Deployment Issues for Biodiesel: Fuel Quality and Emission Impacts

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May 24, 2007

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Fuels Technologies Subprogram
Non-Petroleum Based Fuels Activity
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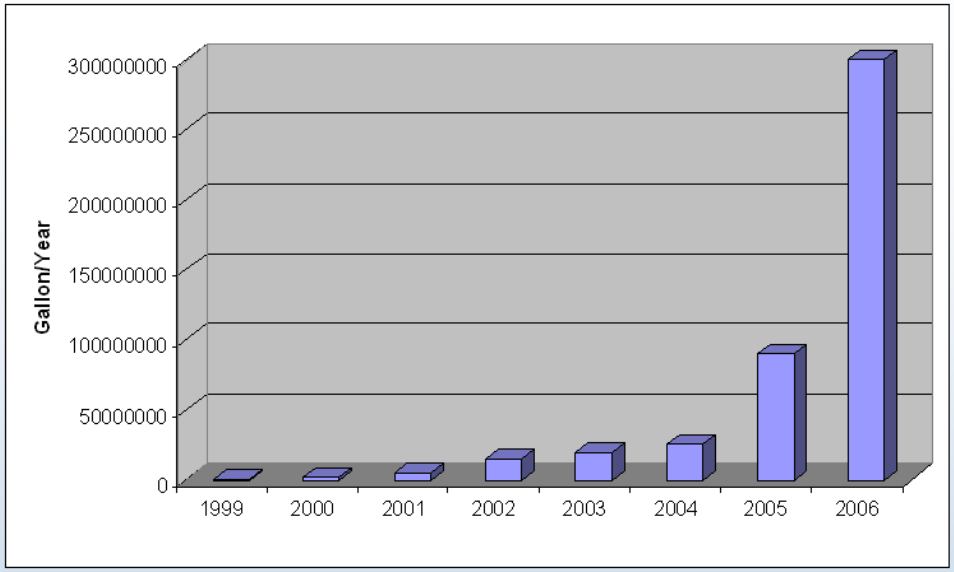
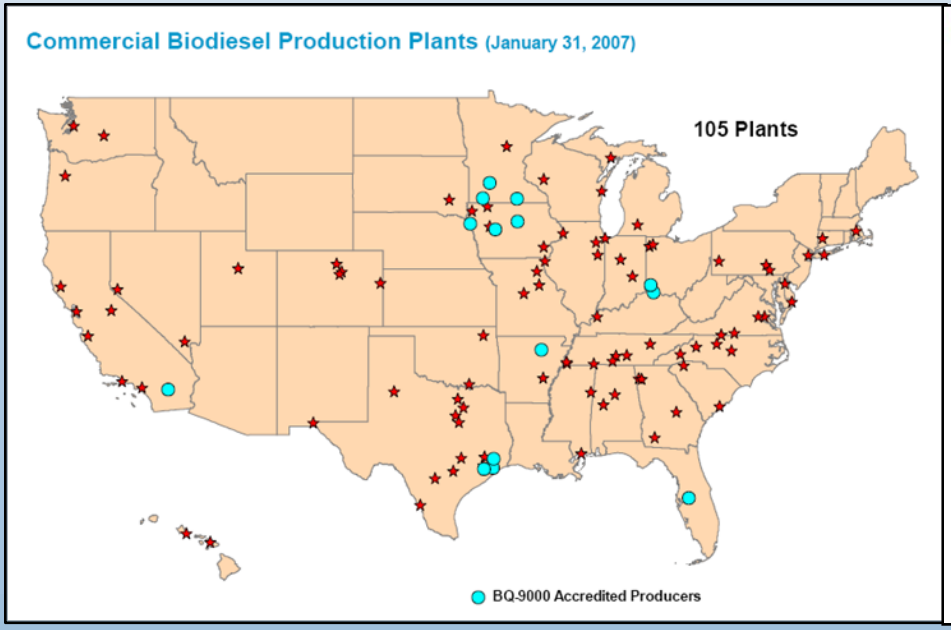
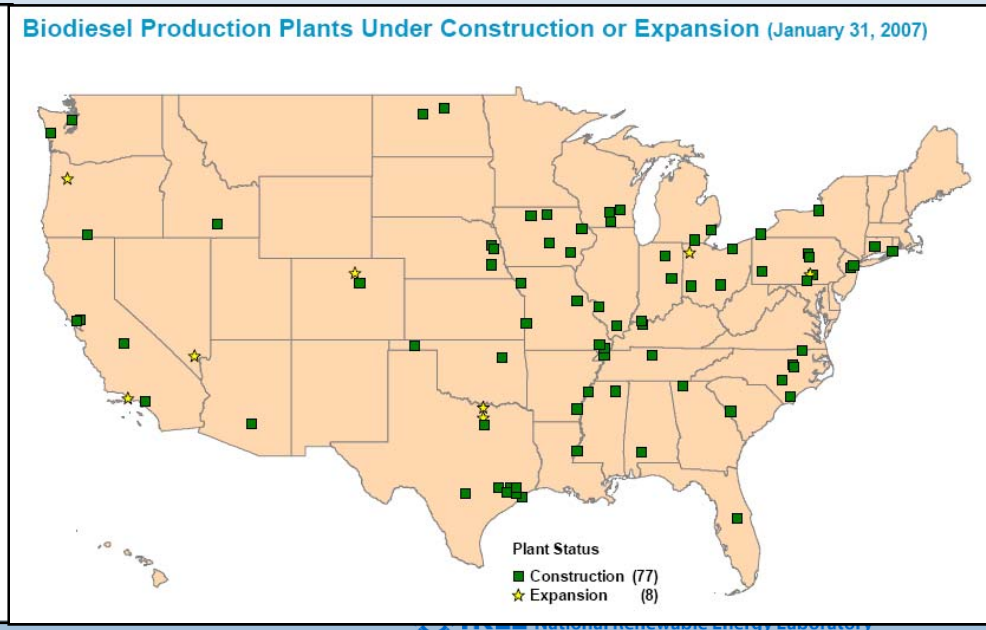
NREL/PR-540-41831
May 2007

Biodiesel Production



- *Current production capacity is more than 864 million annual gallons (Jan. 2007)*
- *Nearly 1.7 billion annual gallon additional capacity under construction or planned (Source: NBB)*





Biodiesel Blenders Tax Credit

- American Jobs Creation Act 2004
- 1¢ per percentage of biodiesel blended
  - Vegetable oils and animal fats
  - B20 = 20 ¢, B2 = 2 ¢
- 1/2 ¢ for recycled oils
- Must meet ASTM D6751
- Highway Trust Fund is not impacted
- Effective January 1, 2005
- Expires December 31, 2008 (extended in 2005 Energy Policy Act)

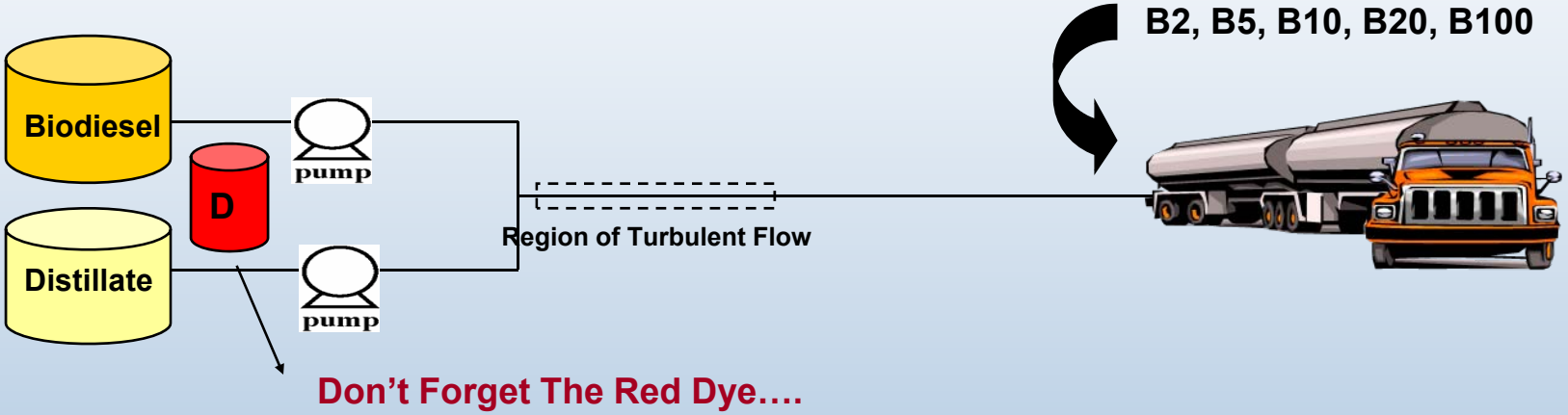
Renewable Diesel Tax Credit

- Energy Policy Act of 2005
- Renewable diesel defined as:
  - Produced by thermal depolymerization
  - Meeting ASTM D975
  - Meeting EPA registration requirements
- 1¢ per percentage of renewable diesel blended
- Expires December 31, 2008
- IRS Notice indicates their interpretation of the definition:
  - Thermal depolymerization is anything using heat
  - Co-processing of renewable feedstock and petroleum can produce a renewable diesel blend
- Must still complete formal rule making process

Ensuring A Quality Blend

Proportional Blending

- Streams are mixed by pumping them at the appropriate ratio of flow rates into a common pipe under turbulent conditions



- Universally used in fuel blending to ensure accurate, homogeneous blends
  - Blending fuel components in the refinery, wholesale terminal or bulk plant
  - Additive addition in the refinery, or at the terminal
  - Method universally used to blend B2 in MN by the petroleum industry

Dyed Fuel Requirement

- Dyed fuel is exempt from taxes – used by tax exempt and off-highway vehicles
- The tax exemption does not apply unless, among other conditions, the fuel is dyed using a mechanical injection system
- Dye requirement is 3.9 pounds of solid dye per 1,000 barrels of oil
  - Cost of dye is less than 0.1 cent gallon
- Biodiesel blends may not meet this requirement as B100 containing no dye is blended into dyed fuel
- Severe fines for not meeting the minimum dye requirement

IRS Transitional Rule on Dyed Biodiesel Blends

A mixture of diesel fuel or kerosene and biodiesel will be treated as being dyed by mechanical injection if all the following requirements are met—

1. the blend contains at least 80% diesel fuel (i.e. blends up to and including B20);
2. the diesel fuel or kerosene in the blend was dyed by a mechanical injection system;
3. the blend is created at a facility that is not a terminal; (note that for tax credit purposes blending requires a license) and
4. the dye concentration of the finished blend meets the federal requirement when it is removed from the facility where it was made.

Volumetric 'Blenders' Tax Credit

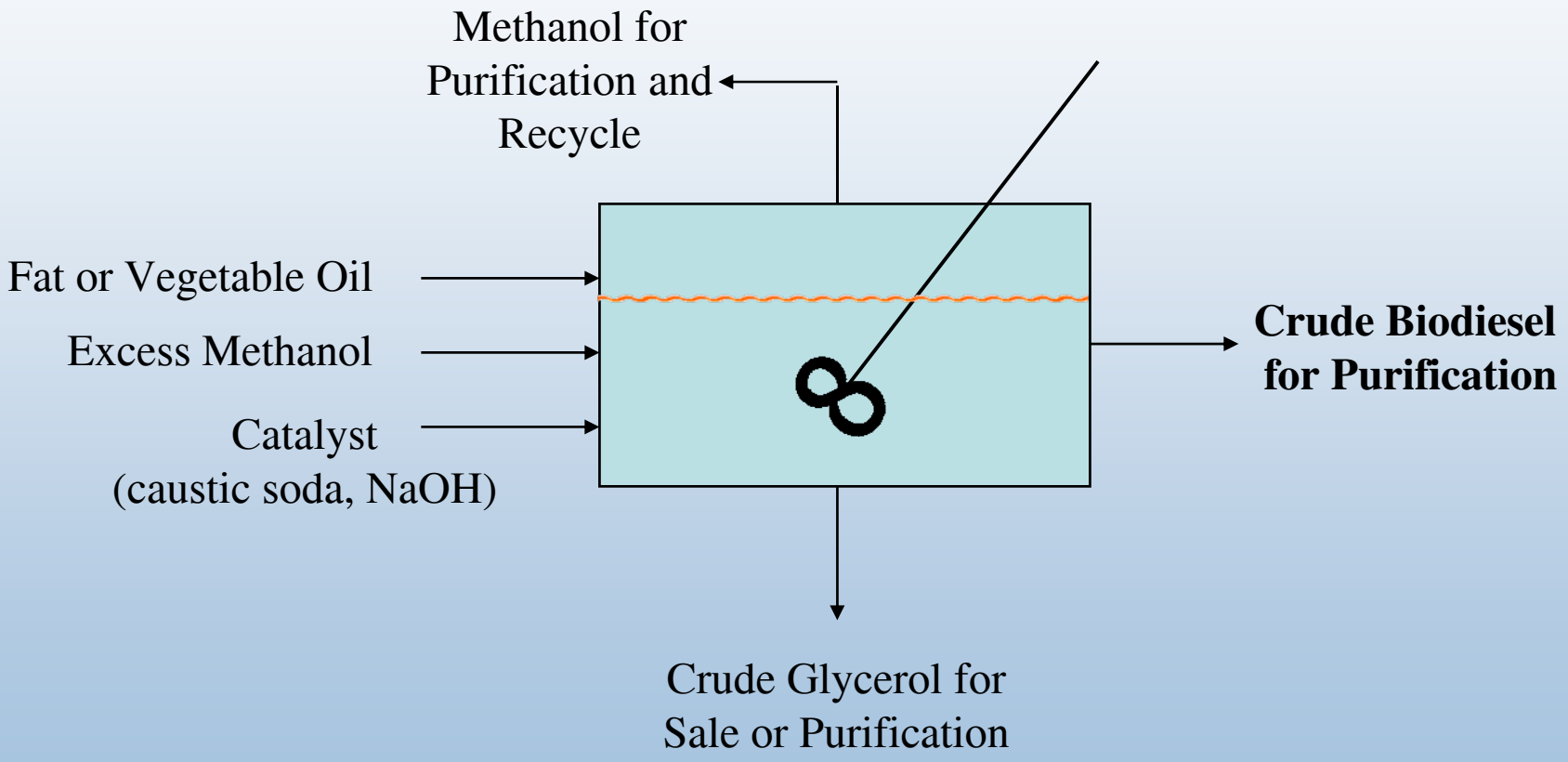
- The IRS has published on its website the various forms associated with the volumetric biodiesel credit. These forms (including Form **637**, Form **720**, Form **8849**, Form **8864**, and Form **4136**) are available by going to the Forms and Publications page of the IRS website, www.irs.gov. A direct link to that page is: http://www.irs.gov/formspubs/lists/0,,id=97817,00.html.

- **Form 637 is the registration application that all biodiesel producers and blenders must complete.** (Note: Becoming officially registered may take a considerable amount of time. Planning accordingly to meet the deadlines prescribed by the IRS is critical. For information about the registration process and timing, contact your local IRS Field Office.)

- Form **720** is the Quarterly Federal Excise Tax Return. Entities utilize this form to report and pay federal excise tax.
  Form **8849** is a general claim form for periodic refunds of federal excise tax.
  Form **8864** is a claim form for credits claimed as income tax credits.
  Form **4136** credit for federal tax paid on fuels.

Biodiesel Quality

Biodiesel Production Process –Crude Products



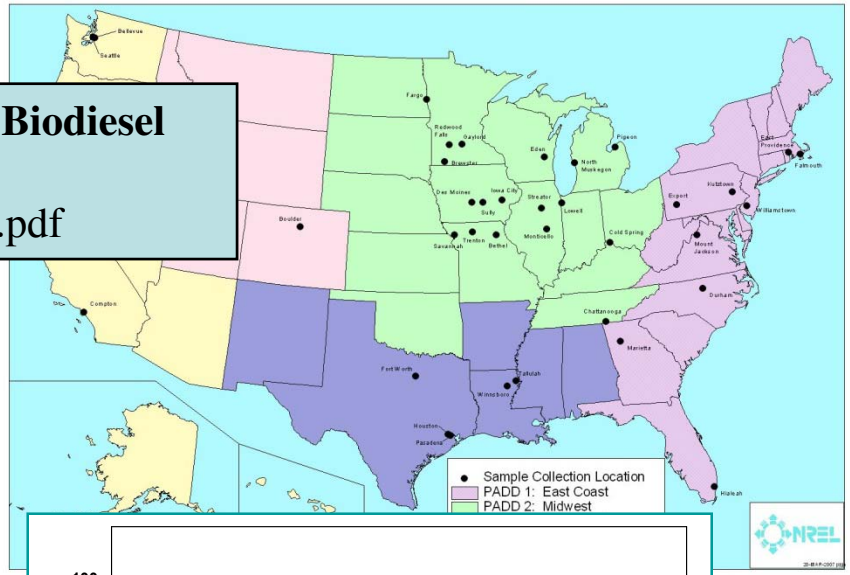
Potential Impurities in Biodiesel

- Methanol
  - Degrades some plastics and elastomers, corrosive
  - Can lower flashpoint to unsafe levels (fire safety)
- Unconverted/partly converted fat (bound glycerin)
  - Results in very poor cold flow properties, injector and in-cylinder deposits, potential engine failure
- Glycerin (free glycerin)
  - Results in injector deposits, clogged fuel filters, deposit at bottom of fuel storage tank
- Catalyst (caustic, NaOH)
  - Excessive injector, fuel pump, piston, and ring wear, filter plugging, issues with lubricant
- *All are limited by ASTM D6751 specification*

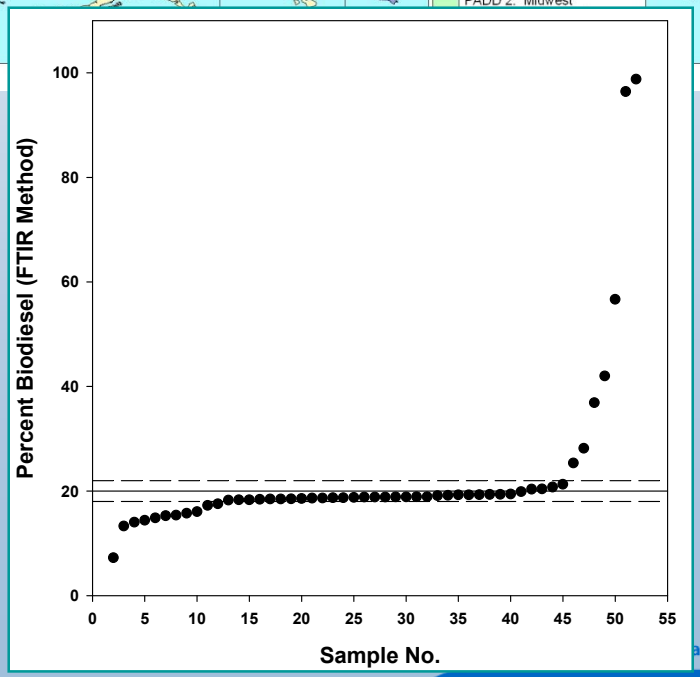
Biodiesel Quality Surveys

- B100 exhibited 15% failure rate in 2004

Survey of the Quality and Stability of Biodiesel and Biodiesel Blends in the United States in 2004
http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/38836.pdf



- Showed significant problem with meeting B100 requirements in 2006
  - 50% failure rate
  - Report in preparation
  - NBB response
- Identified problems with consistent blending of B20 in 2004
- Additional surveys ongoing
  - Surveys and education needed on a continuous basis

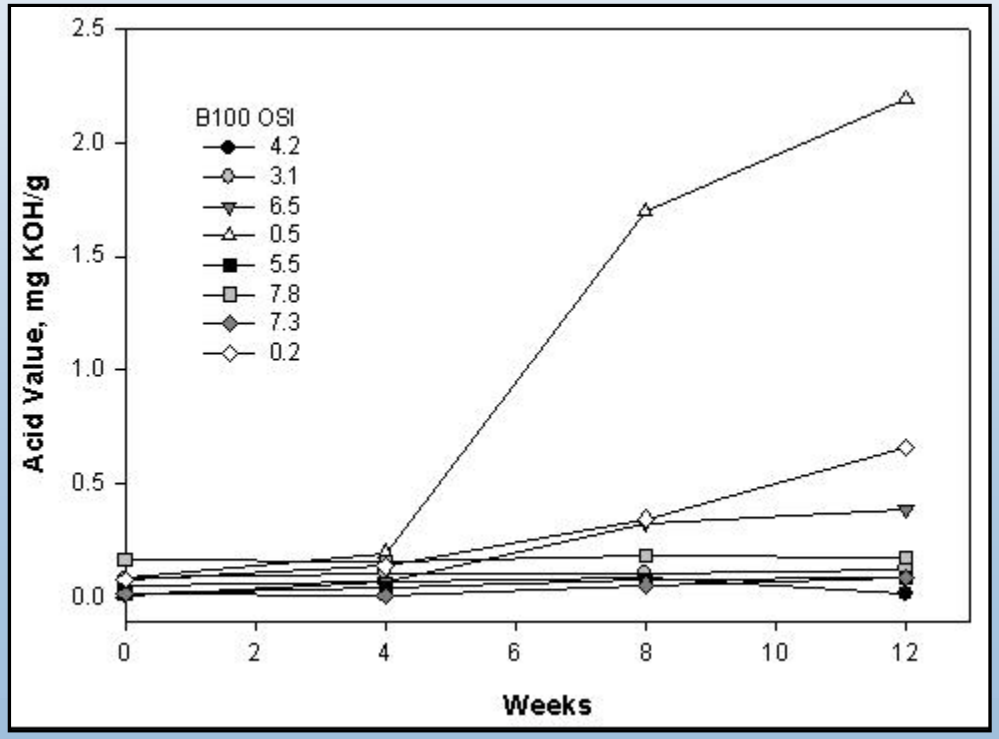


Biodiesel Degradation

- Microbial contamination
  - Biodiesel is biodegradable
  - Microbes form films or mats that can plug filters
  - Requires water in storage tank
  - Storage tank housekeeping issue/biocide treatment
  - Also an issue for petroleum fuels
- Oxidation
  - Increases acidity (limited in D6751 to 0.5)
  - Forms gums
  - A stability requirement is included in D6751

Biodiesel Stability

- NREL/NBB stability study shows that blend stability is dominated by B100 stability
- This work led directly to the adoption of a stability requirement for B100 by ASTM
  - 3 hour OSI induction time
  - Final report in preparation



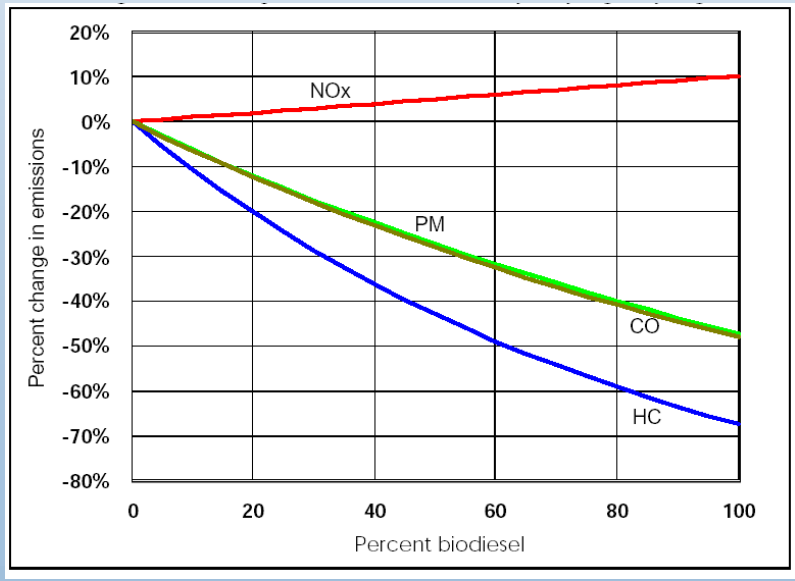
"Cummins is able to upgrade its previous position on the use of biodiesel fuel, which limited the use to B5 blends only, up to B20 for three key reasons. First, the American Society of Testing Materials specification ASTM D6751 now includes an important stability specification for B100 biodiesel."
http://www.everytime.cummins.com/every/news/release99.jsp

Stability of Biodiesel and Biodiesel Blends: Interim Report
http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/39721.pdf

Emissions

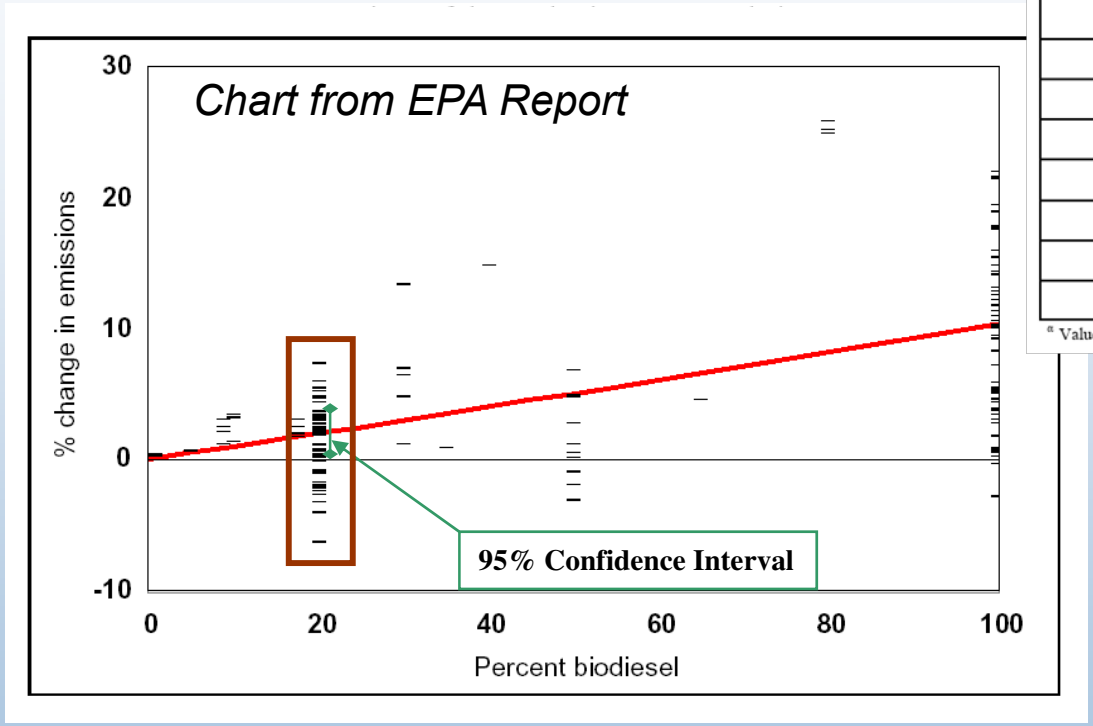
Emission Impact of B20

- 10% to 25% reduction in PM and CO, depending on engine, test cycle, and other factors
- 5% to 15% reduction on total HC and toxic compounds including: Aldehydes, PAH, NPAH
- Impact on NO_x emissions less certain
  - EPA review of published data found B20 causing NO_x to go up ~2%
  - *But many studies show NO_x going down*



Biodiesel's Effect on NO_x Emissions EPA Review - Engine Data

- **Percent change in NO_x for B20 ranges from -7% to +7%**
- **Average change in NO_x +2% (*EPA's conclusion*)**



Standards group	Model years	HD highway engines	NOx observations
B	2002 - 2006	0	0
C	1998 - 2001	2	14 (2)[a]
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)

[a] Values in parentheses are percent of total observations

- 43 engines included
- 72% of engines pre-1994
- 95% pre-1998

Many B20 tests show NO_x decreasing:

- **All are for soy biodiesel**
- **Engine standards groups D and E**

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

NREL Vehicle Testing Summary

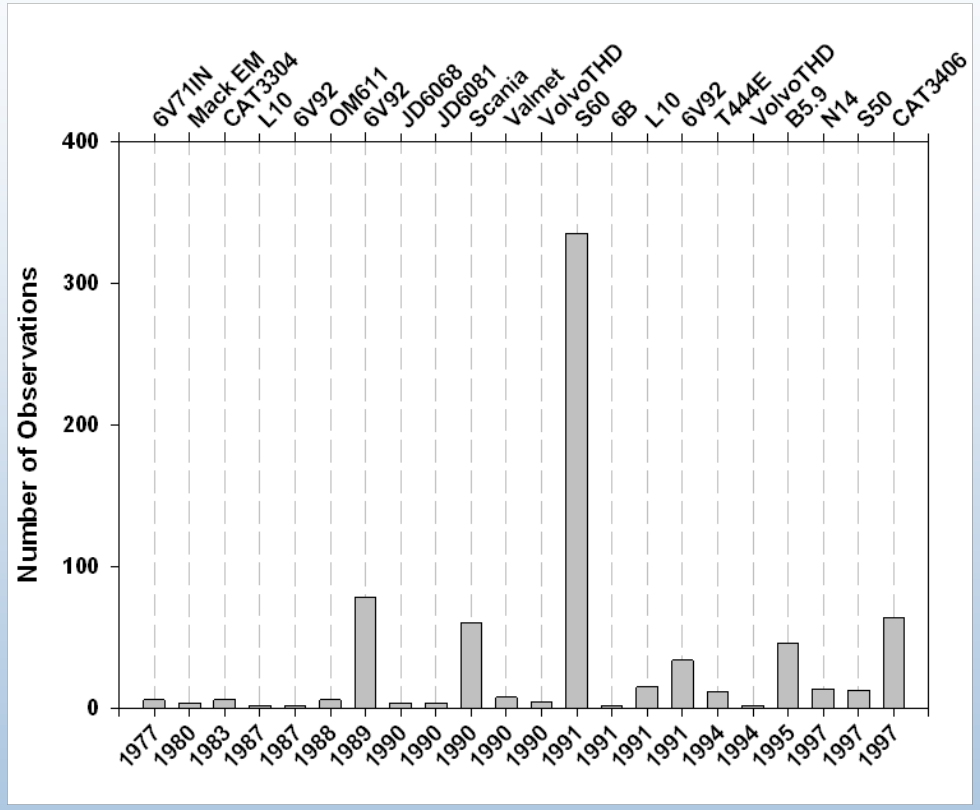
- Percent change in NO_x ranges from -5.8% to +6.2%
- *Average change in NO_x is 0.6% ±1.8%*
- Because of variability, conclusion may not apply to all in-use vehicles

Vehicle	Cycle	NO_x % Change	PM % Change	CO % Change	THC % Change
Transit Bus #1	CSHVC	-5.8	-17.4	-26.8	-28.3
Transit Bus #2	CSHVC	-3.9	-33	-20.3	-28
Transit Bus #3	CSHVC	-3.2	-18.85	-15.25	-24.05
Freightliner Class 8	CSHVC	2.1	-19.4	-10.7	-15.2
	Freeway	3.6	-26.2	-6.9	-16
Motor Coach	CSHVC	2.8	-28.1	-22.3	-14.5
	UDDS	3.4	-30	-19.2	-3.4
International Class 8	CILCCmod	-0.1	-27.2	-15.3	-16.8
	Freeway	2.3	-34.7	-14.5	-12.4
Green Diesel School Bus	CSHVC	-0.8	*		
	RUCSBC	2.3	*		
Conventional School Bus	CSHVC	-0.7	2.5	9.5	-1.1
	RUCSBC	6.2	-24	-22.6	-19.6
	Average	**0.6**	**-16.4**	**-17.1**	**-11.6**
	95%+/-	**1.8**	**10**	**6.1**	**8.6**

**Vehicle equipped with diesel particle filter, changes in PM, CO, and THC not statistically significant*

Effects of Biodiesel Blends on Vehicle Emissions:
http://www.nrel.gov/docs/fy07osti/40554.pdf

Engines Included in EPA Review



- 785 NO_x observations considered in EPA review
- ~45% of the data are for 1991 DDC Series 60 engines
  - Shows a consistent small increase in NO_x for B20
- Given engine-to-engine variability for B20:
  - EPA analysis weights results for this engine too heavily

Biodiesel Effect on NO_x

- *NO_x can go up or down depending on engine*
- *Data compilations that are not weighted to one engine model show no change in NO_x on average for B20*
- *Additional research is needed to quantify impact*
- *Reduction in PM and other pollutants is robust*

These results have led EPA to make a more neutral statement about biodiesel's NOx impact (RFS Final Rule):

-Conclusion that NOx goes up not widely accepted

-Conflicting results from other studies

-Additional studies involving all stakeholders are planned

Effects of Biodiesel Blends on Vehicle Emissions:
http://www.nrel.gov/docs/fy07osti/40554.pdf

Closing Remarks

- Biodiesel is a significant sustainable energy resource for the United States
- Use of high quality biodiesel meeting ASTM D6751 (or other national standard) is critical for good performance
- B20 produces robust reductions in emissions of soot, toxics, and carbon monoxide
- B20 appears to have no consistent impact on emissions of NO_x

Recent Publications

http://www.nrel.gov/vehiclesandfuels/npbf/pubs_biodiesel.html

- ***Effect of Biodiesel Blends on Diesel Particulate Filter Performance*** (Cummins, Inc. and NREL) SAE Paper No. 2006-01-3280 http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40015.pdf
- ***100,000 Mile Evaluation of Transit Buses Operated on Biodiesel Blends* (B20)** (Cummins, Inc., NREL, and Regional Transportation District) SAE Paper No. 2006-01-3253 http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40128.pdf
- ***Impact of Biodiesel Blends on Fuel System Component Durability*** (The Associated Octel Company, NREL, Marathon Petroleum Company) SAE Paper No. 2006-01-3279
- ***Spectroscopic Study of Biodiesel Degradation Pathways*** (Cummins, Inc. and NREL) SAE Paper 2006-01-3300
- ***Quantification of Biodiesel Content in Fuels and Lubricants by IR Spectroscopy*** (Cummins, Inc. and NREL) SAE Paper 2006-01-3301