

E85 and Biodiesel Deployment

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September 18, 2007

NAFA- Rocky Mountain Chapter

Office of Energy Efficiency and Renewable Energy's Vehicle Technologies
Technology Evaluation and Integration Group
Clean Cities Activity

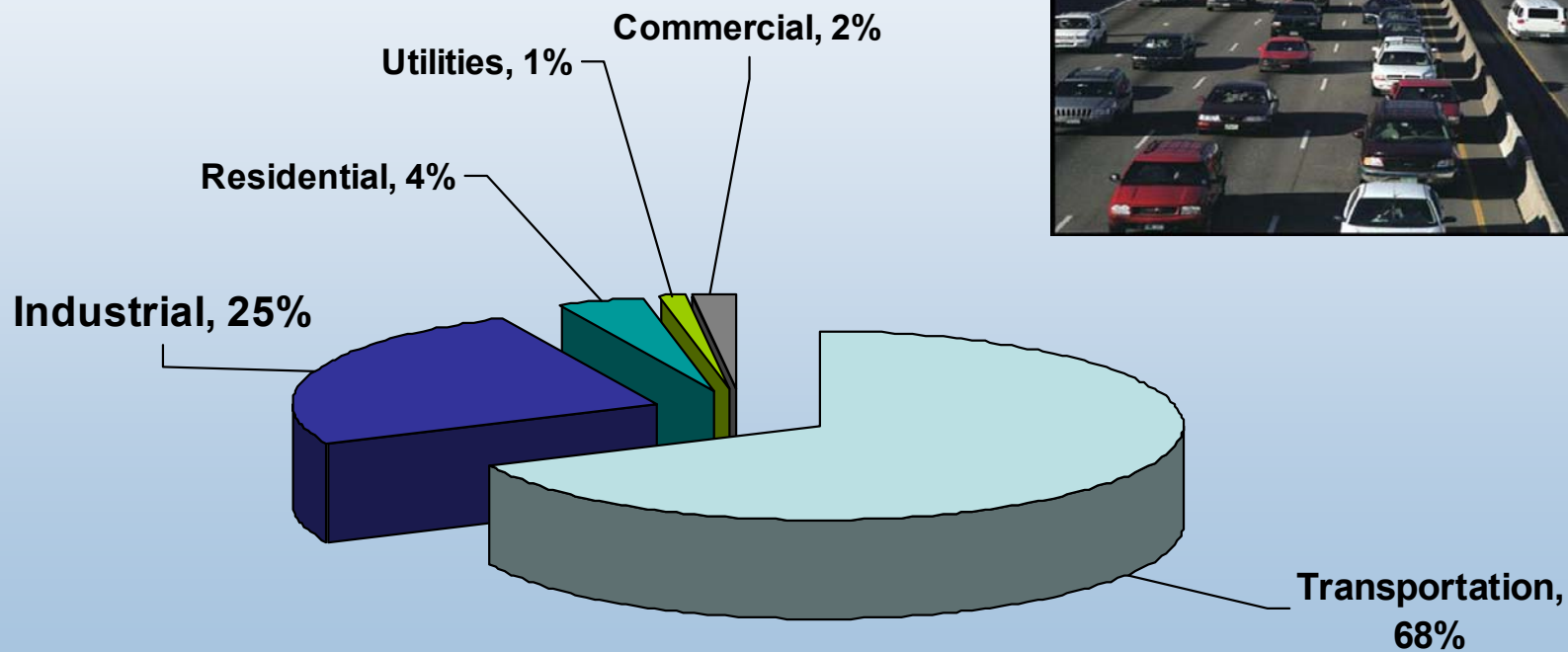
Dennis A. Smith, Clean Cities Director, Department of Energy

Agenda

- Background
- E85
- Biodiesel
- Federal Incentives
- Department of Energy- Clean Cities Organization
- National Renewable Energy Laboratory
- Governor's Biofuels Coalition
- Conclusions

2006 Oil Use

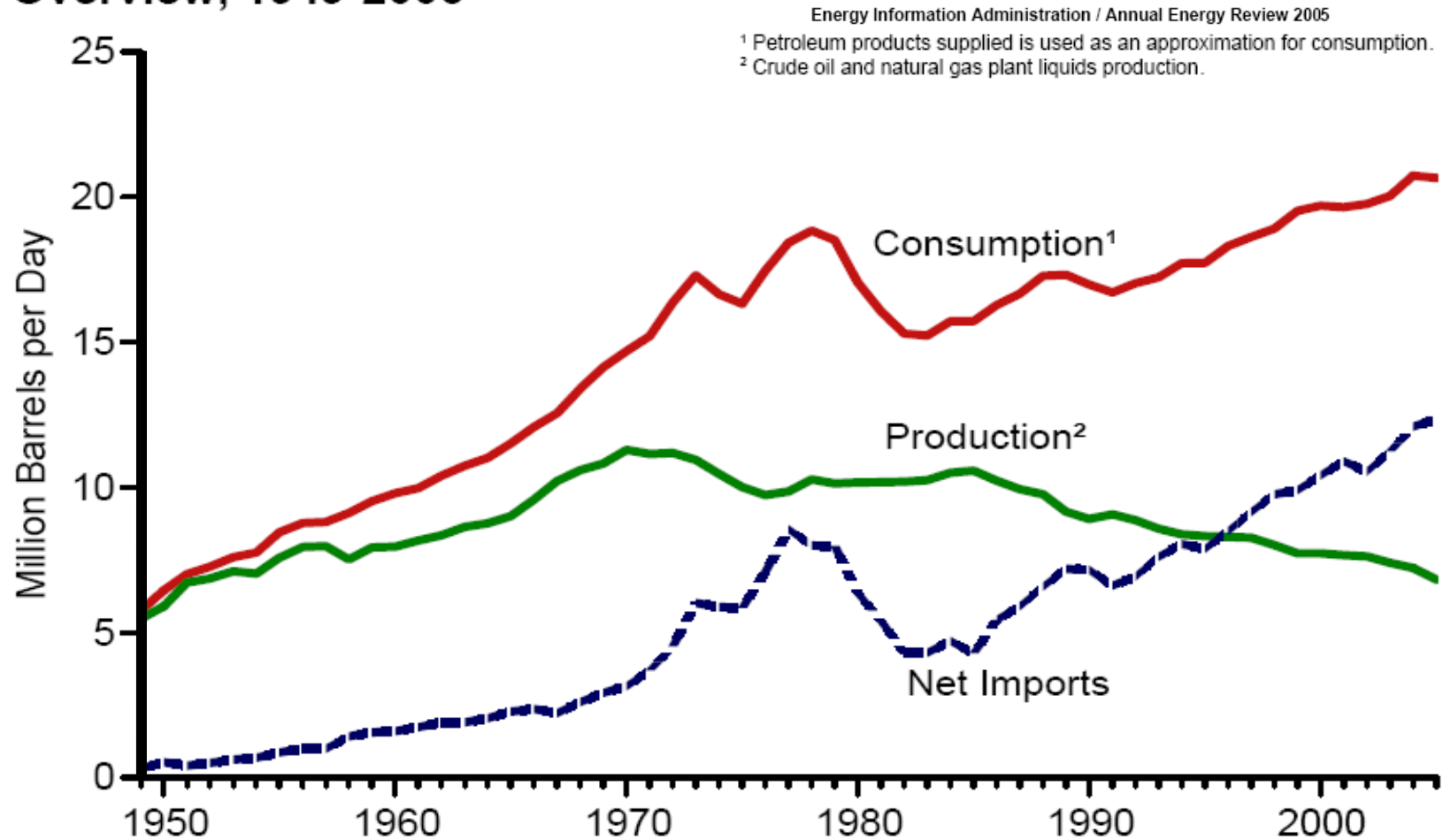
Globally 80 MB/day
Nationally 21 MB/day



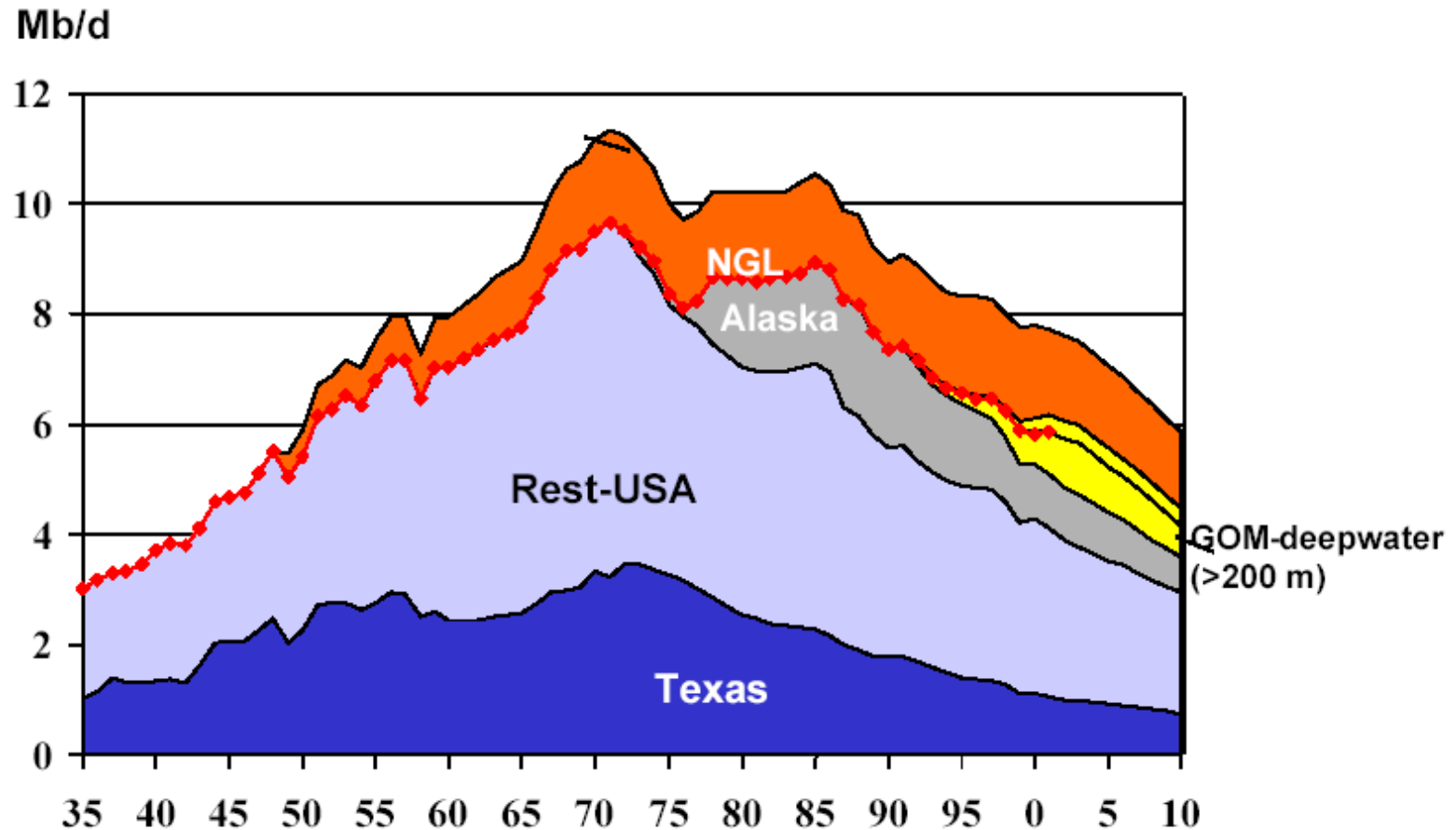
Data Source: EIA Annual Energy Review 2006

U.S. Consumption Grows While Production Declines

Overview, 1949-2005

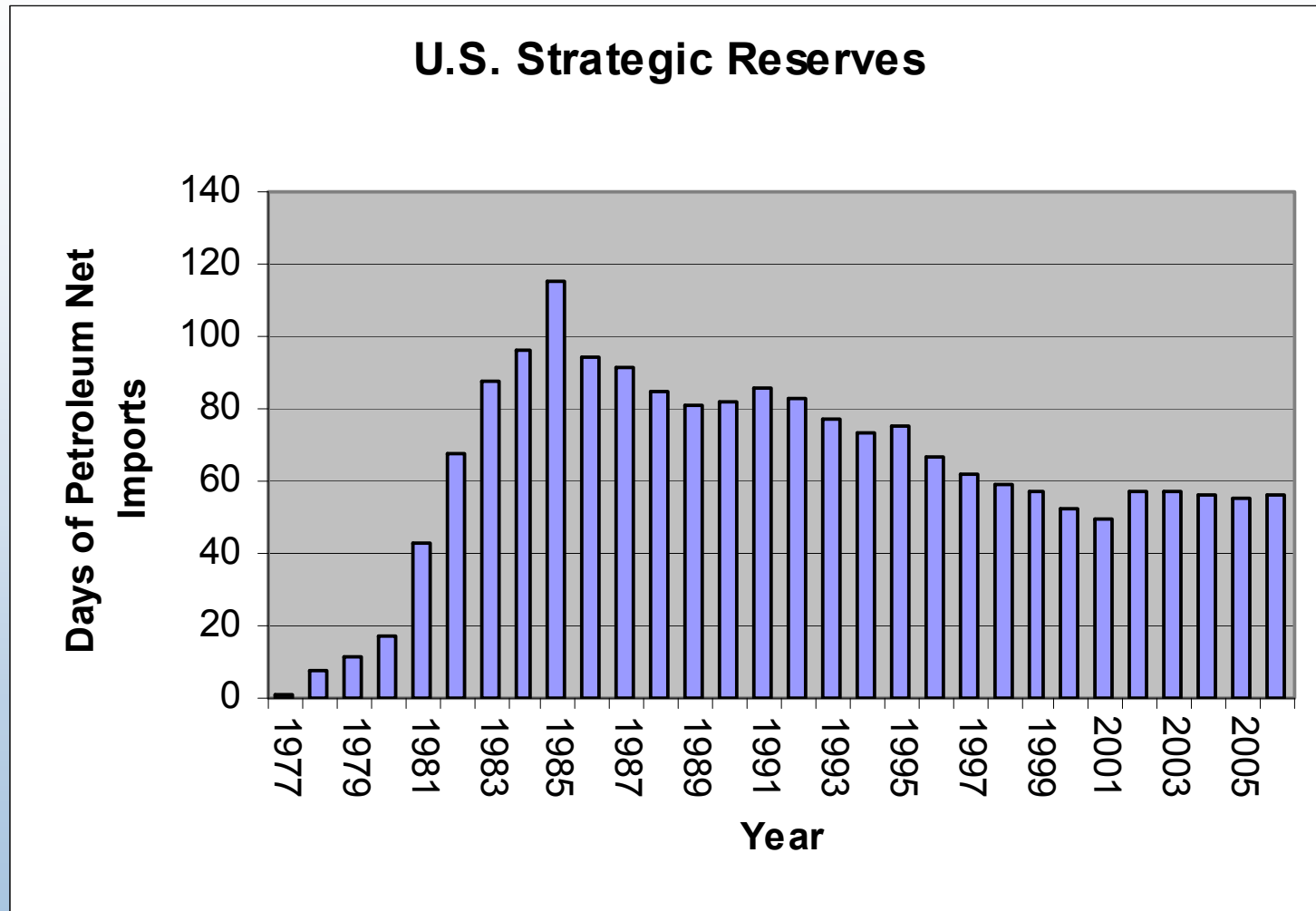


U.S. Oil Production Peaked in Mid-70's



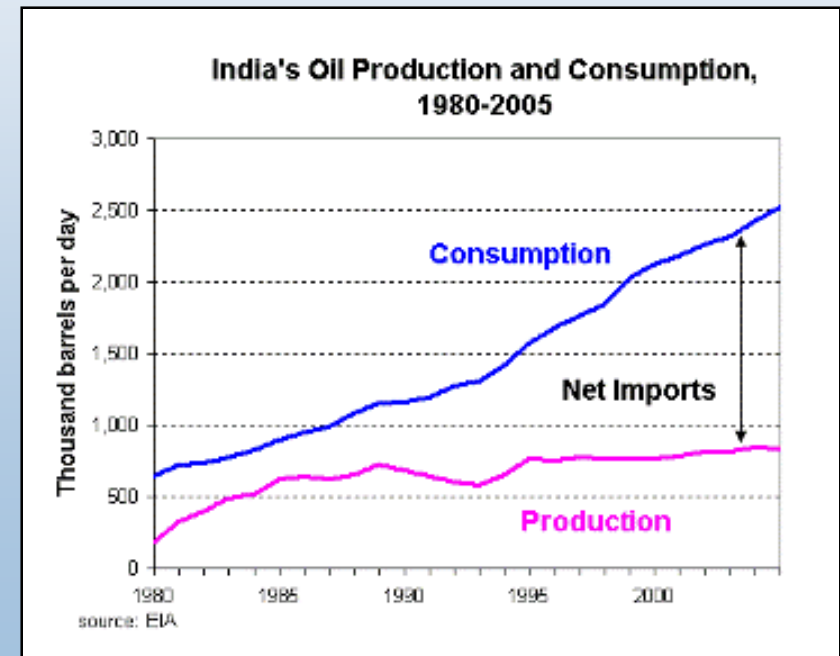
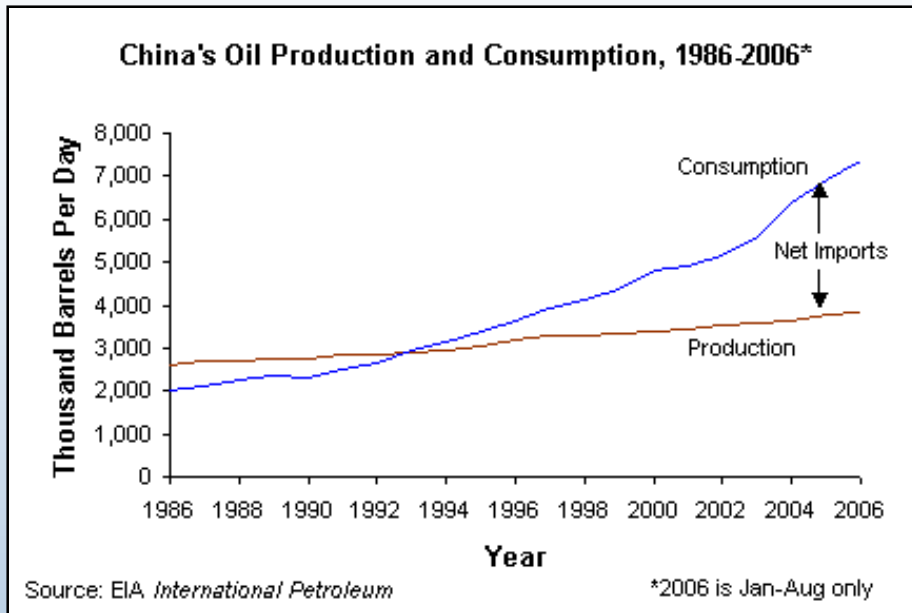
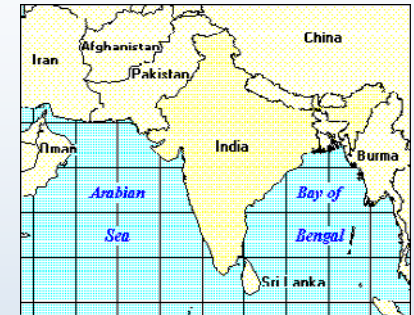
Source: Texas Railroad Commission, US Energy Information Administration

Strategic Petroleum Reserve



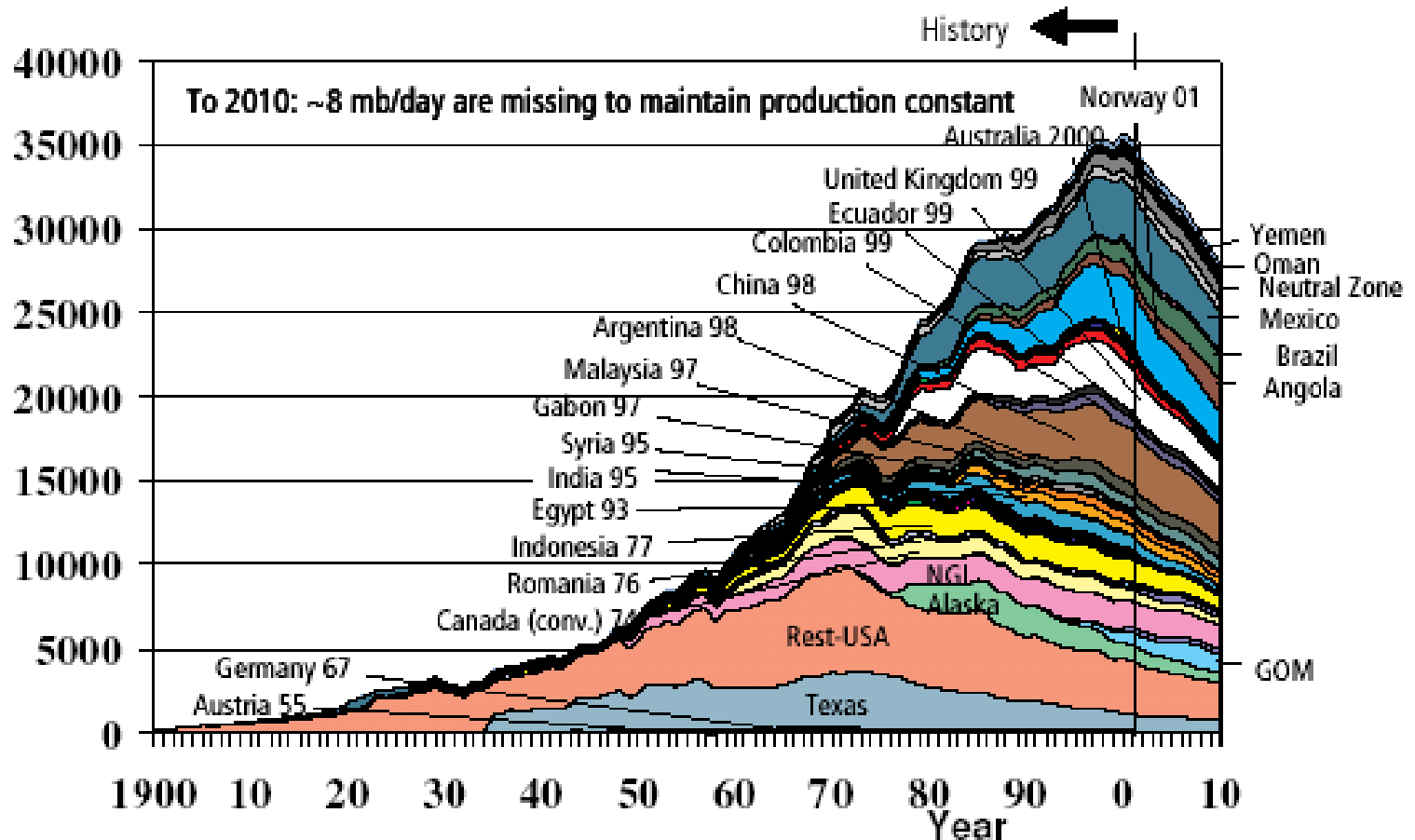
Sources: **Imported by SPR** and **End-of-Year Stocks, Quantity:** 1977-1980 Energy Information Administration (EIA), Energy Data Report, *Petroleum Statement, Annual*, annual reports. 1981-2005 EIA, *Petroleum Supply Annual*, annual reports. 2006 EIA, *Petroleum Supply Monthly* (February 2007). **Imported by Others, Domestic Crude Oil Receipts,** and **Withdrawals:** U.S. Department of Energy, Assistant Secretary for Fossil Energy, unpublished data.

Significant World Growth



Peak Oil Production

1000 Barrel per day



Source: Industry data base, 2003; Analysis: LBST

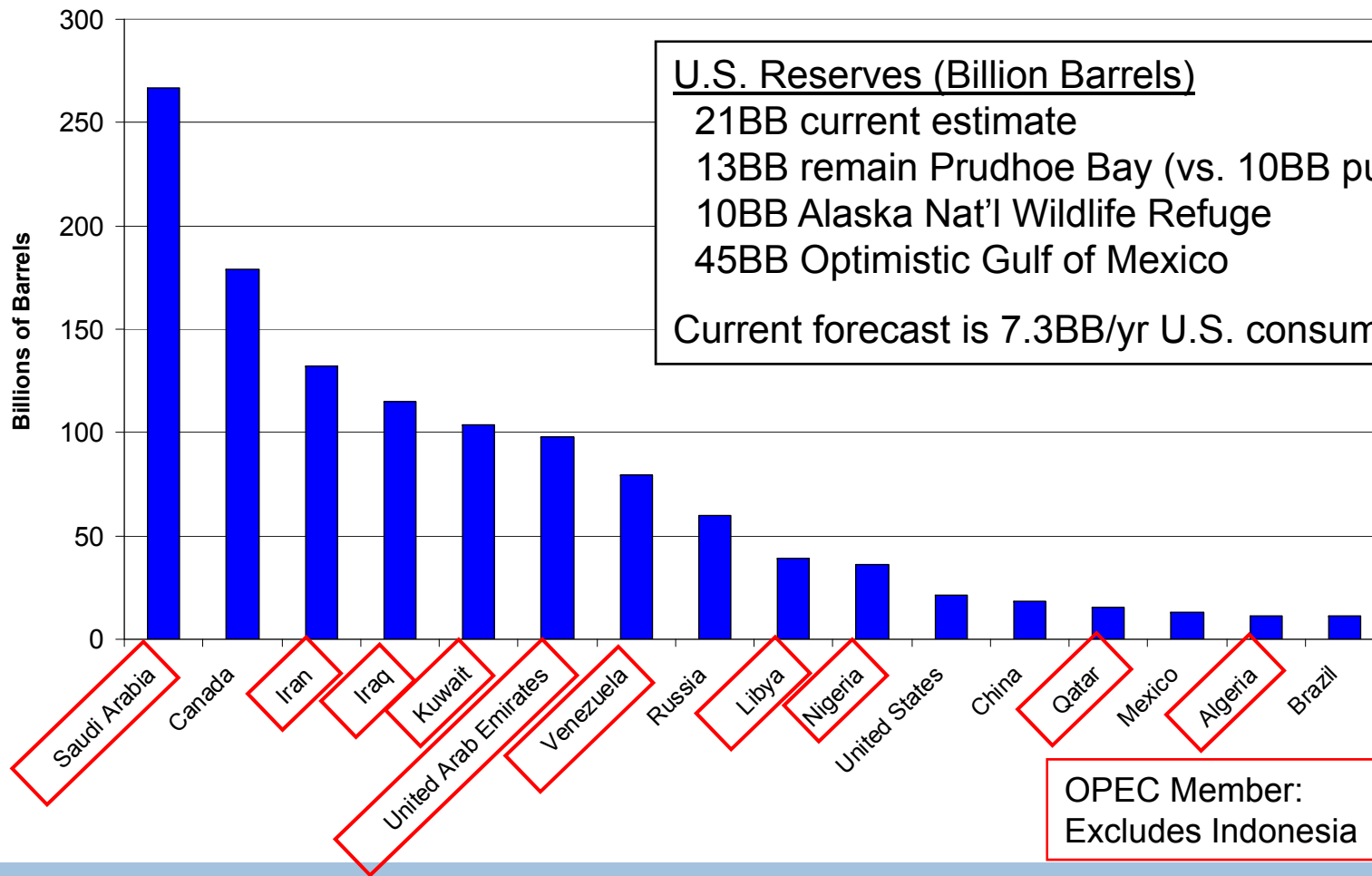
World excl. OPEC, former Soviet Union and non-conventional Canadian oil (tar sands). (Peak years for each country are shown.); The peak 35 million barrels per day is 42% of world production. SOURCE: Salzburg 2003 Summer School

NGL = Natural Gas Liquids including ethane, propane, butane, and sulfur, are derivatives of natural gas, extracted during gas refining.

Proven Reserves, 2006

World Total ~1.3 Trillion Barrels

Energy Information Administration / Annual Energy Review 2005



Ethanol Deployment

Ethanol and Ethanol Blends

- Alcohol-based fuel produced from starch crops or cellulosic biomass such as trees and grasses:
 - Currently, corn is primary feedstock
 - Cellulosic feedstock in development
- High octane (100+):
 - Used to enhance octane of gasoline (E10)
 - As oxygenate in the winter to reduce CO emissions during combustion (E10)
- As an alternative fuel, most commonly used in a summer blend of approximately 85% ethanol and 15% gasoline (E85). Winter blends may be as low as 70% ethanol.
- E85 has 27-36% less energy content than gasoline so mileage is adversely affected. OEM's estimate 15-30% decrease in mileage.



Flex Fuel Vehicles (FFVs)

- Flex fuel vehicles use E85, unleaded gasoline or any combination of the two. Conventional vehicles are not certified for use with E85
- Key component differences in a flex fuel vehicle are:
 - Higher volume fuel pump, larger diameter injectors, different materials in the fuel system, heads, valves, and piston rings, and different ECM calibration
- If E85 is used in a non- flex fuel vehicle the driver will experience very poor acceleration, a substantial increase in maintenance costs, eventually component failure
- FFVs are available in light duty vehicles including cars, vans, ½ ton pickups, and SUV's. There are an estimated 6 million FFVs on the road in the U.S.

For more information: <http://www.eere.energy.gov/afdc/pdfs/41597.pdf>

Flex Fuel Vehicle Components

Engine calibration updates: Fueling and spark advance calibrations directed by vehicle computer and software to optimize combustion, enable cold start, and meet emissions requirements

Insulated wiring: Made from special materials to handle ethanol's increased conductivity and corrosiveness

Fuel pump assembly: In-tank components made from ethanol-compatible materials; larger capacity fuel pump to deliver more fuel to compensate for ethanol's lower energy density

Piston rings: Special materials used to minimize wear from ethanol's alcohol properties, which wash lubrication from parts

Cylinder heads, valve seats, and valves: Special materials used to minimize wear from ethanol's alcohol properties, which wash lubrication from parts

Fuel sensor: Automatically senses the composition of fuel to adjust for ethanol blends

Fuel injectors: Made from ethanol-compatible materials; designed to deliver greater fuel volume required by ethanol's lower energy density

Fuel rail and fuel lines: Made from ethanol-compatible materials; designed to handle increased fuel volume requirements to compensate for ethanol's lower energy density

Fuel filler neck: Anti-siphon and spark arrestor features included to meet U.S. regulations

Fuel tank: Composed of special materials to minimize evaporative emissions from ethanol



FFV Conversions

- FFV conversions are considered “Aftermarket Conversion Systems”, not just “Devices” and therefore are required to obtain a Certificate of Conformity
 - The same emission certification required of a new vehicle
- Currently no converted vehicles are approved by the EPA.
 - To date none have obtained a Certificate of Conformity. Two are in the approval process.

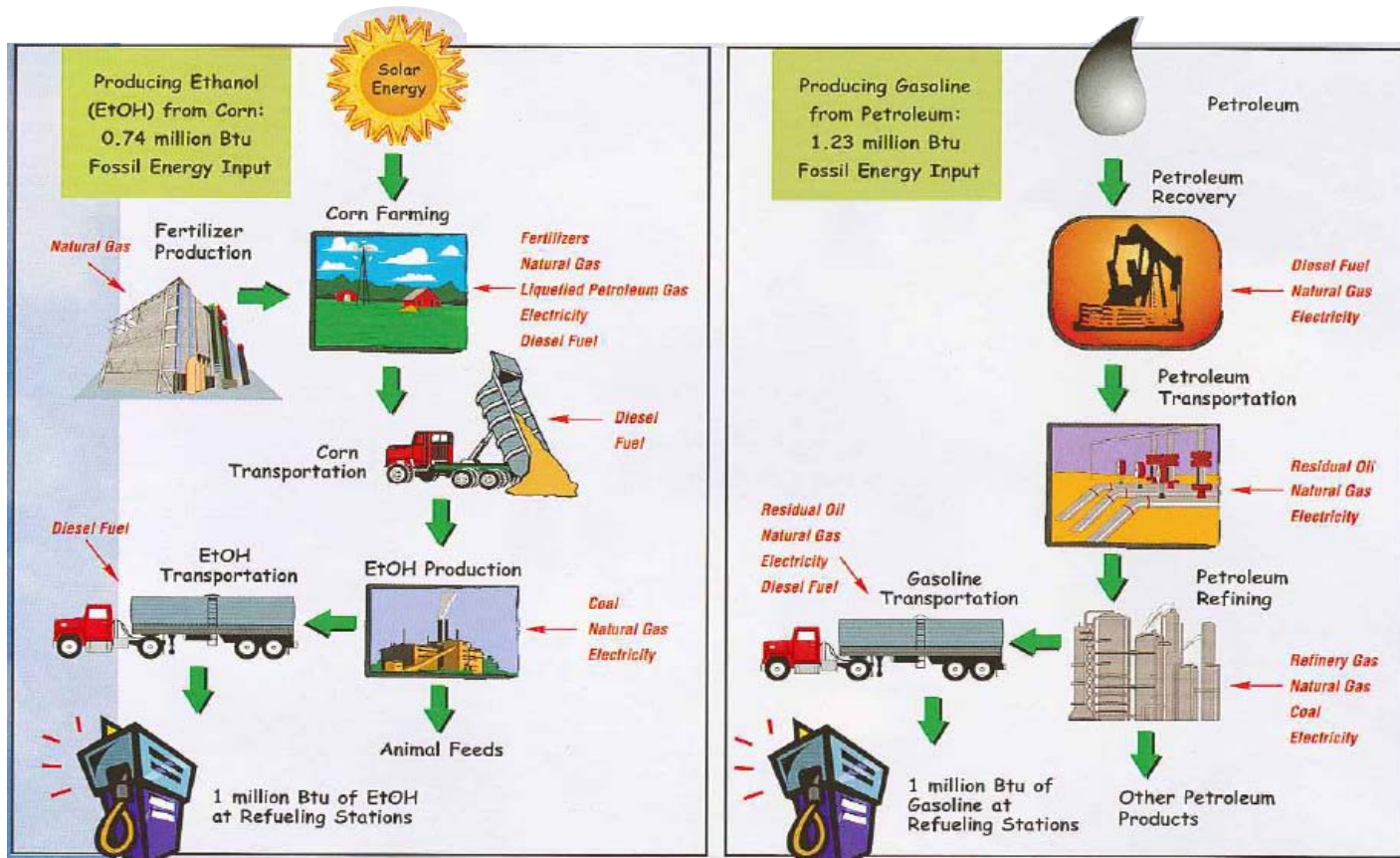
For more information on the approval process:

http://www.eere.energy.gov/afdc/resources/technology_bulletin_0807.html

Points to Consider for E85

- Decreased mileage and range when using E85
- High level of fuel pricing volatility until demand and supply balance
 - Needs to cost 20%-30% less to make economic sense
- Refueling infrastructure not in place in all geographies. Currently there are approximately 1200 stations in the U.S. offering E85.
- Colorado currently has 30 stations with over 50 projected by end of 2007.
- Controversy in press over life cycle energy balance and greenhouse gas emissions
- Limited tailpipe emission data.

Life Cycle Energy Balance



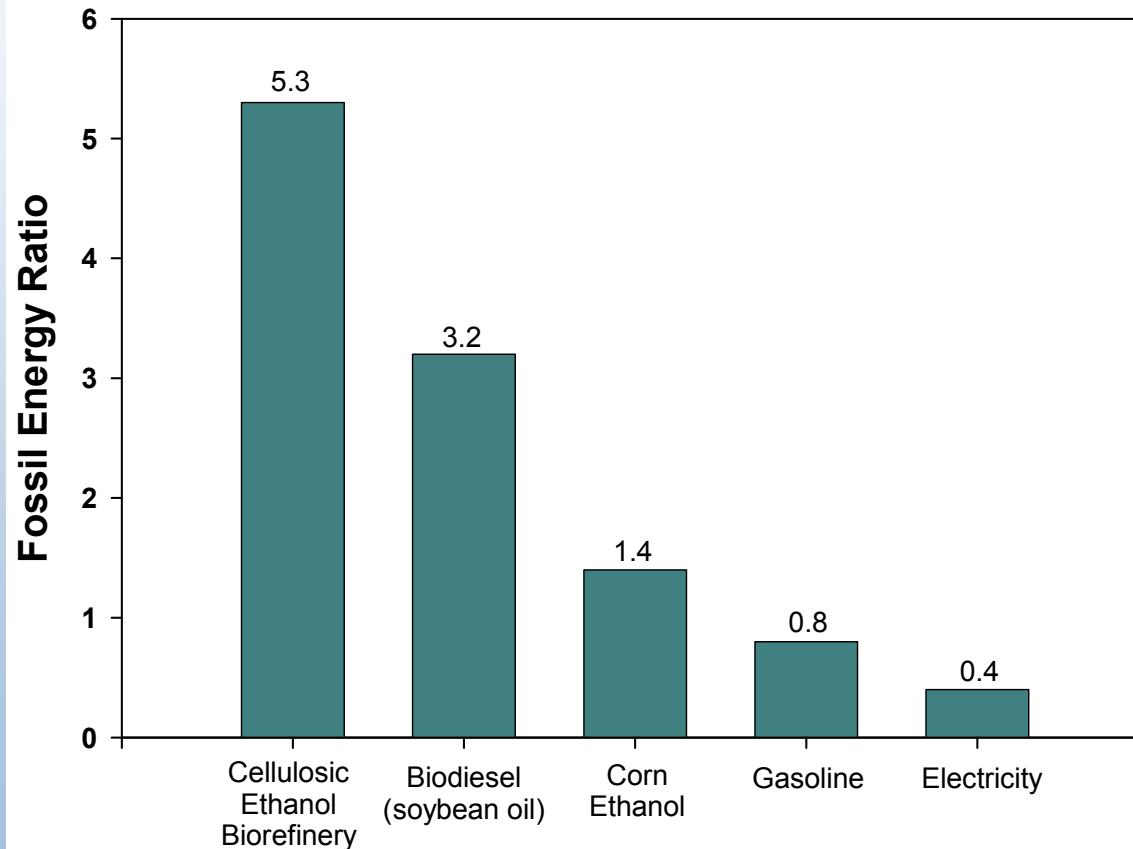
*Argonne National Laboratory, "Ethanol, The Complete Energy Lifecycle Picture", March 2007

For complete brochure:

http://www.eere.energy.gov/vehiclesandfuels/pdfs/program/ethanol_brochure_color.pdf

Fossil Energy Ratio

$$\text{Fossil Energy Ratio (FER)} = \frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$$



Biodiesel data from: "An Overview of Biodiesel and Petroleum Diesel Life Cycles", J. Sheehan, et al. (1998).
Additional source: J. Sheehan & M. Wang (2003)

E85 Emissions

Greenhouse Gas (GHG) Impact*

Replacing a gallon of gasoline with equivalent EtOH

- Corn EtOH using coal as the energy source- approx. 2% increase in GHG's
- Corn EtOH using current energy sources- approx. 15% decrease in GHG's
- Corn EtOH using Natural Gas- approx. 28% decrease in GHG's
- Cellulosic EtOH- approx. 85% decrease in GHG's

*Argonne National Laboratory, "Ethanol, The Complete Energy Lifecycle Picture", March 2007

Flexible Fuel Vehicle Emissions

- Limited data on recent model year vehicles
- Available data currently being reviewed by NREL
- Further testing being completed by NREL, EPA and CRC
- Past data shows for operation on E85:
 - GHG- reduced CO₂ emissions and increased CH₄ emissions
 - Slightly reduced evaporative emissions compared to gasoline
 - Reduced air toxic emissions for benzene and 1,3 butadiene
 - Increased air toxic emissions for acetaldehyde and formaldehyde

NREL E85 Emissions Testing

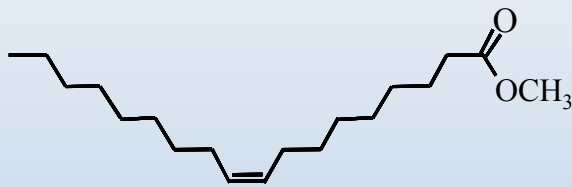
- Testing being performed at Colorado Department of Public Health and Environment mobile source emissions lab as part of Colorado E85 Coalition initiative
 - Winter E85 (~71% ethanol) and winter gasoline (E10)
 - Summer E85 (~85% ethanol) and summer gasoline (E0)
- Using standard EPA testing requirements and protocol
- Using Colorado state fleet vehicles and possibly EPA fleet vehicles (minimum 5 vehicles)
- All testing to be completed Fall 2007
 - Some of the only available data on recent model year FFVs
- Report to be issued 4th Qtr 2007

Biodiesel Deployment

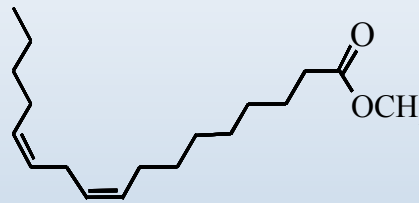
What is biodiesel?

- Mono-alkyl esters of fatty acids (i.e. methyl or ethyl esters)

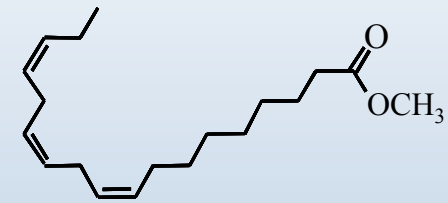
100 lb triglyceride + 10 lb alcohol = 10 lb glycerine (byproduct) + 100 lb mono-alkyl ester
soy oil methanol Biodiesel



Methyl Oleate



Methyl Linoleate



Methyl Linolenate

- Must meet the quality requirements of ASTM D6751
- Typically used as blend with petrodiesel (up to 20%)
- DOE R&D effort focused on use of biodiesel at 20% or lower

Biodiesel Attributes

- High cetane (avg. over 50)
- Ultra low sulfur (avg ~ 2 ppm)
- Blends have similar energy content per gallon
- High lubricity, even in blends as low as 1-2%
- Poorer cold flow properties with high blends
- Renewable
- Reduces HC, PM, CO in pre-2007 diesel engines
- Blends can be used with no engine modification

Biodiesel Warranty Issues

- *Manufacturers warrant their products against defects in materials and workmanship*
- *In general use of a particular fuel should have no effect on the materials and workmanship warranty*
- *Use of biodiesel does not “void the warranty”, this is prohibited by the Magnuson-Moss Warranty Act*
- *Manufacturers are concerned that extensive use of biodiesel will result in increased numbers of warranty claims for what are actually problems caused by the fuel*

Engine and vehicle manufacturers are generally comfortable with blends up to 5%

Lack of experience plus concerns about fuel quality and stability are what is preventing approval of blending levels above 5% for most manufacturers

Why biodiesel?

Biodiesel is truly renewable

$$\text{Fossil Energy Ratio (FER)} = \frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$$

Petroleum diesel uses 1.2 MJ of fossil energy to produce 1 MJ of fuel product energy

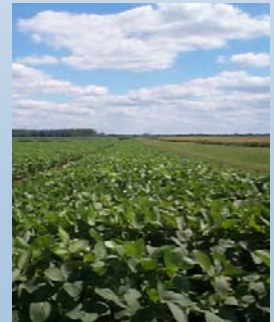
Fossil energy ratio = 0.83

Biodiesel uses 0.31 MJ of fossil energy to produce 1 MJ of fuel product energy

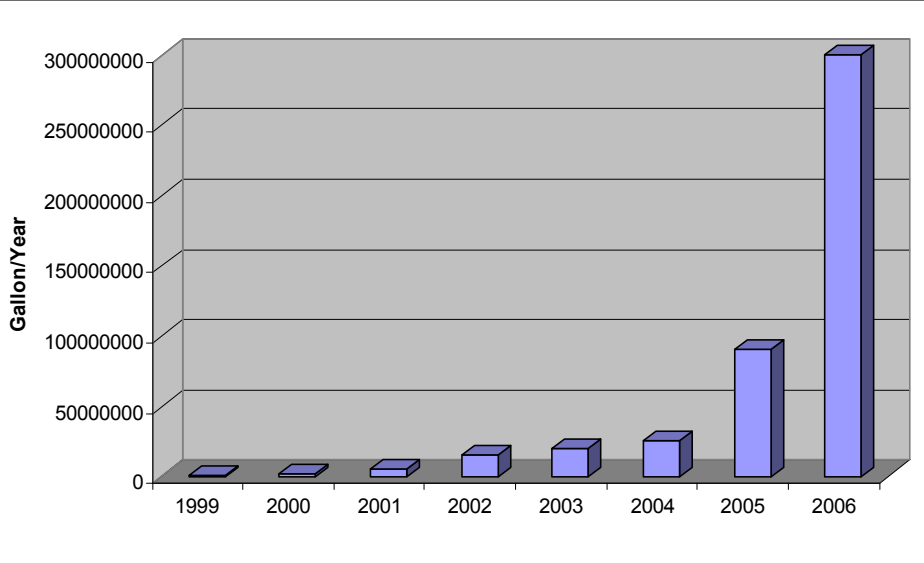
B100 Fossil energy ratio = 3.2

B20 reduces life cycle petroleum consumption by 19%

B20 reduces life cycle CO₂ emissions by 16%

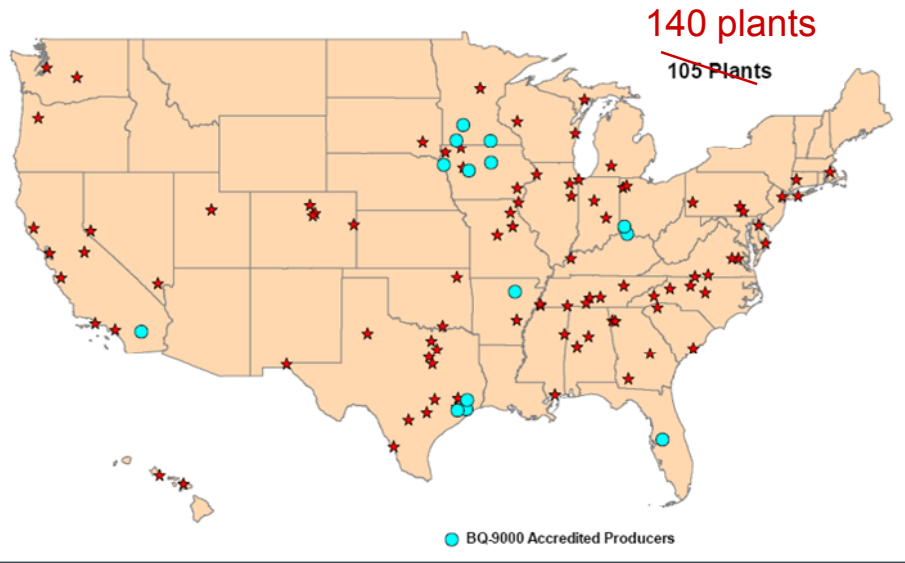


Biodiesel Production

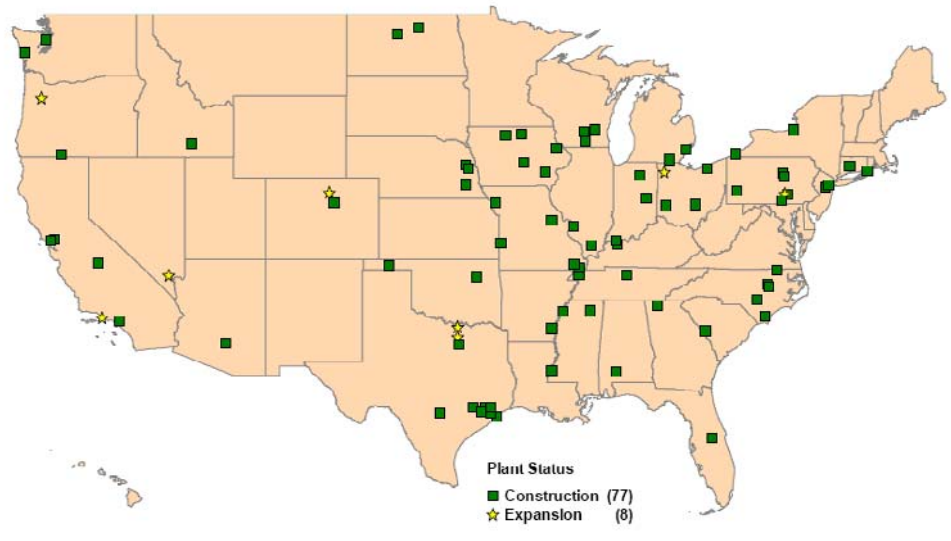


- 400-450 million gallons demand predicted for 2007
- Current production capacity is more than 1.4 billion annual gallons (Sept. 2007)
- Nearly 1.9 billion annual gallon additional capacity under construction or planned (Source: NBB)

Commercial Biodiesel Production Plants (January 31, 2007)

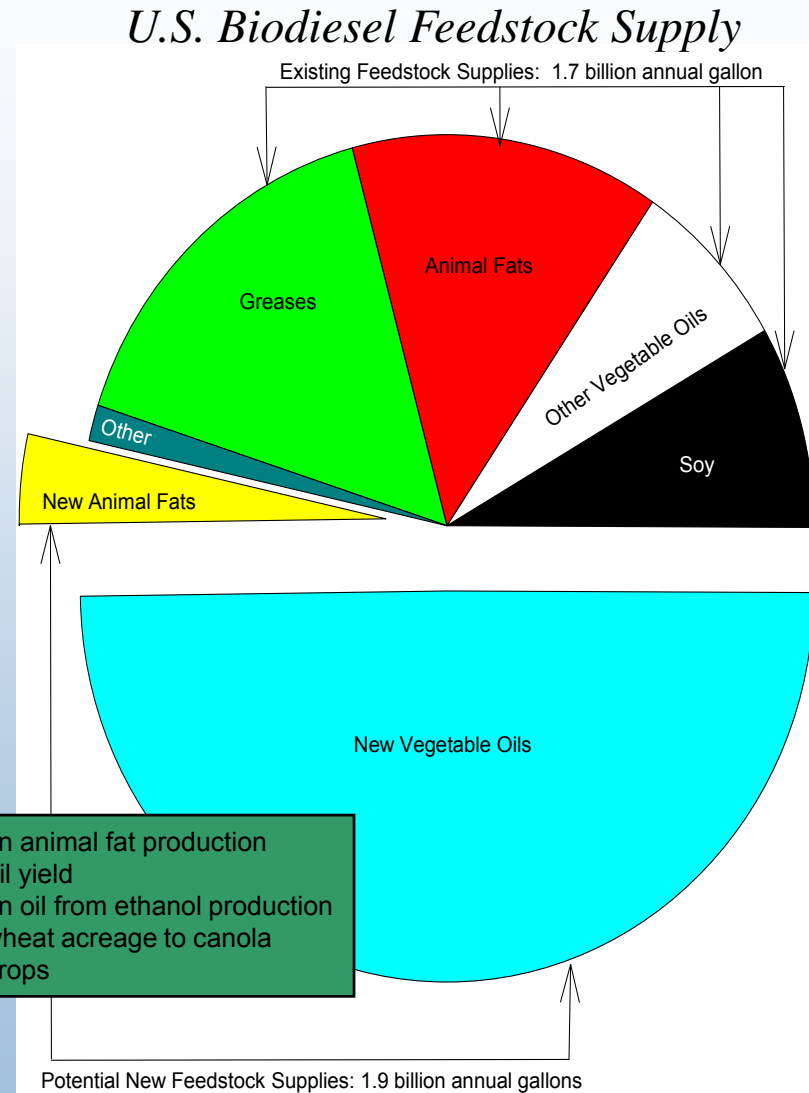


Biodiesel Production Plants Under Construction or Expansion (January 31, 2007)



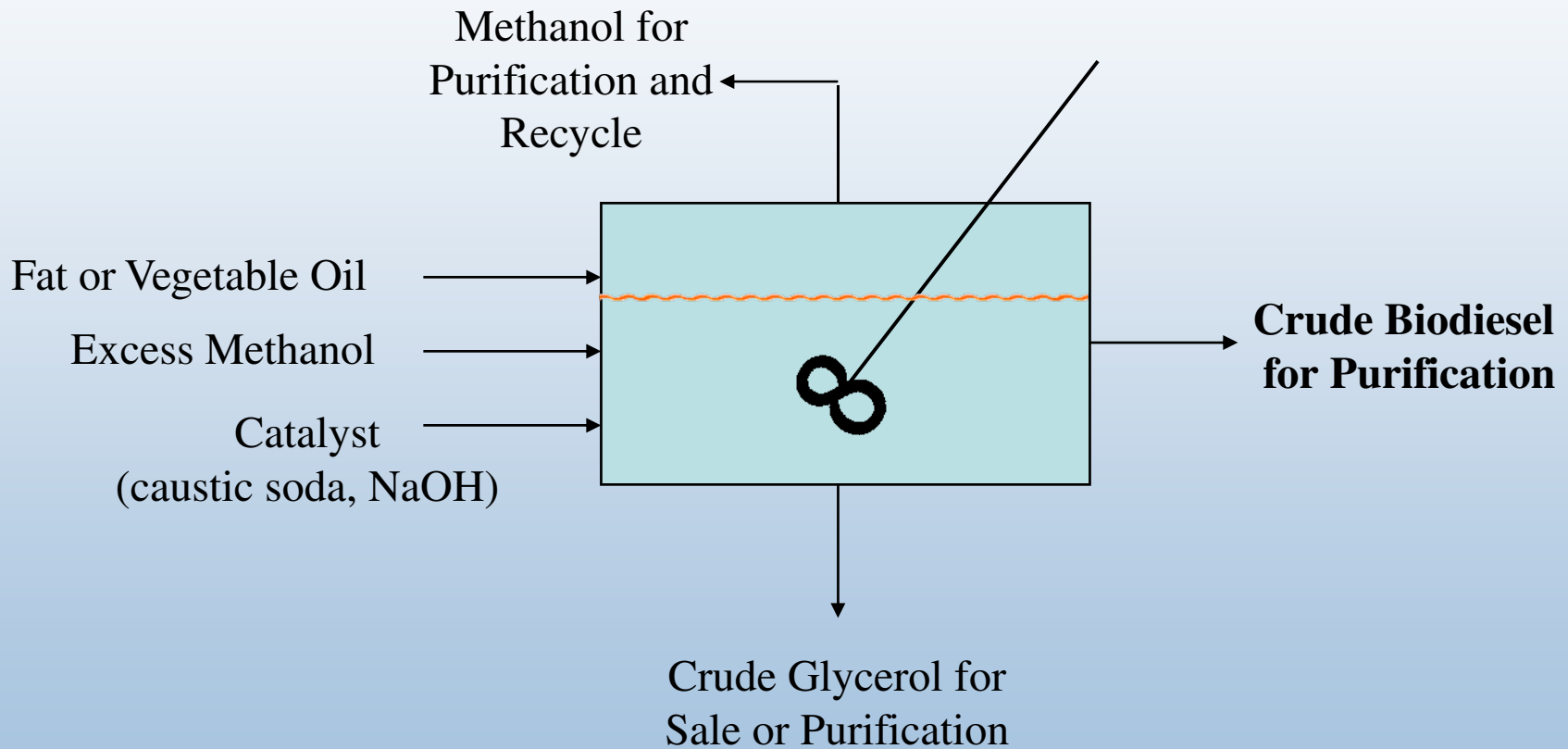
How Much Biodiesel?

- 1.7 billion annual gallon resource
- 3.6 billion annual gallons by 2016
- Long-Term Potential: 10 billion annual gallons by 2030
- US on-road market: 40 billion annual gallons
 - Developing new feedstock sources should be a priority
 - Algae
 - New crops
 - Higher oil yield



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

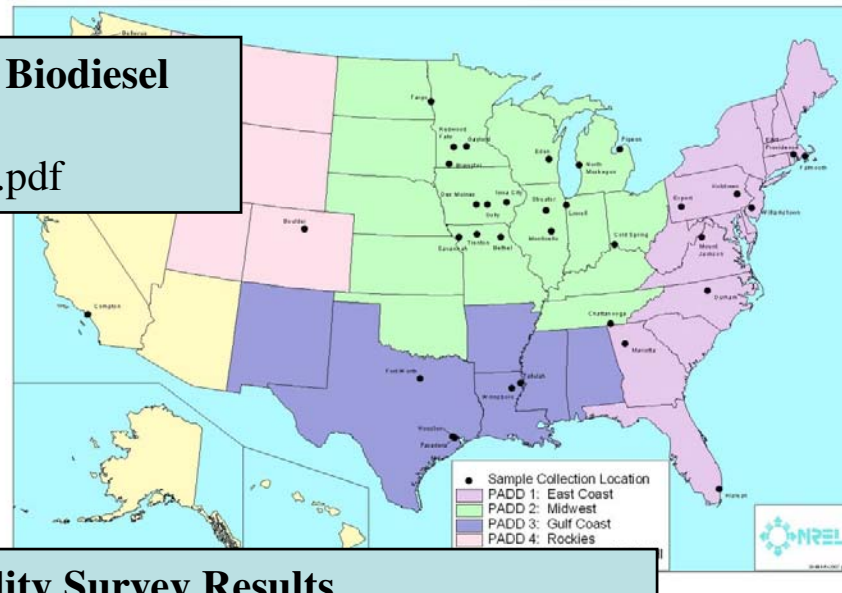
<http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/38836.pdf>

- Showed significant problem with meeting B100 requirements in 2006

- 50% failure rate
- Report in preparation
- NBB response

2006 B100 Quality Survey Results

<http://www.nrel.gov/docs/fy07osti/41549.pdf>



- Ongoing 2007 survey
 - Sample collection from every producer
 - Preliminary results show improving quality
 - Publicly present prelim. results in Oct.

Buying Quality Biodiesel – B100

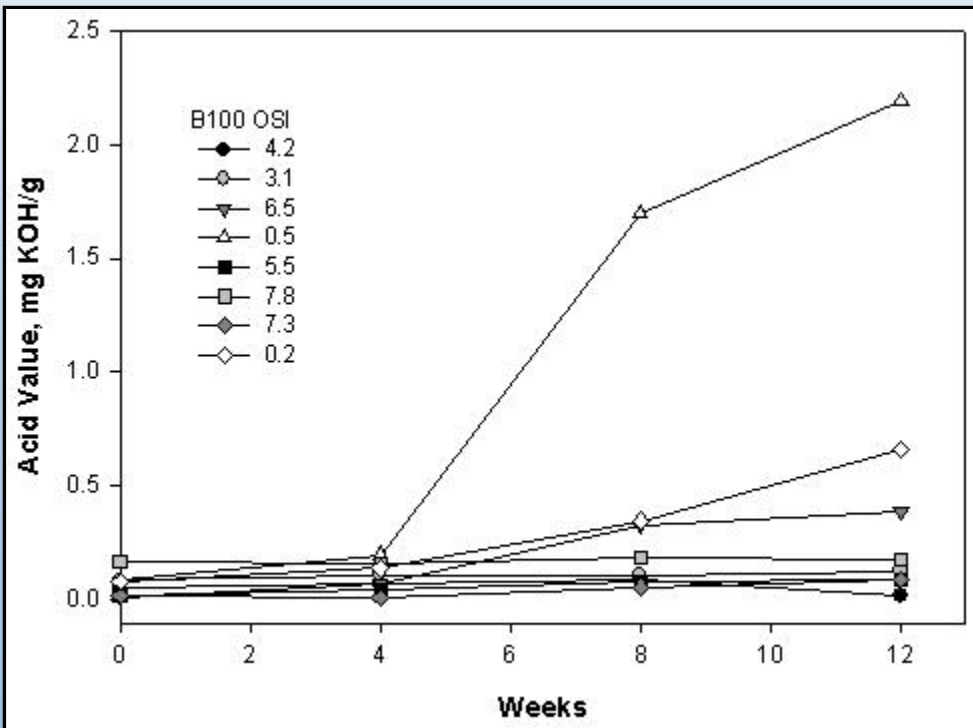
- Demand that the supplier provide a certificate of analysis showing compliance with D6751 for every batch of biodiesel they produce
 - This is the basic requirement of the BQ-9000 program
 - If the supplier cannot provide this, find a different supplier

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



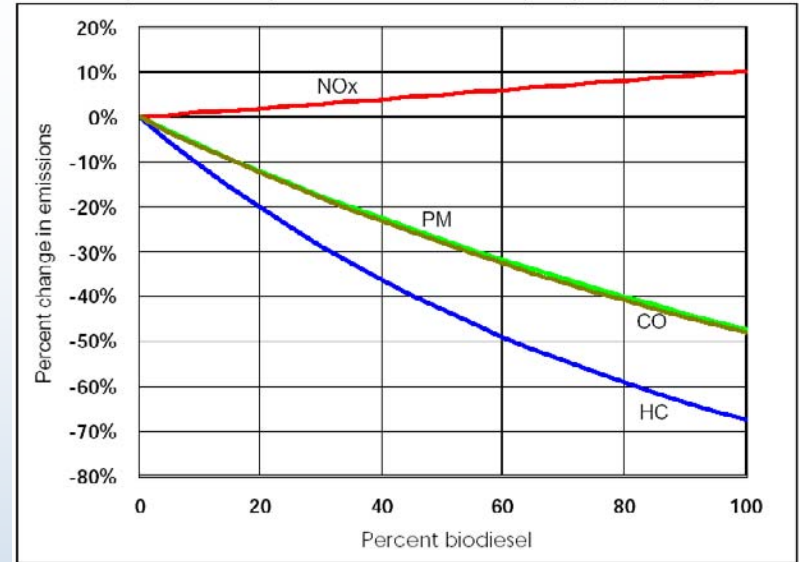
“Cummins is able to upgrade its previous position on the use of biodiesel fuel, which limited the use to B5 blends only, up to B20 for three key reasons. First, the American Society of Testing Materials specification ASTM D6751 now includes an important stability specification for B100 biodiesel.”
<http://www.everytime.cummins.com/every/news/release99.jsp>

Empirical Study of the Stability of Biodiesel and Biodiesel Blends
<http://www.nrel.gov/docs/fy07osti/41619.pdf>

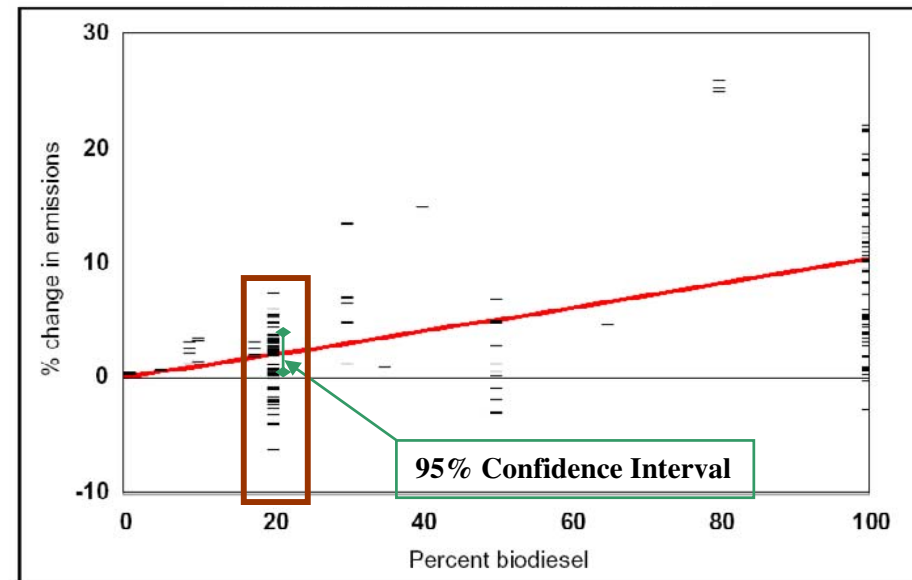
Emissions

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*



Charts from EPA Report-EPA 420-P-02-001, Draft Report, October 2002



Recent NREL Testing – Biodiesel NO_x Impact

- NO_x can increase or decrease 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, CO, and THC is robust

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

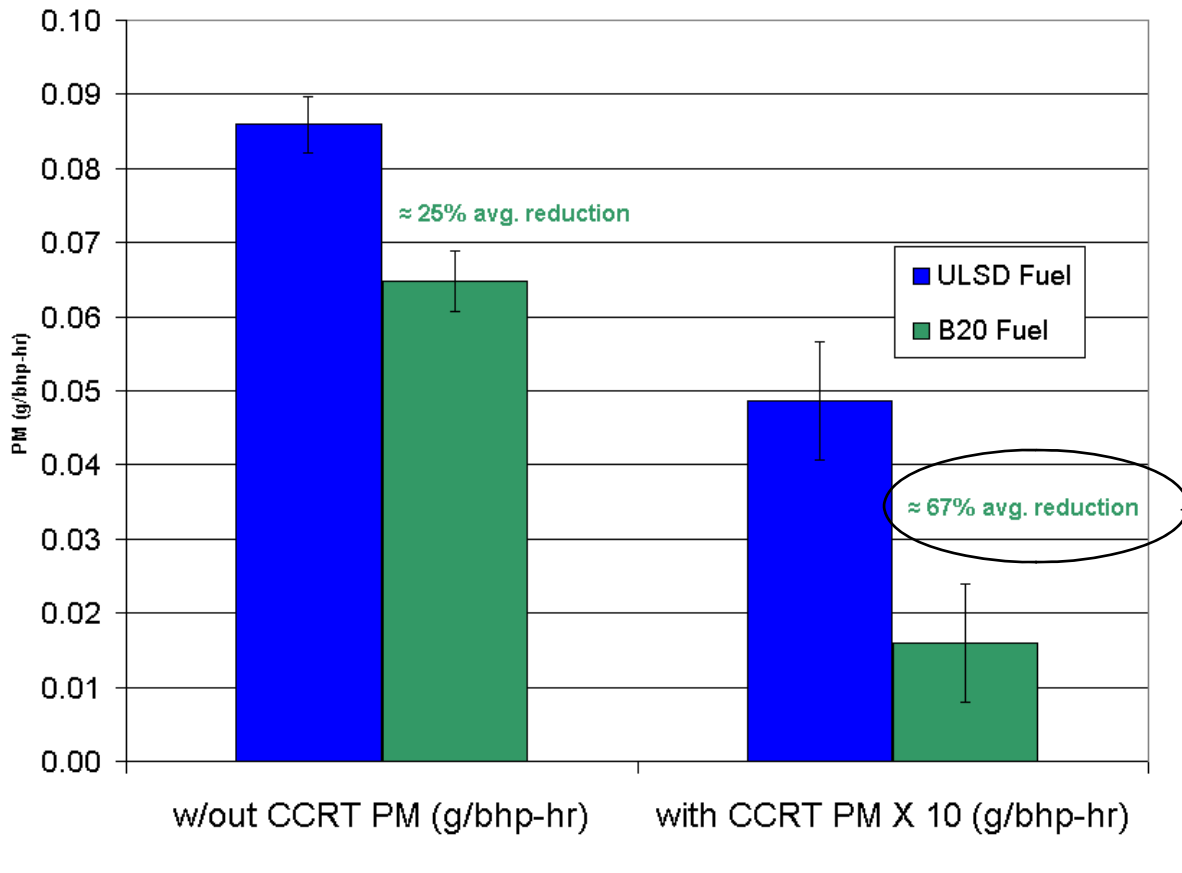
- Conclusion that NO_x increases not widely accepted
- Conflicting results from other studies
- Additional studies involving all stakeholders are planned

Effects of Biodiesel Blends on Vehicle Emissions:

<http://www.nrel.gov/docs/fy07osti/40554.pdf>

B20 Testing with DPF & ULSD

B20 results in substantial PM reduction even with DPF
(data for 2003 Cummins ISB with Johnson Matthey CCRT on HD FTP)



Reduction with DPF ranges from 20% to 70%, depending on basefuel, test cycle, and other factors

- Reduction in sulfate emissions
- Increased PM reactivity

Williams, et al., "Effect of Biodiesel Blends on Diesel Particulate Filter Performance" SAE 2006-01-3280

Biodiesel Summary

- 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
- Development of new feedstock sources (energy crops, algae,....) is critical for the development of this industry
- B20 produces robust reductions in emissions of soot, toxics, and carbon monoxide
- B20 appears to have no consistent impact on emissions of NO_x

Federal Incentives

Federal Incentives

- EPA Act of 1992 as amended by EPA Act of 2005
 - Requires certain regulated fleets of 50 or more LDV's, located in Metropolitan Service Areas, and centrally fueled to buy alt fuel LD vehicles
- Executive Order (E.O.) 13423 signed in 2007
 - Requires certain federal fleets to decrease petroleum consumption by 2% per year relative to their fiscal year (FY) 2005 baseline through FY 2015. Also requires agencies to increase alternative fuel use by 10% per year relative to the previous year.
- Infrastructure tax credits
 - 30% up to \$30,000
- Hybrid and Alternative fuel vehicle tax credits (EPA Act 2005)
 - Depending on model and # of units sold
 - Hybrid tax credits ranges from \$400 to \$2,400 for LD and \$7,500 to \$30,000 for HD
 - Alternative Fuel vehicle credits are 50% of incremental cost with an additional 30% available if vehicle meets rigorous emission standards. Maximum tax credits by weight class range from \$4,000 for up to 8,500 pounds to \$32,000 for more than 26,000 pounds.
- Excise and fuel use tax credits
 - Excise tax credit for non-taxable use
 - Biodiesel- 24.3 cents per gallon of biodiesel, E85- 18.4 cents per gallon, CNG & LPG- 18.3 cents per GGE, LNG- 24.3 cents per GGE
 - Fuel use credit
 - Biodiesel- 50 cents or \$1.00 per gallon of biodiesel depending on feedstock, E85- 51 cents per gallon, CNG, CNG & LPG- 50 cents per GGE

Department of Energy Clean Cities Organization



Clean Cities Origin and History

- Created by DOE to address requirements in Energy Policy Act of 1992
 - Technical, financial, and information assistance to communities with alt fuel deployment plans and to regulated fleets
- Uses a local strategy to advance a national goal.



Clean Cities Goal

By 2020 displace 2.5 billion gallons of petroleum annually.

For more information: <http://www.eere.energy.gov/cleancities/>

Clean Cities Coalitions

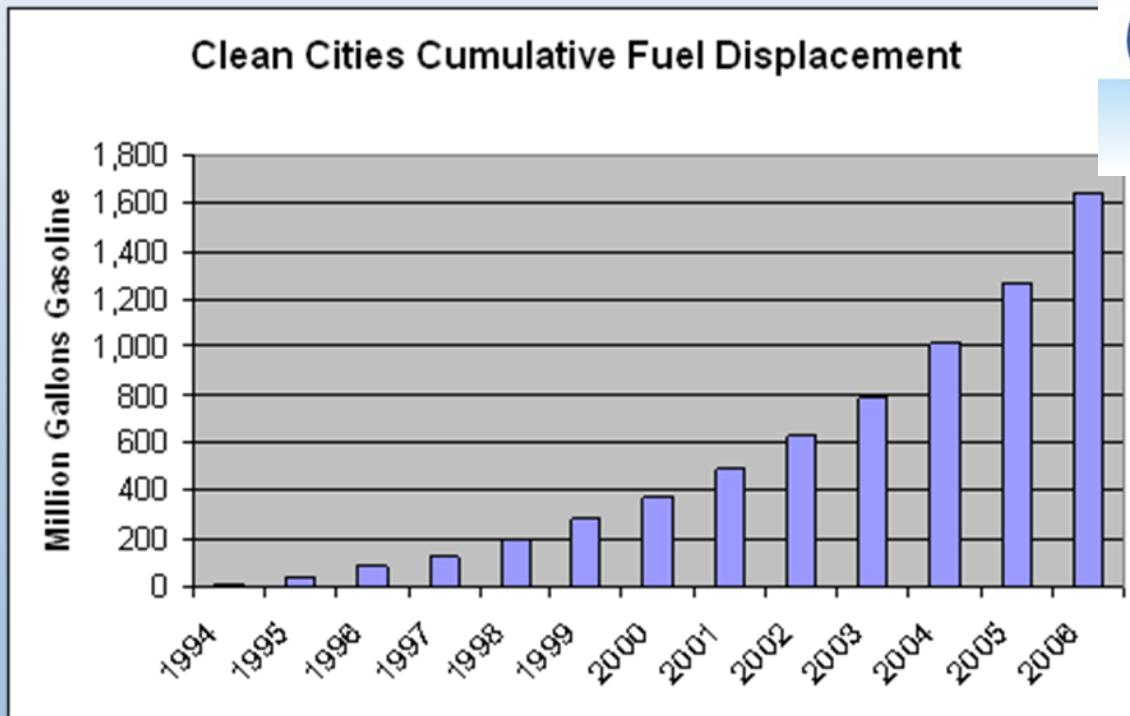
- Public-private partnerships at local, regional, or state level to speed implementation of advanced vehicles and alternative fuels
- Three active Coalitions in Colorado



For contact information: <http://www.eere.energy.gov/cleancities/coordinators.html>

Clean Cities Progress

- At the end of 2006, the Clean Cities stakeholders had saved over 1.6 billion gallons
- The program is on track to exceed it's 2020 goal of 2.5 billion gallons

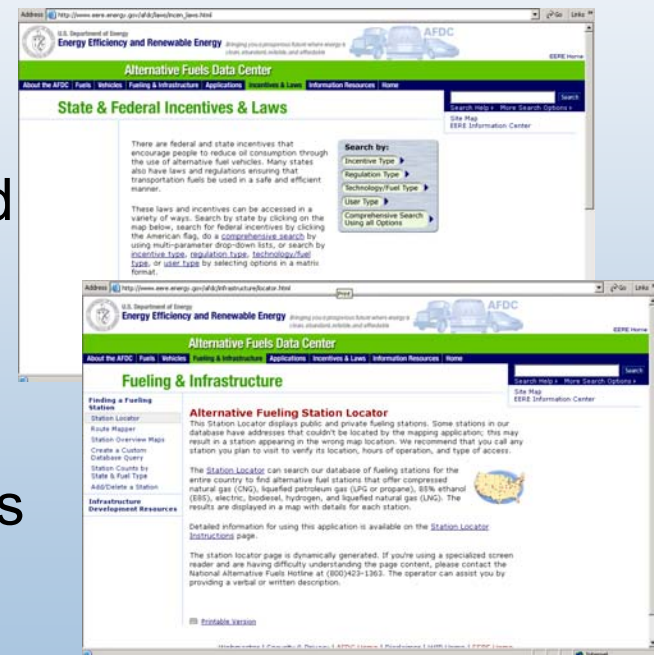


Clean Cities Technical Support

- Alternative Fuels Data Center (<http://www.eere.energy.gov/afdc/>)
 - Website with technical info on technologies
 - Resource for coordinators and the public
- Program and technology analysis
 - Program metrics
 - Analysis of emerging technologies and issues
- Tiger Teams
 - Technical experts to solve vehicle and infrastructure implementation problems
- Technical Response Service
 - Knowledgeable resources for questions

For help in any of these areas, contact your local Clean Cities Coordinator

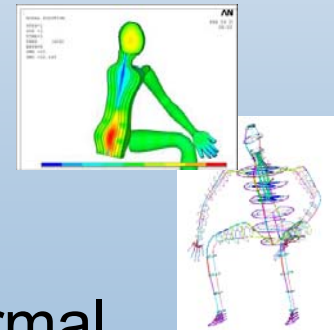
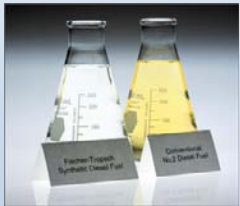
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National Renewable Energy Laboratory

Additional Transportation and Fuels Related Tasks at NREL

- Cellulosic ethanol
- Fleet evaluations
 - HD cab design, HD hybrids and impact of duty cycle
 - Biodiesel
 - UPS Hybrid
- Fuels
 - Mid level ethanol blends
 - Biodiesel and E85; quality, emissions, fuel standards
 - Other non-petroleum based fuels (GTL)
- Vehicles
 - Plug in and alternative fuel hybrids
 - Climate control strategies
- Energy storage technologies and thermal management



Colorado Governor's Biofuels Coalition



- Formed in Fall of 2005 by the Governor's Energy Office
- Volunteer membership with diverse group of stakeholders
- Currently has \$50,000 to help fund infrastructure (SEP, PVE, CMAQ)
- Project funding is 35% of net cost after tax incentives or a maximum of \$15,000 for E85 and \$10,000 for biodiesel
- Application forms and process details are online
- State fleet is partnering with other fleets

<http://www.colorado.gov/oemc/programs/transportation/biofuels/index.htm>

Concluding Remarks

Some Sensible Solutions

- “Right Size” the fleet
- Reduce VMT
 - Mass transit, carpool, bike, walk, telecommute
- Replace Fuels
 - Biofuels
 - Clean diesel
 - Hydrogen
 - Electricity
- Reduce Vehicle Fuel Consumption
 - All vehicles
 - Reduce mass, aerodynamic drag, rolling resistance
 - Conventional vehicles
 - Cylinder deactivation, 6-speed transmissions
 - Advanced powertrains
 - Hybrid-electric vehicles
 - Plug-in HEVs
 - Fuel cell vehicles
 - Consider replacing light-duty gasoline vehicles with more efficient clean diesel/biodiesel vehicles



Conclusions

- Our country requires a reliable transportation system
 - Our current transportation system is inflexible, depending on one fuel from increasingly limited sources in politically unstable regions
- Oil
 - Production is flat or declining
 - Demand is increasing (domestically and globally)
 - Reserves are diminishing and are in politically unstable areas
- Oil infrastructure is vulnerable
 - Natural disasters, equipment failures, terrorism/war, politics
- Multiple solutions are available and required
 - Fewer VMT
 - More efficient vehicles
 - Diverse sources of fuel, including electricity, biodiesel, ethanol, natural gas, propane
- Multiple sources of funding are available

