National Renewable Energy Laboratory

Biodiesel and Renewable Fuels

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Biofuels versus Alternative Fuels

Biofuels are renewable fuels: made from plant or animal products.

These include ethanol and biodiesel.

Alternative fuels are defined under the Energy Policy Act and include options that are not renewable but have energy security benefits.

EPAct Alternative fuels are:

- methanol and denatured ethanol alcohol fuels (no less than 70% alcohol)
- natural gas (compressed or liquefied)
- liquefied petroleum gas
- hydrogen
- coal-derived liquid fuels
- fuels derived from biological materials
- electricity (including solar energy).

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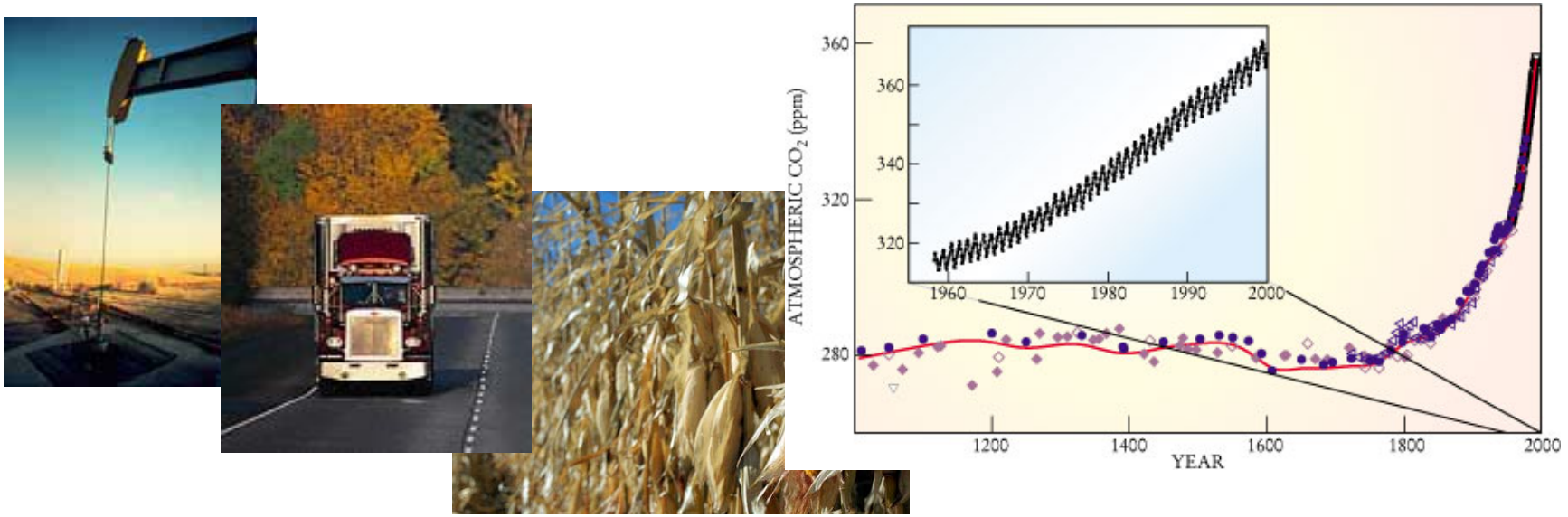
Objectives for Renewable Fuels

- **Enhance U.S. energy supply and displace petroleum**
- Reduce greenhouse gas emissions
- Spur rural economic development



Biofuel Utilization Strategy

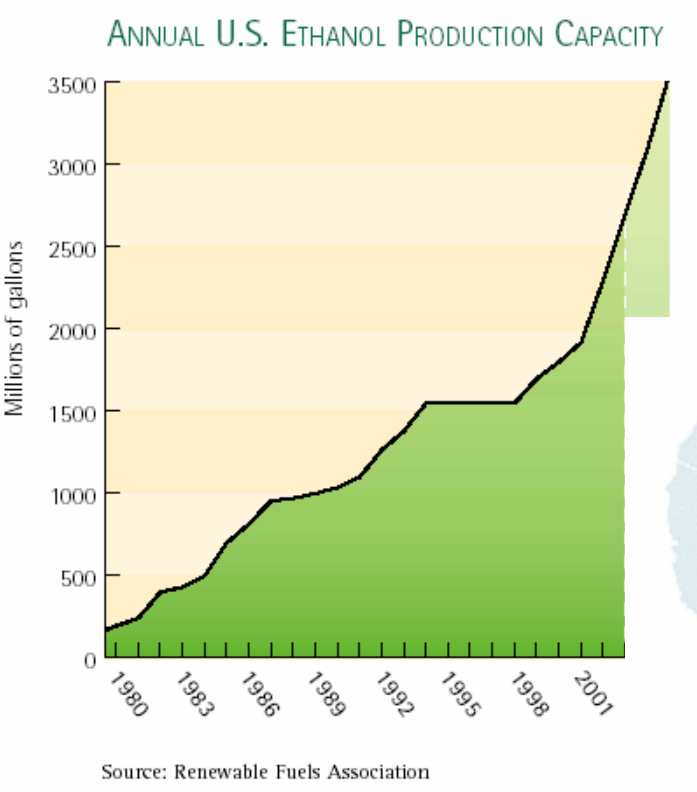
Blending of biofuels with petroleum-derived fuels is the primary strategy:

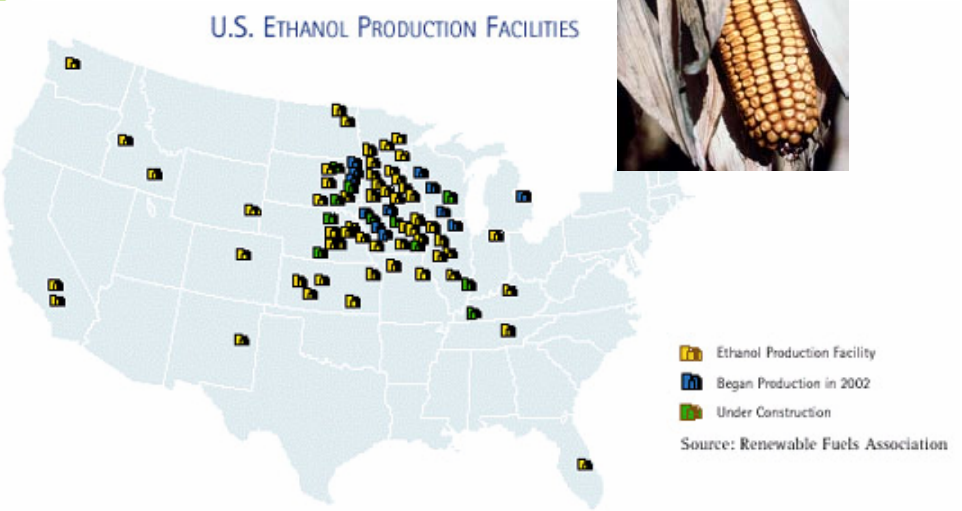
- 10% ethanol blends in gasoline
- 85% ethanol blends in gasoline (E85)
- 20% biodiesel blends in diesel
- Low blend levels (<5%) of biodiesel in diesel in the future

Biofuels for Spark-Ignited Engines

In the U.S. there is essentially one biofuel for this application: ethanol

- Current capacity is 2.5 billion annual gallons with 0.4 billion gallons under construction
- Primarily produced from corn

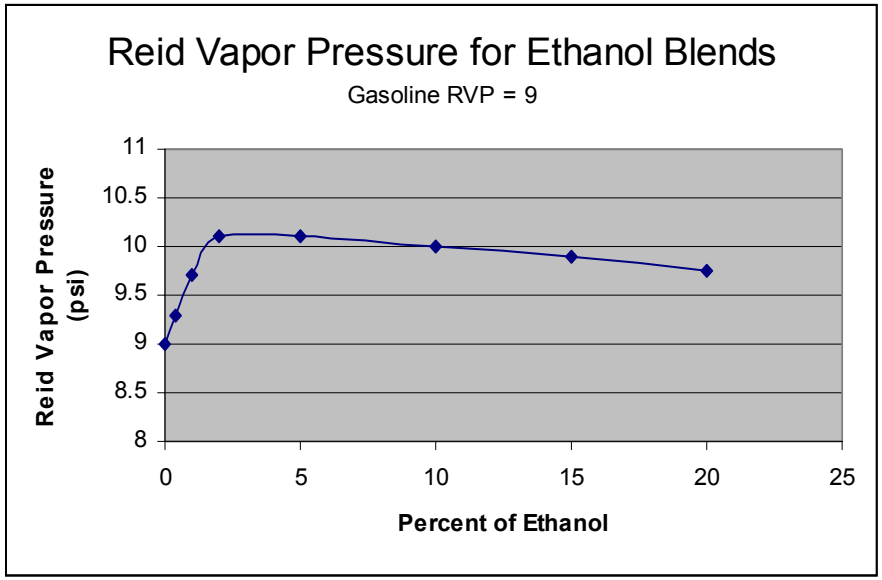




Utilization Status of Ethanol for SI Engines

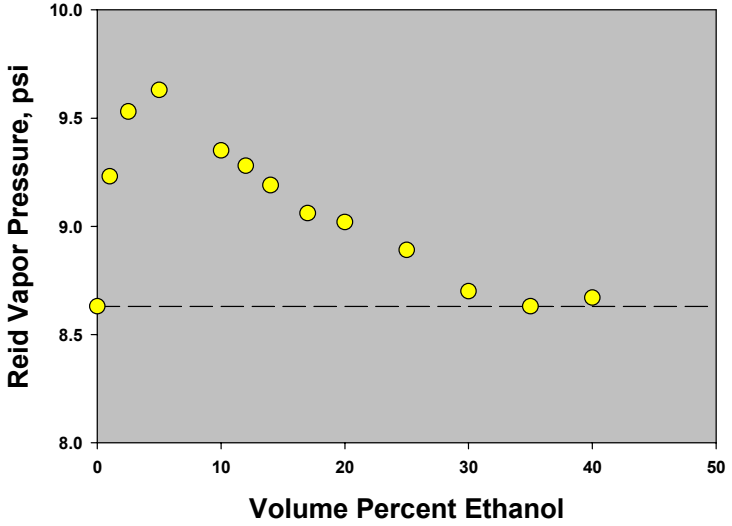
Most fuel ethanol is used as 10% blend in gasoline.

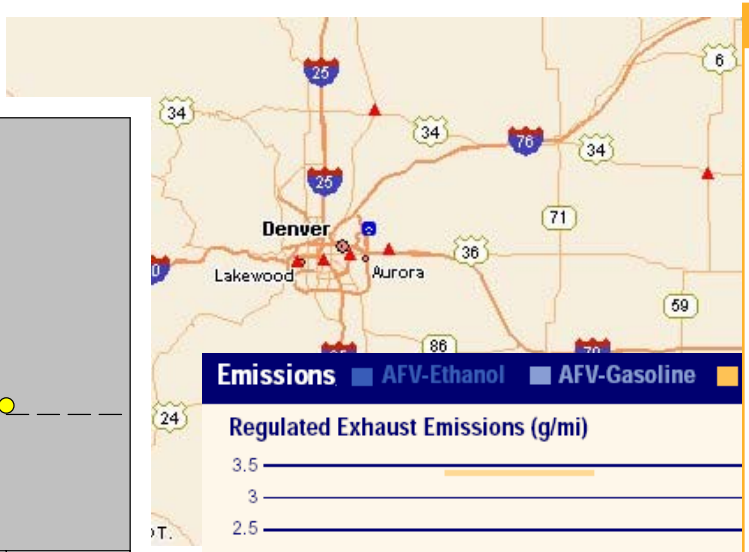
- All automobiles sold in the U.S. are fully compatible
- Shown to reduce CO and overall toxics emissions-carbonyls may increase
- Main issue is increased fuel vapor pressure and evaporative emissions-may be largely solved by vehicle technology

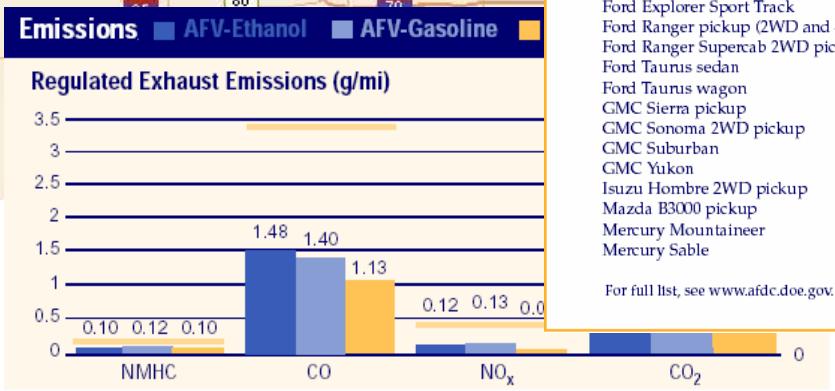


Alternative SI Fuel: E85

- Flexible Fuel Vehicles (FFV's) run on gasoline or blends with ethanol up to 85% - 3 million FFV's have been sold in the US
- Widely available and include sedans, minivans, SUVs, and pickup trucks
- Many consumers are unaware they own FFV's
- Larger energy security and emissions benefits relative to E10
- Evaporative emissions do not increase
- Lack of refueling infrastructure and consumer knowledge may limit use of E85







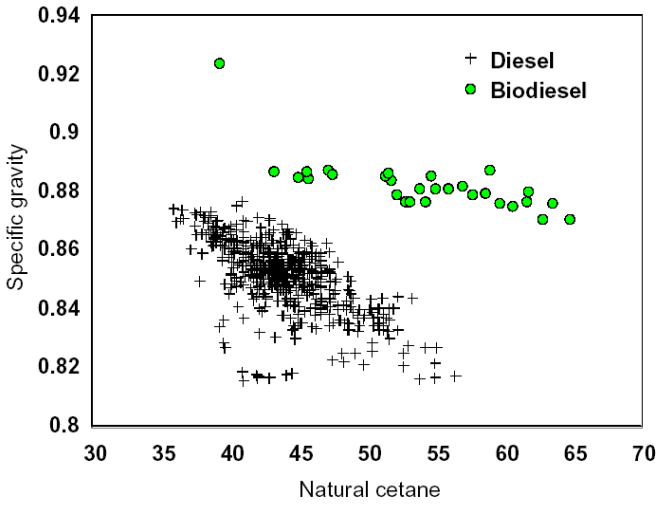
Partial List of Vehicles Capable of E85 Fueling

Make & model	Engine
Chevrolet S10 2WD pickup	2.2L
Chevrolet Silverado pickup	5.3L
Chevrolet Suburban	5.3L
Chevrolet Tahoe	5.3L
Chrysler Sebring sedan and convertible	2.7L
Chrysler Town and Country	3.3L
Chrysler (formerly Plymouth) Voyager	3.3L
Dodge Caravan	3.3L
Dodge Cargo minivan	3.3L
Dodge Grand Caravan	3.3L
Dodge Stratus	2.7L
Ford Explorer (4 door)	4.0L
Ford Explorer Sport	4.0L
Ford Explorer Sport Track	4.0L
Ford Ranger pickup (2WD and 4WD)	3.0L
Ford Ranger Supercab 2WD pickup	3.0L
Ford Taurus sedan	3.0L
Ford Taurus wagon	3.0L
GMC Sierra pickup	5.3L
GMC Sonoma 2WD pickup	2.2L
GMC Suburban	5.3L
GMC Yukon	5.3L
Isuzu Hombre 2WD pickup	2.2L
Mazda B3000 pickup	3.0L
Mercury Mountaineer	4.0L
Mercury Sable	3.0L

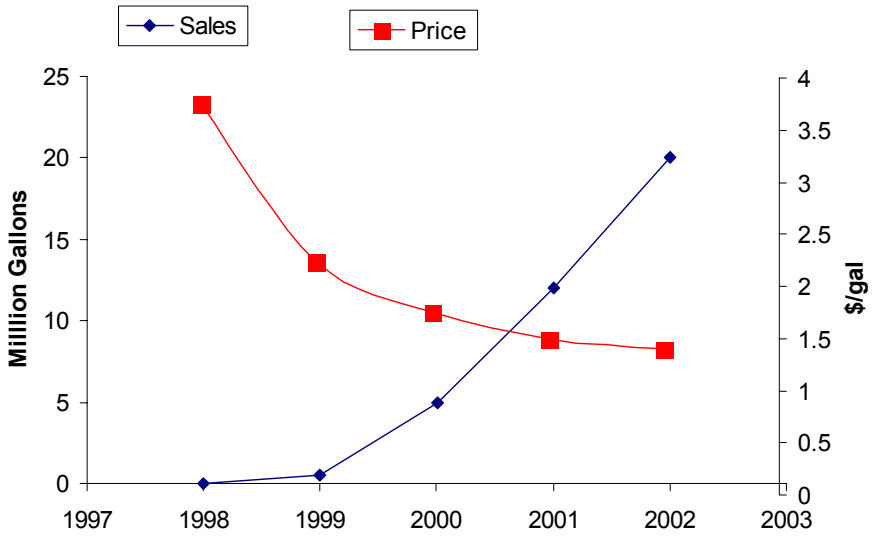
For full list, see www.afdc.doe.gov.

Renewable Diesel: Biodiesel

- Methyl esters of fatty acids, produced from a variety of waste and agricultural feedstocks
- Key properties:
  - CN=45-65
  - S<1ppm (soy) but can be as high as 30 ppm (waste grease)
  - Energy content 10% lower than conventional diesel
- Legal to sell for both on and off-road use, a commercial fuel:
  - ASTM standard finalized in January, 2002 (D6751)
  - EPA fuel registration requirements met (CCA 211b) by National Biodiesel Board

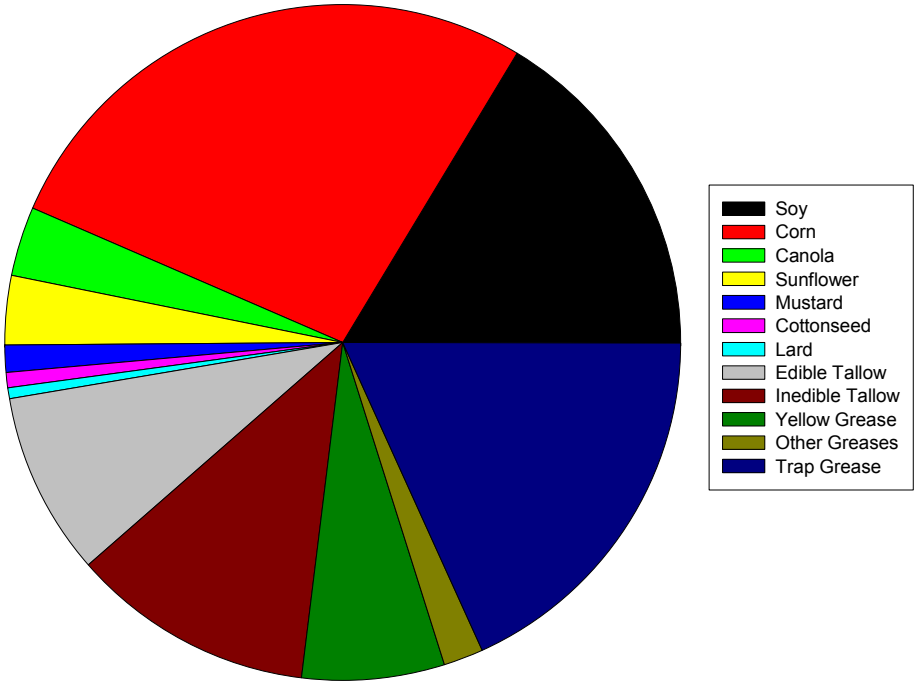


Biodiesel Supply and Production Potential



- Current production capacity ~150 million gal/yr
- ~20 million gal in sales for 2002

Resource size roughly 2 billion gal:



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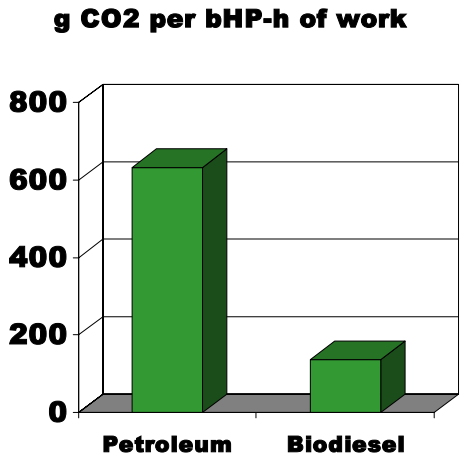
Biodiesel Strategies & Regulatory Status

- 20% (B20) blends initially pursued as economic compromise
- May shift to 5% blends because of OEM concerns
- 20% blends for EPAct fleets
- Energy security and environmental benefits proportional to total volume used, not blend level
- ASTM standard finalized in January, 2002
- EPA fuel registration requirements met (CCA 211b)
- Fossil Energy Ratio = *Fuel Energy/Fossil Energy Inputs* = 3.3

ASTM D6751

TABLE 1 Detailed Requirements for Biodiesel (B100)[A]

Property	Test Method[B]	Limits	Units
Flash point (closed cup)	D 93	130.0 min	°C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity, 40°C	D 445	1.9–6.0[C]	mm^2/s
Sulfated ash	D 874	0.020 max	% mass
Sulfur[D]	D 5453	0.05 max	% mass
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min	
Cloud point	D 2500	Report[E]	°C
Carbon residue[F]	D 4530	0.050 max	% mass
Acid number	D 664	0.80 max	mg KOH/g
Free glycerin	D 6584	0.020	% mass
Total glycerin	D 6584	0.240	% mass
Phosphorus content	D 4951	0.001 max	% mass
Distillation temperature, Atmospheric equivalent temperature, 90 % recovered	D 1160	360 max	°C

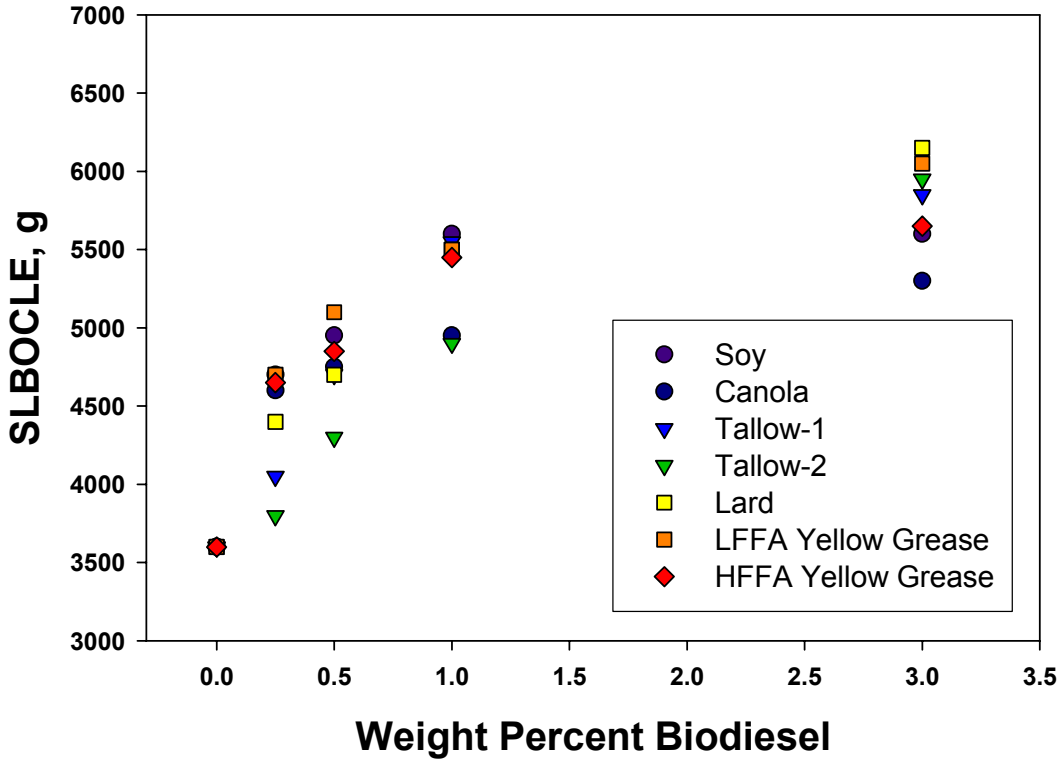


Analysis from NREL/TP-580-24772, May 1998

Biodiesel Effect on Lubricity

ASTM is currently considering a lubricity standard for diesel fuel

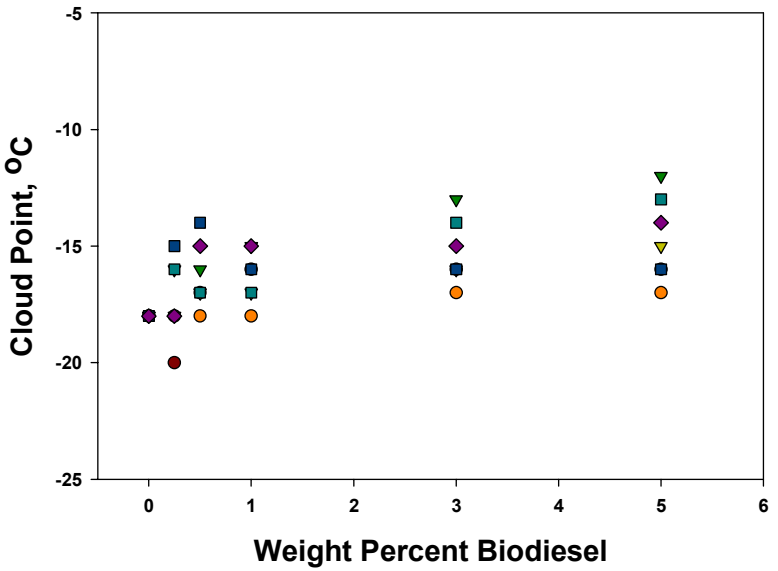
- Minimum SLBOCLE of 3100 g proposed
- 0.5wt% biodiesel can increase SLBOCLE by roughly 1000 g
- Thus low biodiesel blends may reduce engine wear

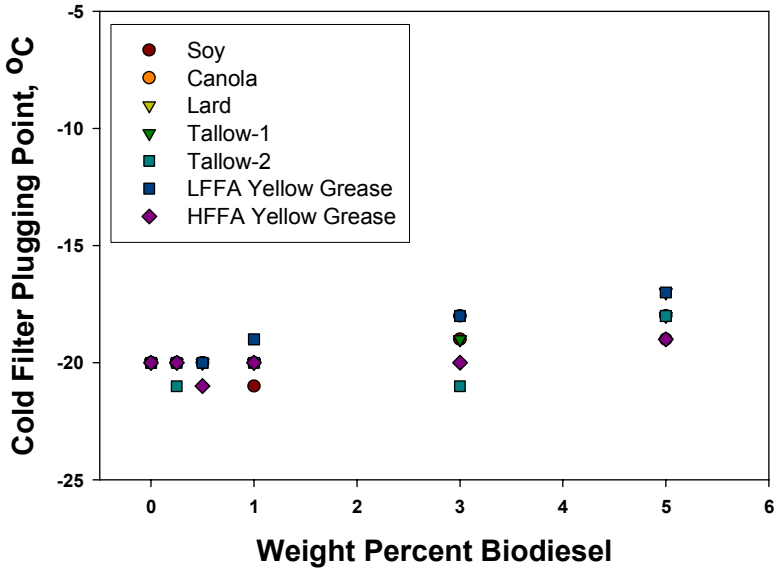


Data from NREL/SR-510-31460, April 2003

Low Biodiesel Blends and Cold Flow

- Pure biodiesel begin to freeze at inconvenient temperatures-above 32°F
- But when blended, impact on cold flow is small below 5%
- For 20% blends cold flow is easily managed by blending No. 1 or additives-identical strategies used for conventional diesel





Data from NREL/SR-510-31460, April 2003

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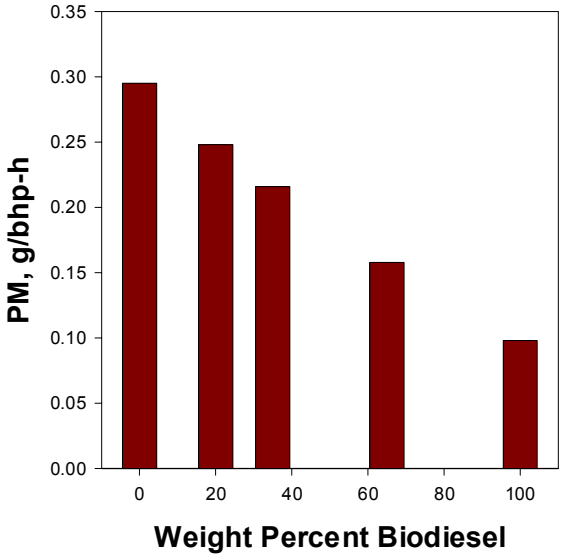
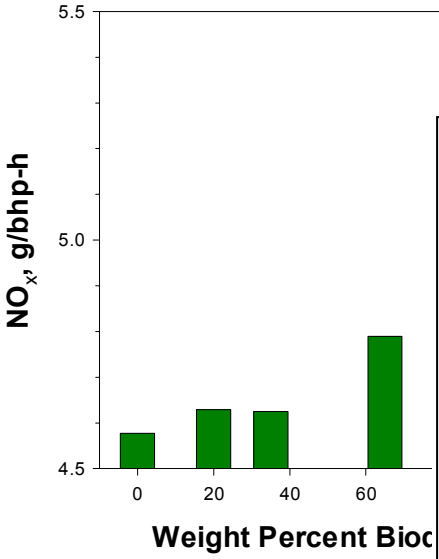
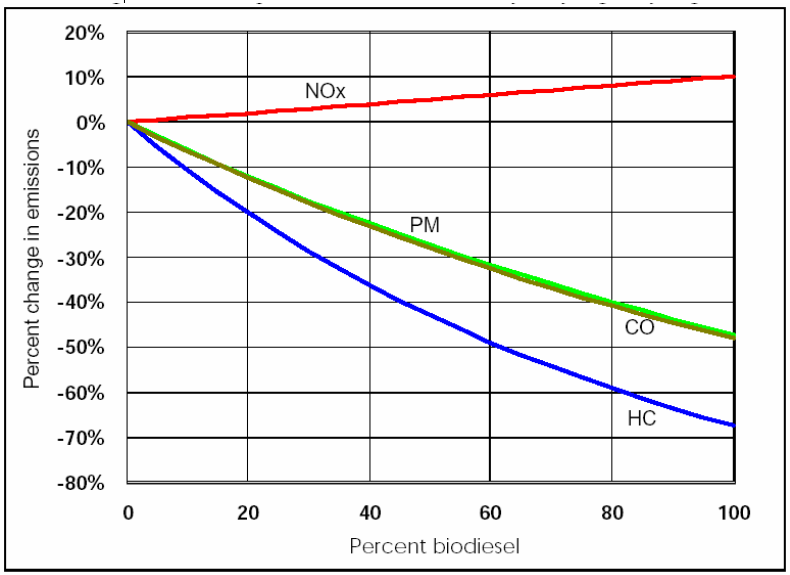
Biodiesel Emissions

- PM reduction
- NO_x increase, 2-4% for B20, insignificant for B5
  - May be reduced with cetane improving additives
- HC and CO emissions also lower





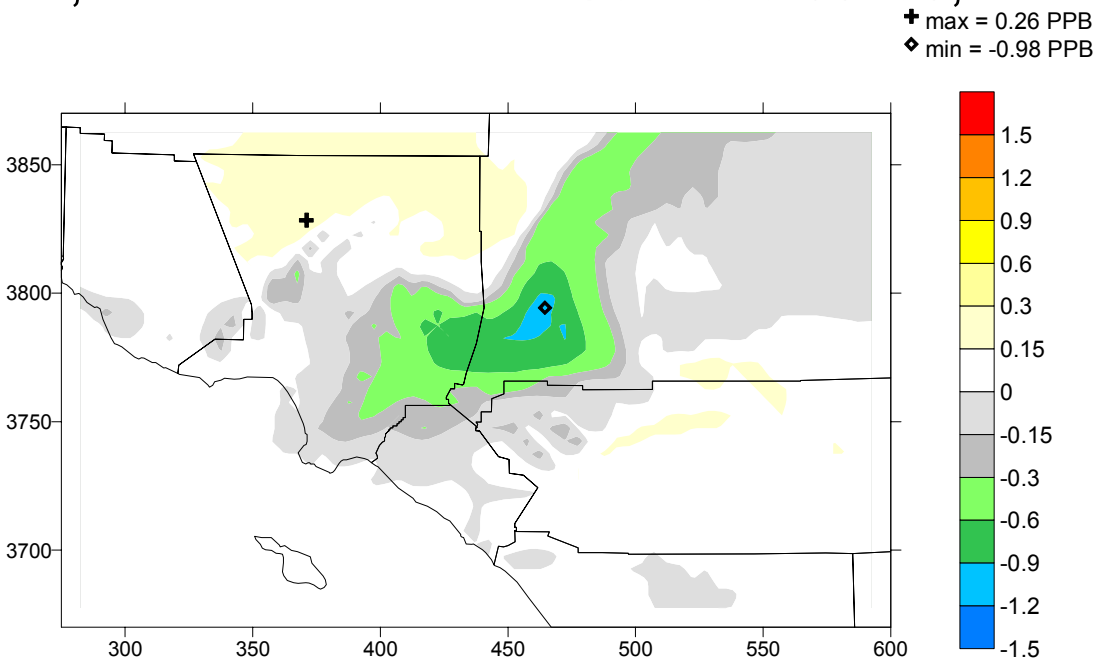
Data from SAE 2002-02-1658



Data from EPA420-P-02-001

Does NO_x Matter? Air Quality Modeling

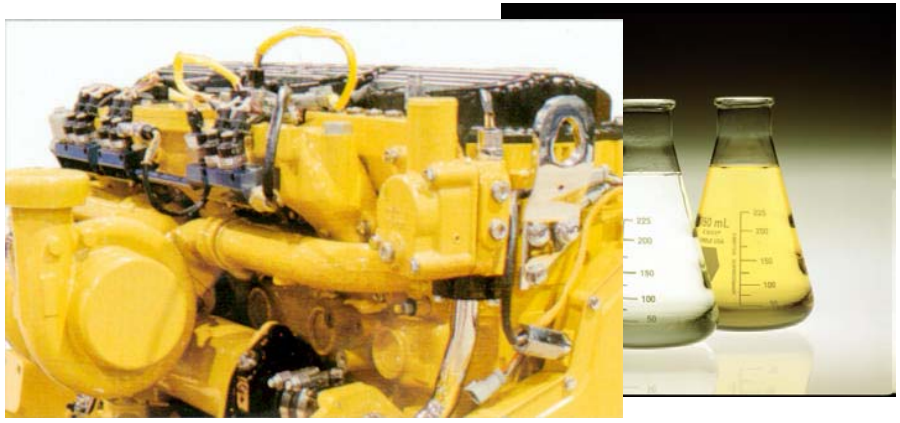
- Impact of 100% market penetration of B20 on air quality in Chicago area, Northeast Corridor, and South Coast Air Basin.
- NO_x from B20 use has no negative air quality impact (changes in ozone less than 1 ppb).
- PM emission reduction has no positive impact.
- Study performed by Environ, for details see NREL/SR-540-33793, April 2003



Difference in Daily Max 1-Hour Ozone (ppb)
August 07, 1997
NREL Biodiesel -- 100% Penetration B20 Biodiesel minus Base

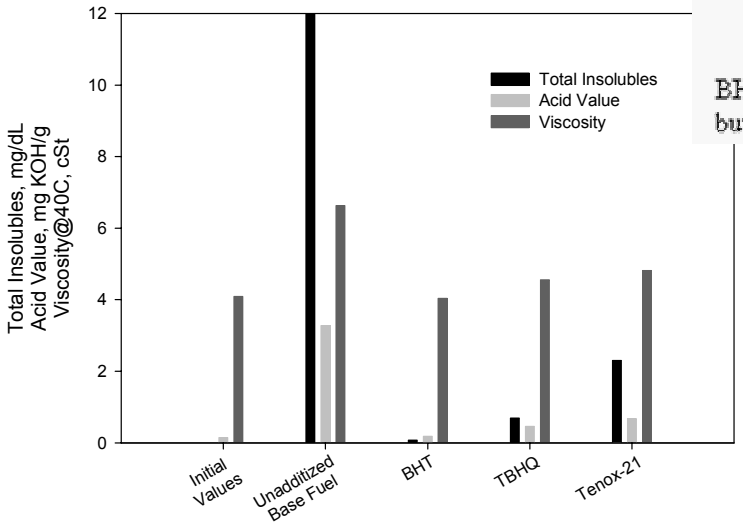
Biodiesel Technical Barriers& Issues

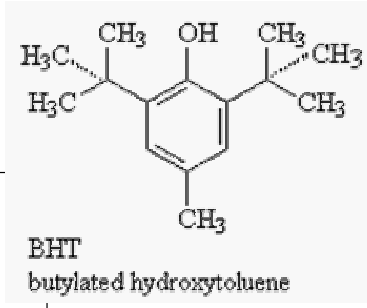
- Engine and fuel injection equipment manufacturers have concerns:
  - Oxidative and thermal stability-deposit formation
  - Residual process chemicals can form deposits.
  - Compatibility with fuel system elastomers.
  - Solvency loosens deposits causing filter plugging.
- Need for understanding of fuel stability issue and possible modification of fuel quality standard to address stability



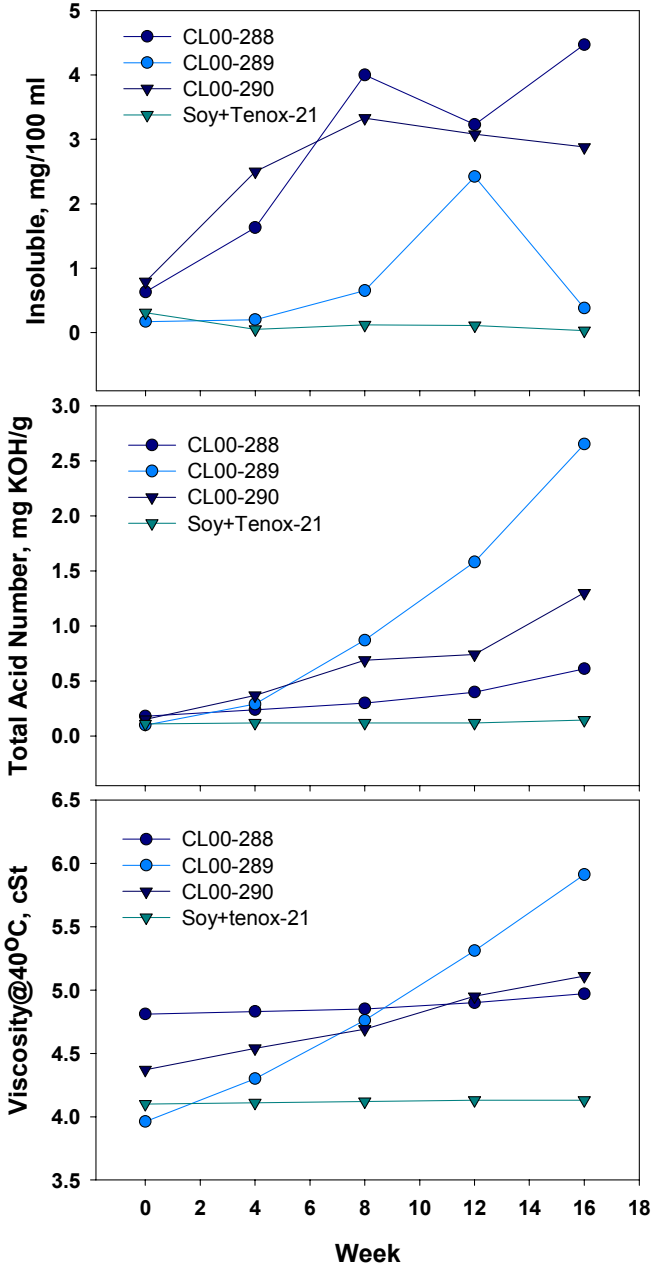
Biodiesel Oxidative Stability

- Long-term tests show that biodiesel is unstable to oxidation
- Anti-oxidants can be effective, some biodiesel contains natural antioxidants





ASTM D4625 Standard Test for Distillate Fuel Storage, 43°C



Concluding Remarks

- Renewable motor fuels can have an impact on U.S. energy security, air pollution, and global warming gas emissions
- Some technical issues remain for R&D, particularly for biodiesel
- Questions?

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