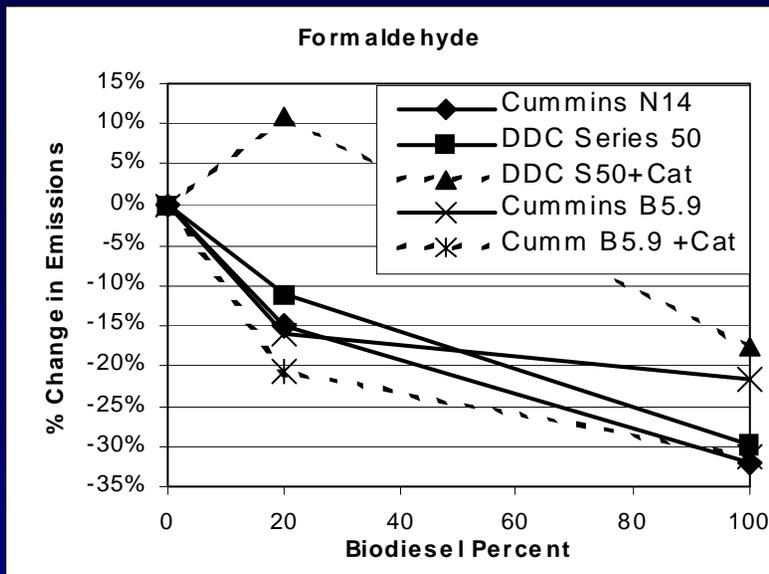
Effect of Biodiesel Use on Diesel Emissions

- **NO_x and PM Emission effects depend on engine loading**
- **Under moderately high engine loads (e.g. HDFTP)**
 - NO_x emissions tend to increase
 - less with saturates, more with polyunsaturates
 - PM emissions tend to decrease
 - Solid carbon greatly reduced
 - SOF increases
- **Under light engine loads (e.g. FTP 75 for pickups)**
 - NO_x emissions tend to decrease
 - PM emissions tend to increase
 - SOF increase outweighs reduction in solid carbon
- **CO, HC, most toxic emissions reduced**
- **Nano-PM probably increase**
 - Health effects of biodiesel nano-PM may be different

Biodiesel Effect on HDFTP Emissions

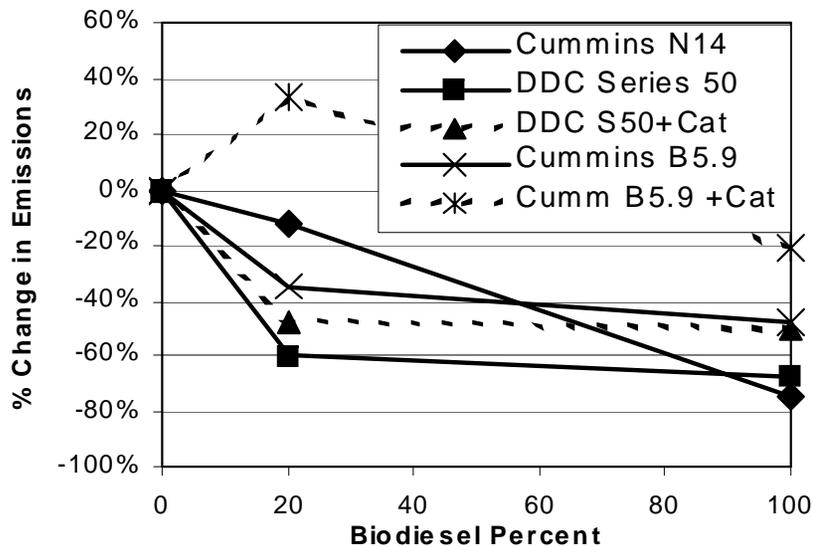


Biodiesel Effect on HDFTP Emissions

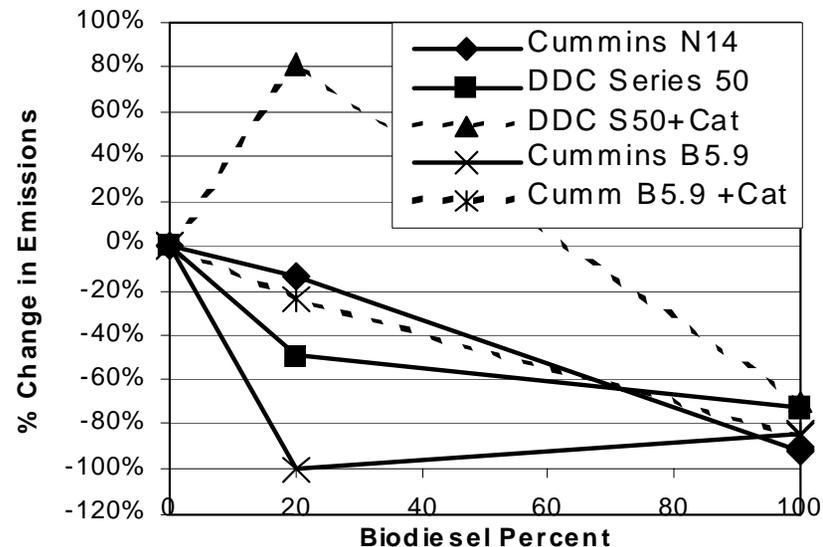


Biodiesel Effect on HDFTP Emissions

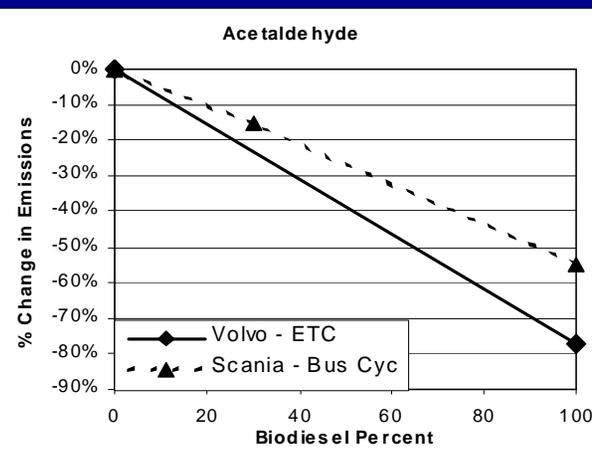
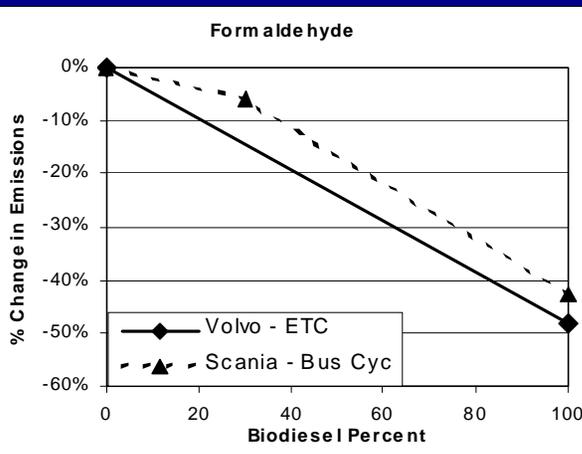
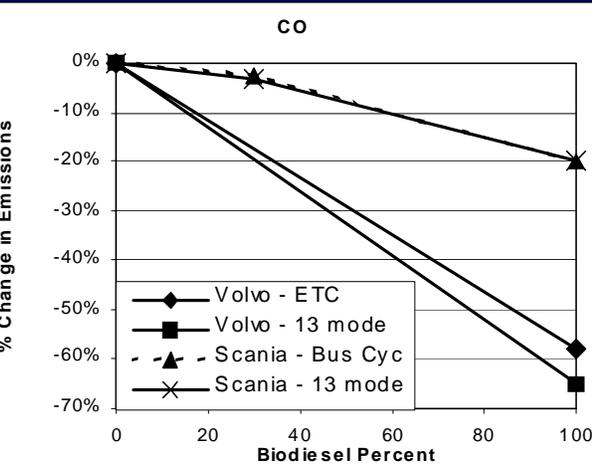
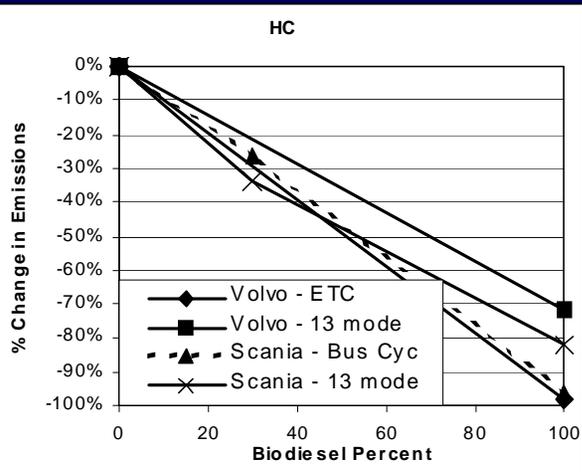
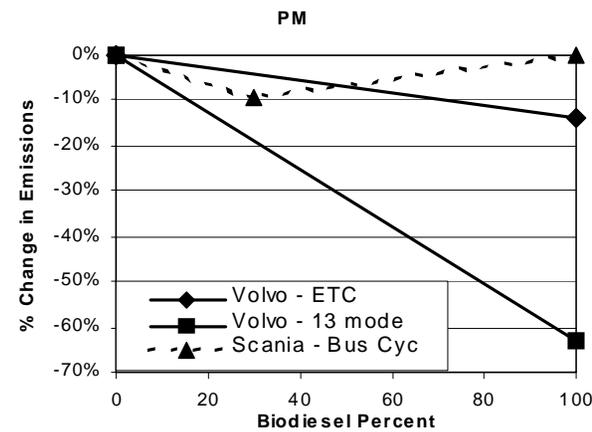
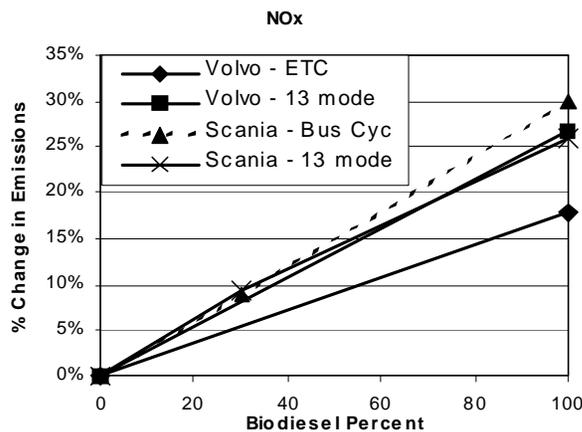
Total PAH



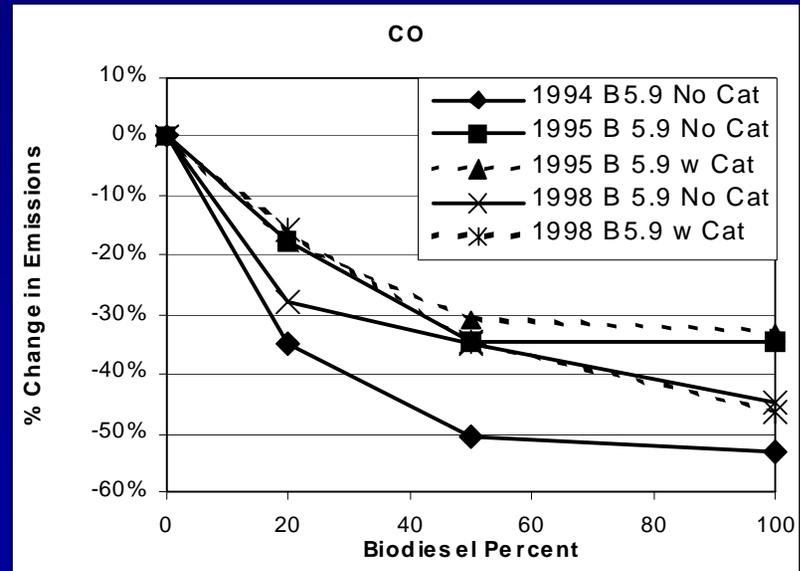
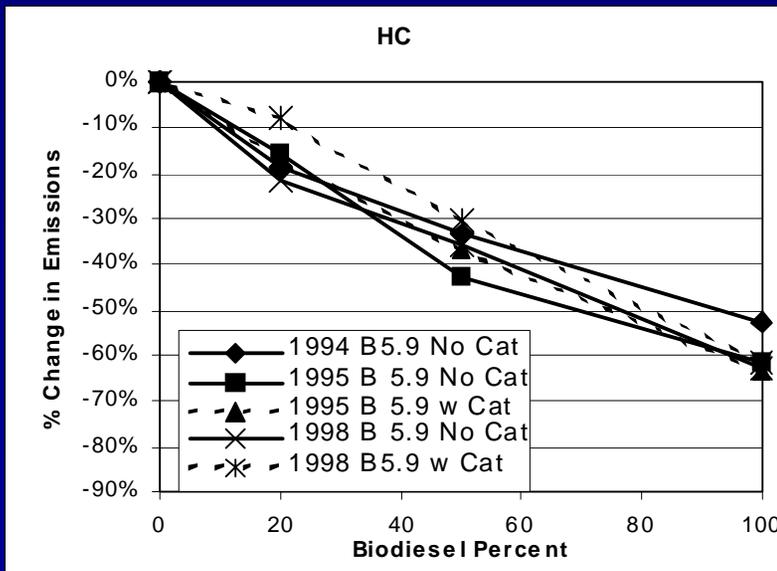
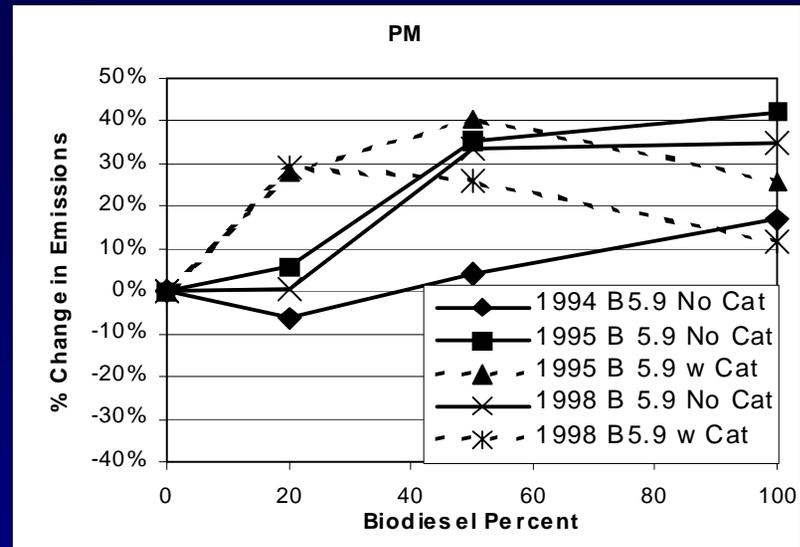
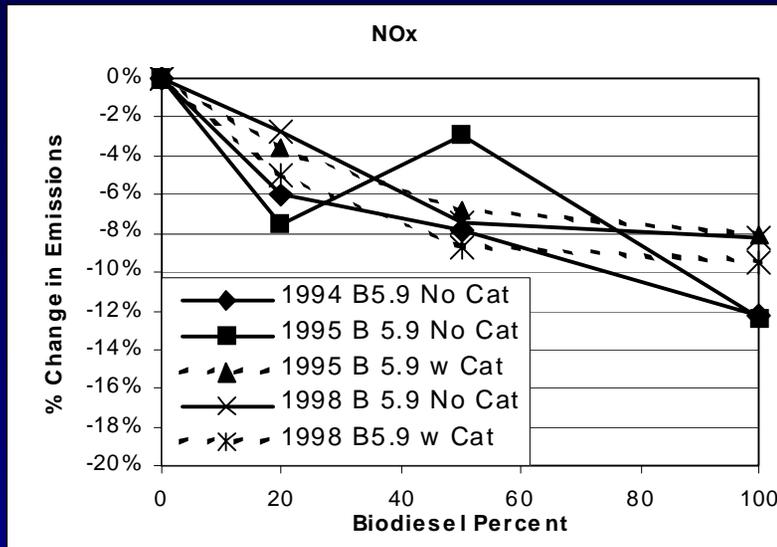
Nitro-PAH



Biodiesel Effect on Other HD Cycles

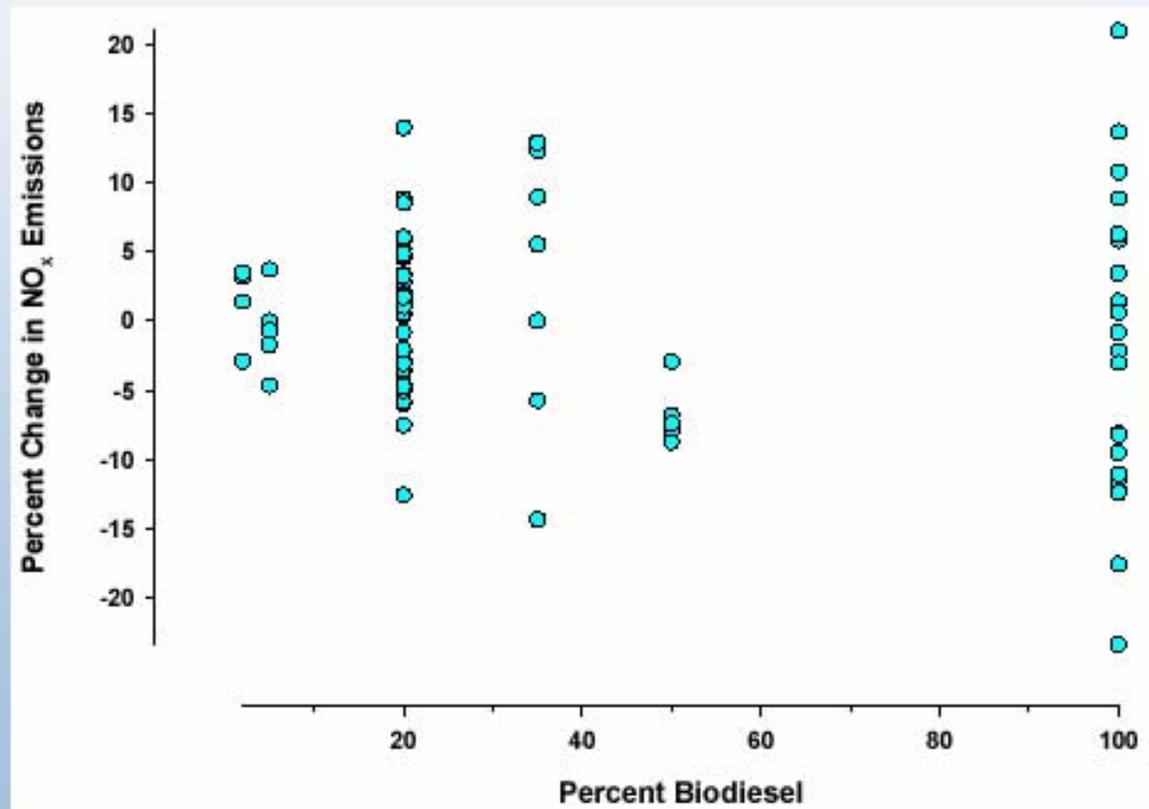


Biodiesel Effect on the FTP 75 Diesel Pickup Trucks



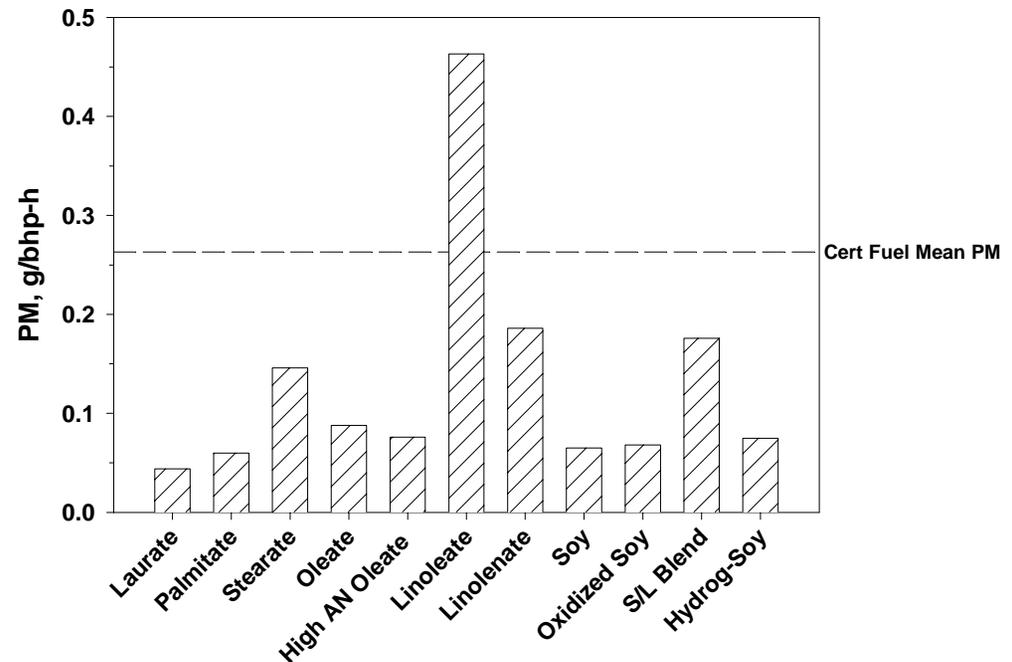
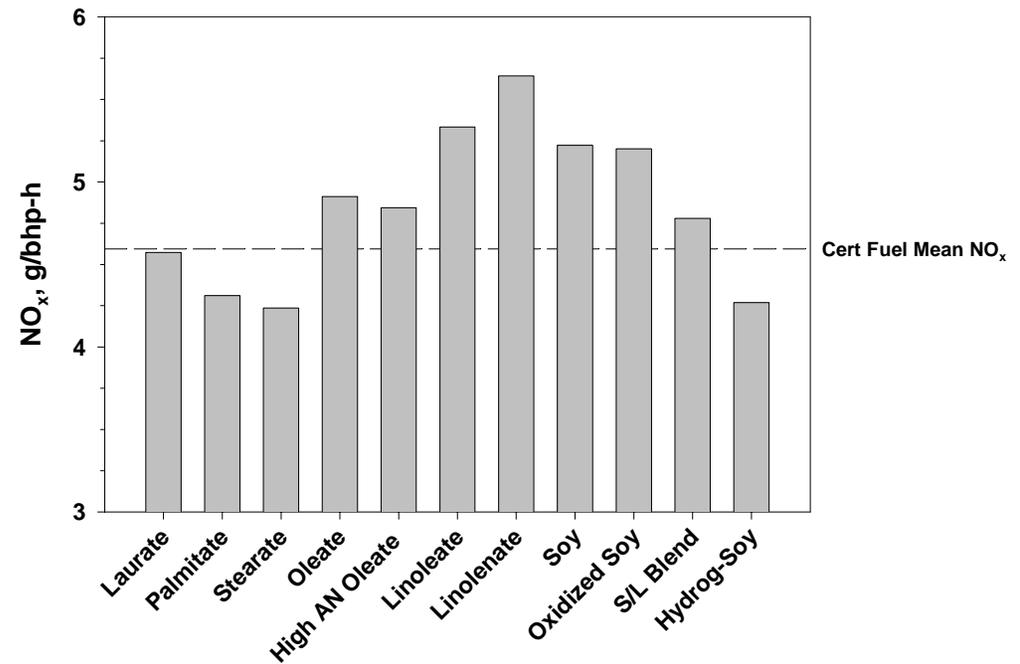
Biodiesel's Effect on NO_x Emissions -Vehicle (Chassis) Data

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

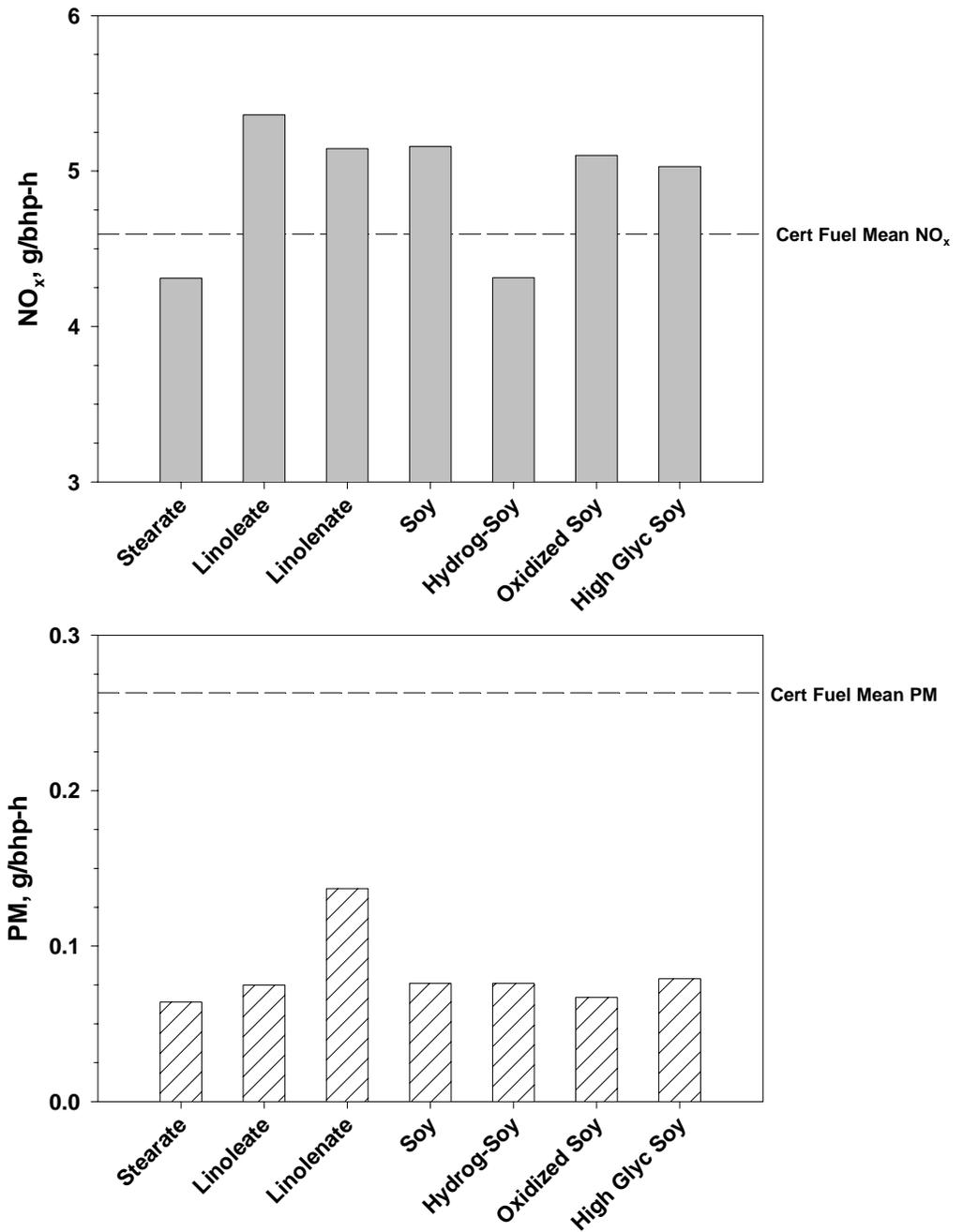


Data from EPA report plus additional chassis data in public domain

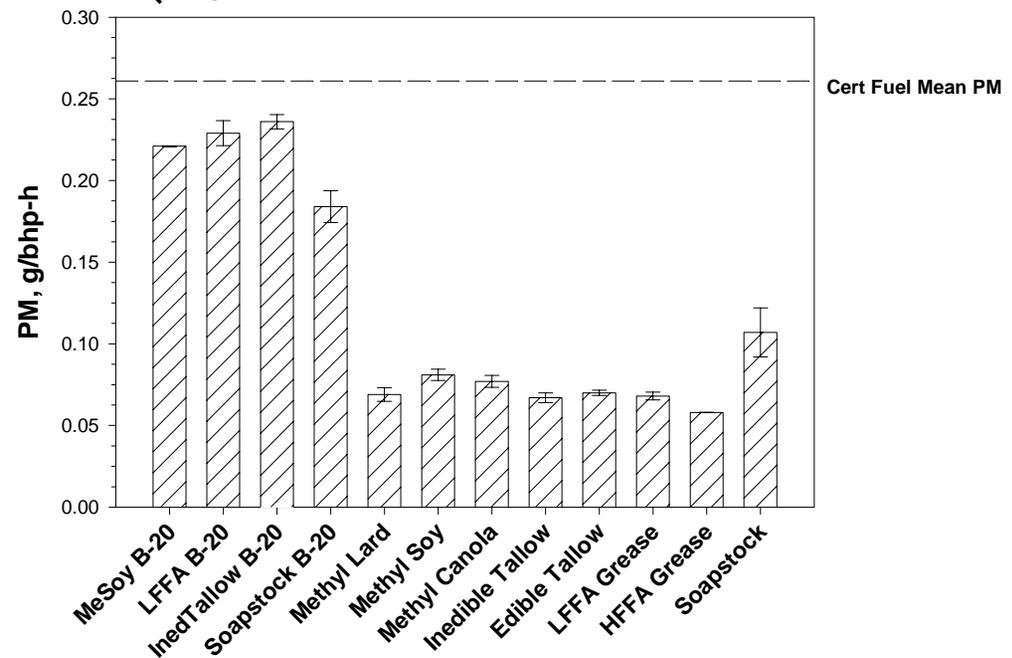
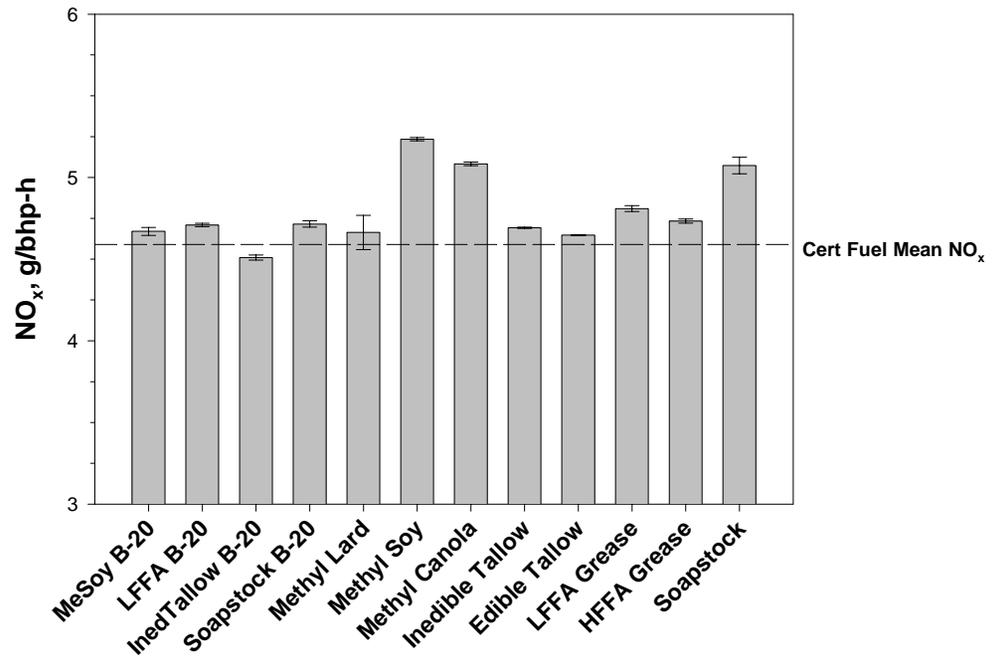
Effect of Fatty Acid Composition on HDFTP Emissions - Methyl Esters



Effect of Fatty Acid Composition on HDFTP Emissions - Ethyl Esters



Effect of Biodiesel Feedstock on HDFTP Emissions



Synergy with Catalytic Diesel Aftertreatment

- **Biodiesel reduces solid carbon (soot) fraction of PM, but increases soluble organic (SOF) fraction**
- **Diesel oxidation catalysts and vanadia-titania catalysts used for diesel SCR systems oxidize and destroy the SOF, but have little effect on the soot fraction**
- **Combination of biodiesel + catalyst could be more effective than either one alone**
- **Biodiesel plus catalytic DPF also more effective than DPF alone**
- **Deployment of catalyst retrofit systems for diesel exhaust risk reduction potentiates further PM reduction via biodiesel blends**

Other Environmental Effects of Biodiesel

- **Biodegradable**
- **Relatively harmless if spilled in water or soil**
- **Not hazardous - reduced hazwaste generation**
- **Much lower greenhouse emissions**
 - 78% reduction for methyl soyate if ag machinery, transport, and processing use non-renewable fuels
 - Biodiesel use in ag machinery and transport trucks would further reduce greenhouse emissions
- **Environmental impacts of increased farming**
 - pesticides
 - fertilizer runoff

Conclusions

- **Biodiesel production and use are likely to increase**
 - Economics
 - Energy security / EPACT
 - Global warming
- **Air quality impacts of biodiesel are mixed, depending on engine and driving cycle**
 - Net effect on NO_x uncertain
 - Overall benefits for PM, CO, HC
- **Air quality impacts of B5 and B20 blends are minor**
- **Potential synergy with catalytic aftertreatment systems**
- **Consider combined approaches such as SCR+Biodiesel**
- **Need to assess emission impacts under real-world driving**
 - Regulatory cycles not representative