E10 & E85 and Other Alternative Fuels Storage, Transport, Blending Emergency Response and Exposure/Receptor Scenarios

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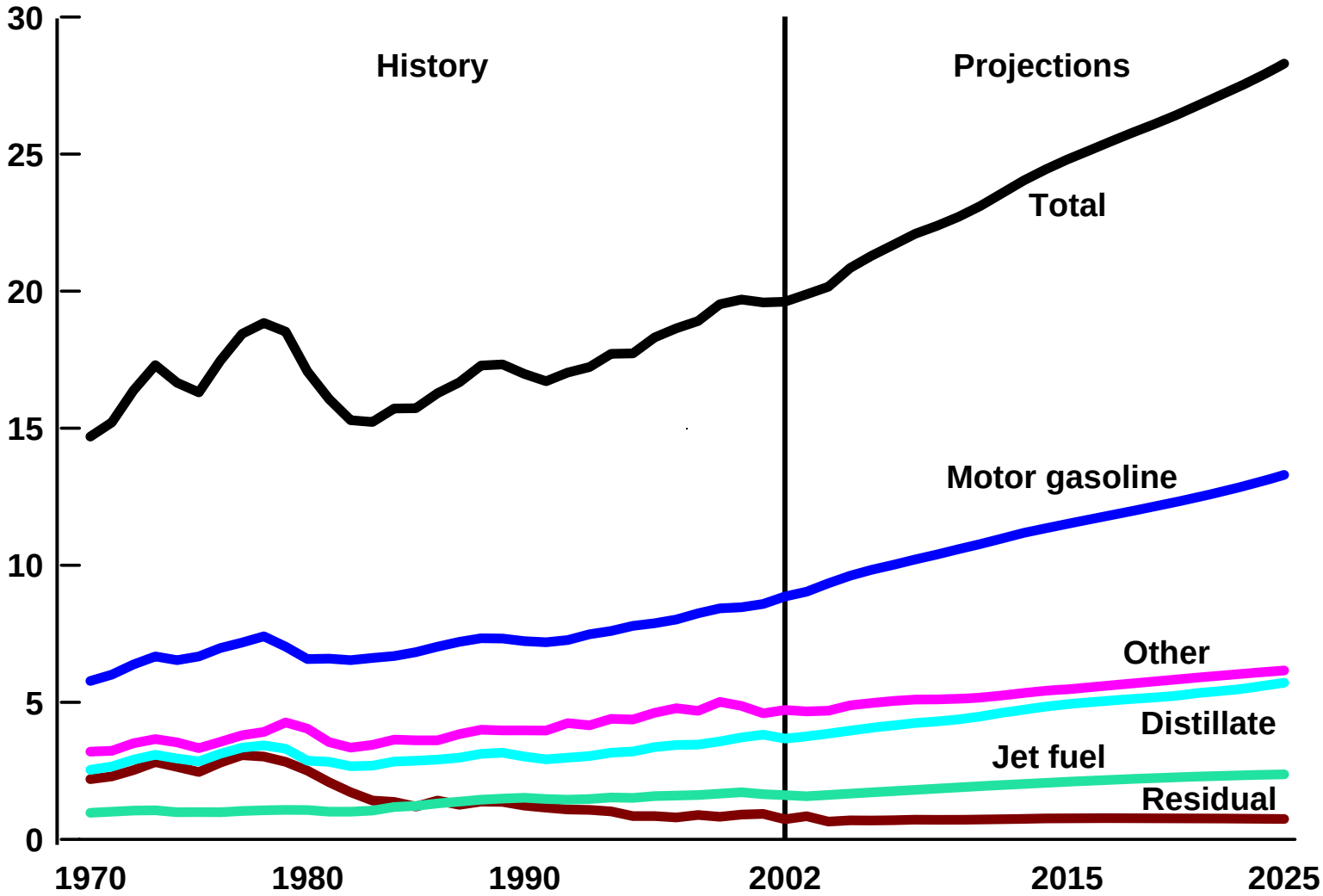
www.api.org/groundwater

The Migration of Petroleum Products in Soil and Ground Water

PRINCIPLES AND COUNTERMEASURES

December 1972

Consumption of Petroleum Products, 1970-2025 (million barrels per day)

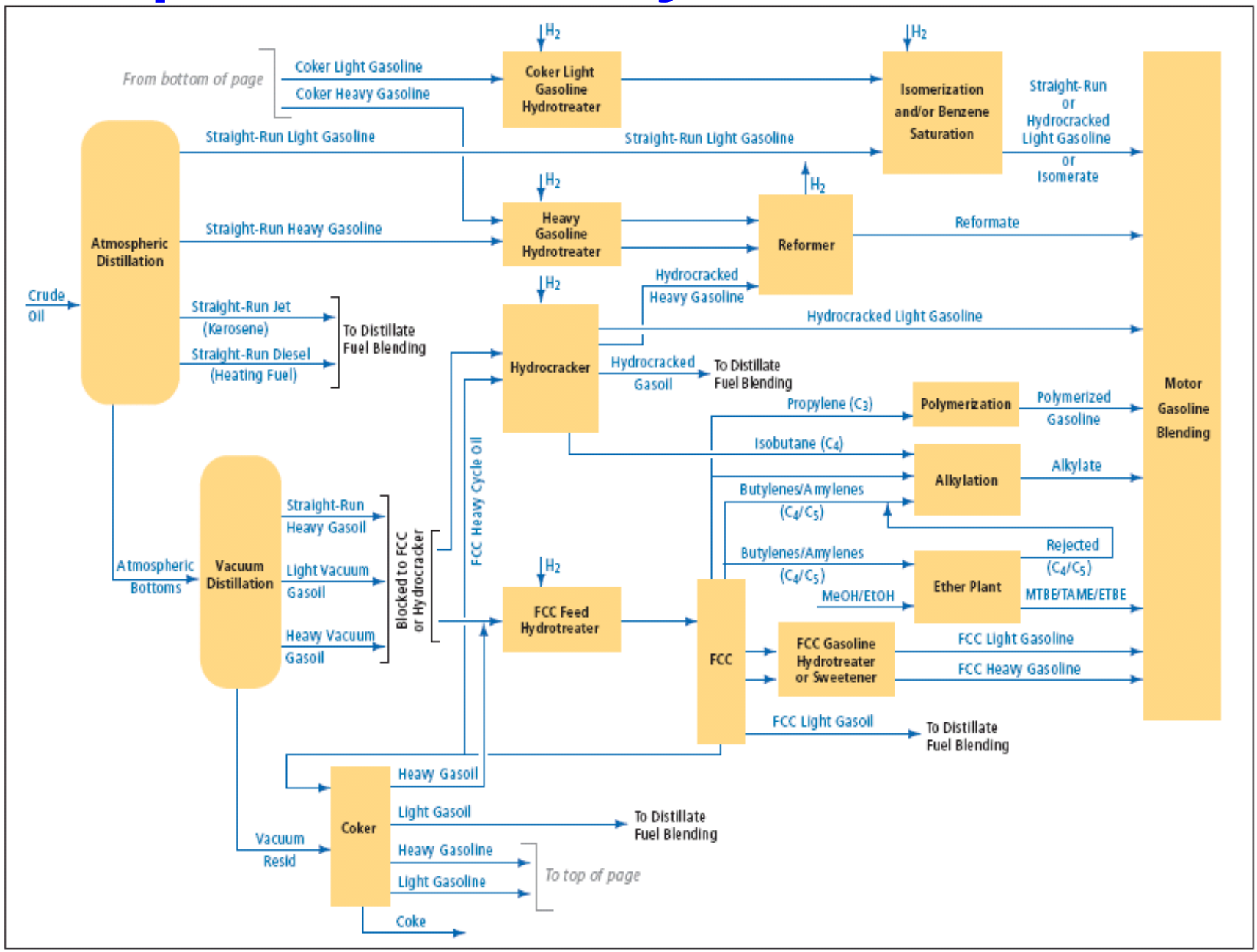


www.eia.doe.gov

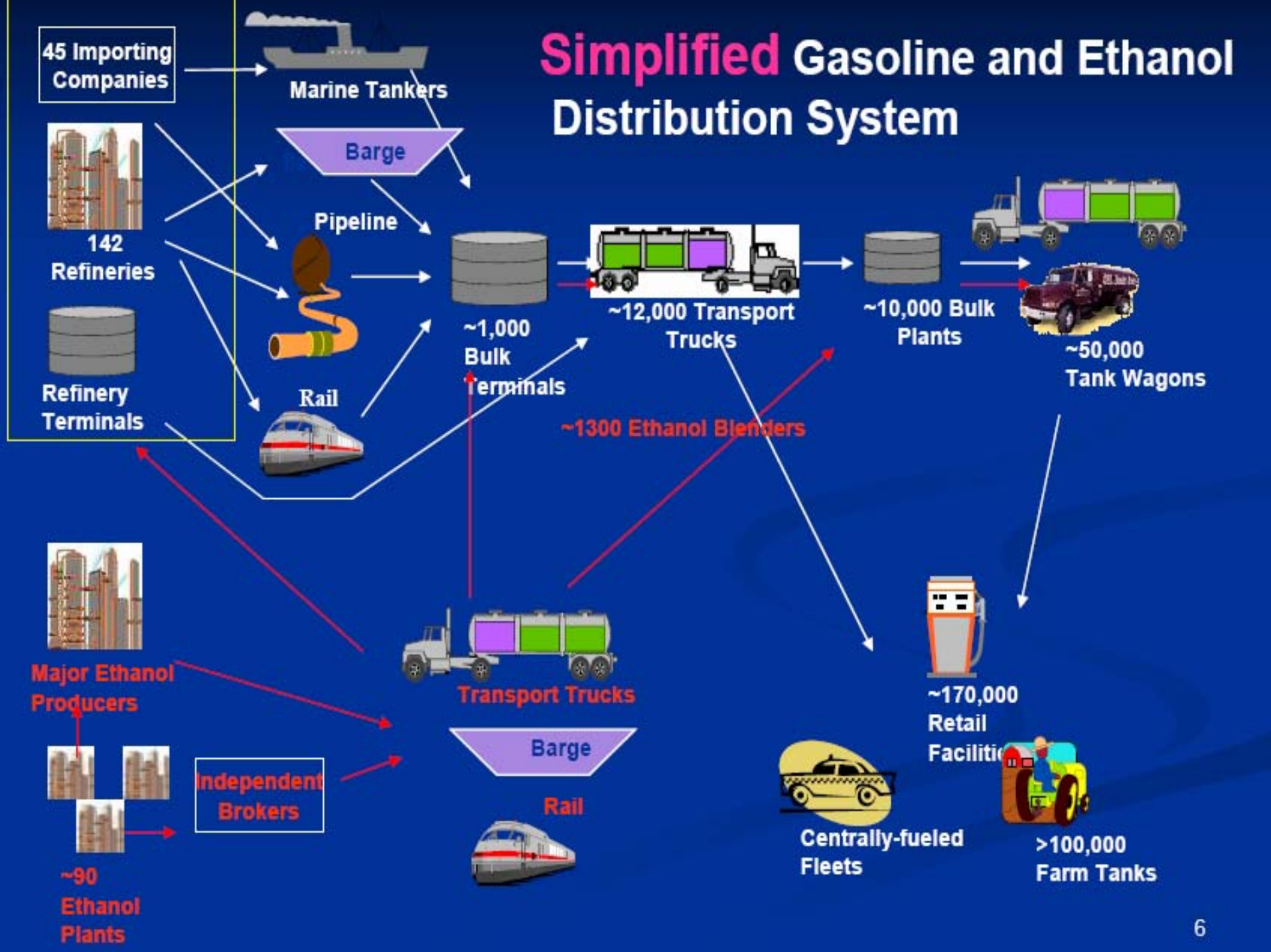
What is Produced from a Barrel of Crude Oil

Product	Percent of Total
Finished Motor Gasoline	51.4%
Distillate Fuel Oil	15.3%
Jet Fuel	12.6%
Still Gas	5.4%
Marketable Coke	5.0%
Residual Fuel Oil	3.3%
Liquefied Refinery Gas	2.8%
Asphalt and Road Oil	1.9%
Other Refined Products	1.5%
Lubricants	0.9%

“Simplified” Refinery Process Streams



Simplified Gasoline and Ethanol Distribution System



Biofuels for Transportation: Understanding the Properties of Interest for Health and Environmental Assessment and Response

"Conventional" Fuels: Gasoline, Diesels (ULSD), Heating Oil

Ethanol Fuels

- Gasohol: usually E6-E10 (6-10% ethanol)
- E85: 70-81% ethanol, 19-30% gasoline
- E95: denatured ethanol
- E20? – Minnesota has 20% mandate by 2013
- E-Diesel (O2Diesel)

- Biodiesel (B2 – B100)

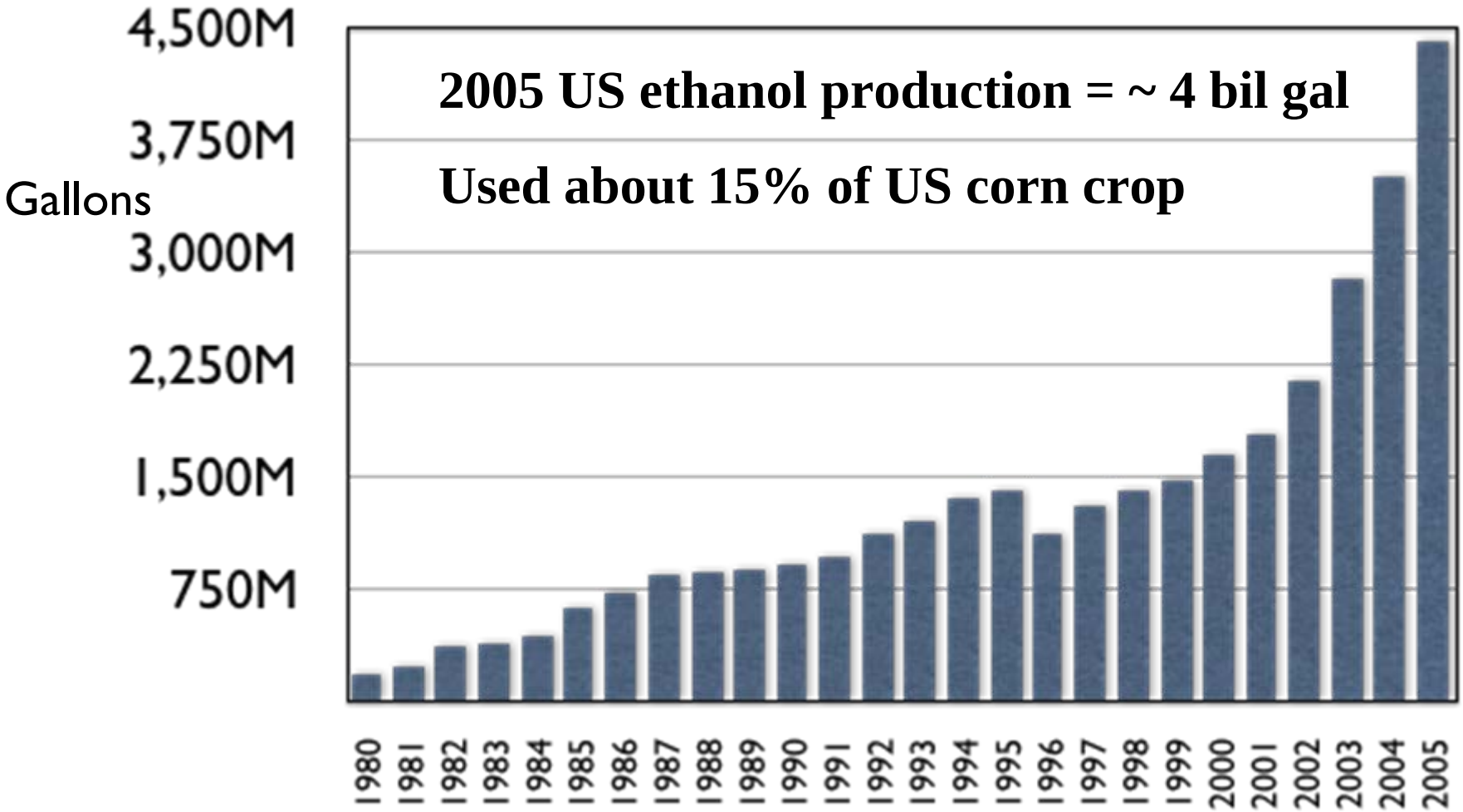
US Gasoline & Diesel Use

- **Gasoline**: **~140 Billion Gallons/year**
  - ~340 million gallons/day
  - **Ethanol Use (2006) : 4.6 bil gal/yr**
  - **~12 mil gallons / day**
- **Diesel**: **~40 Billion Gallons/year**
  - **Biodiesel Use: 0.075 billion gallons (2005)**
  - **300 mil gallons 200; 450+ mil gal in 2007?**
- **Other Distillates** (jet fuel, heating oil, etc)
  - ~45 billion gallons/year
- **Any continued MTBE use post-Oxygen Mandate repeal?**

US Petroleum Product Imports
(Thousands of barrels / day)

Year/Product	Jan	Feb	Mar	Apr
2006				
Total Motor Gasoline	1,091	1,149	1,172	1,247
Reformulated	209	277	126	30
Conventional	396	361	427	480
Blending Components	486	511	618	737
Kerosene-Type Jet Fuel	133	54	117	218
Distillate Fuel Oil	541	385	289	291
15 ppm sulfur and Under	11	1	18	36
> 15 ppm to 500 ppm sulfur	161	97	131	163
> 500 ppm to 2000 ppm sulfur	260	227	74	78
> 2000 ppm sulfur	108	60	66	15
Residual Fuel Oil	548	448	344	281
Propane/Propylene	200	201	169	234
Other Petroleum Products[1]	1,350	1,187	967	1,257

U.S. Ethanol Production Has Tripled Since 2001



Biofuel Production in European Union

Most ethanol is from sugar beets and wheat, and used to make ETBE

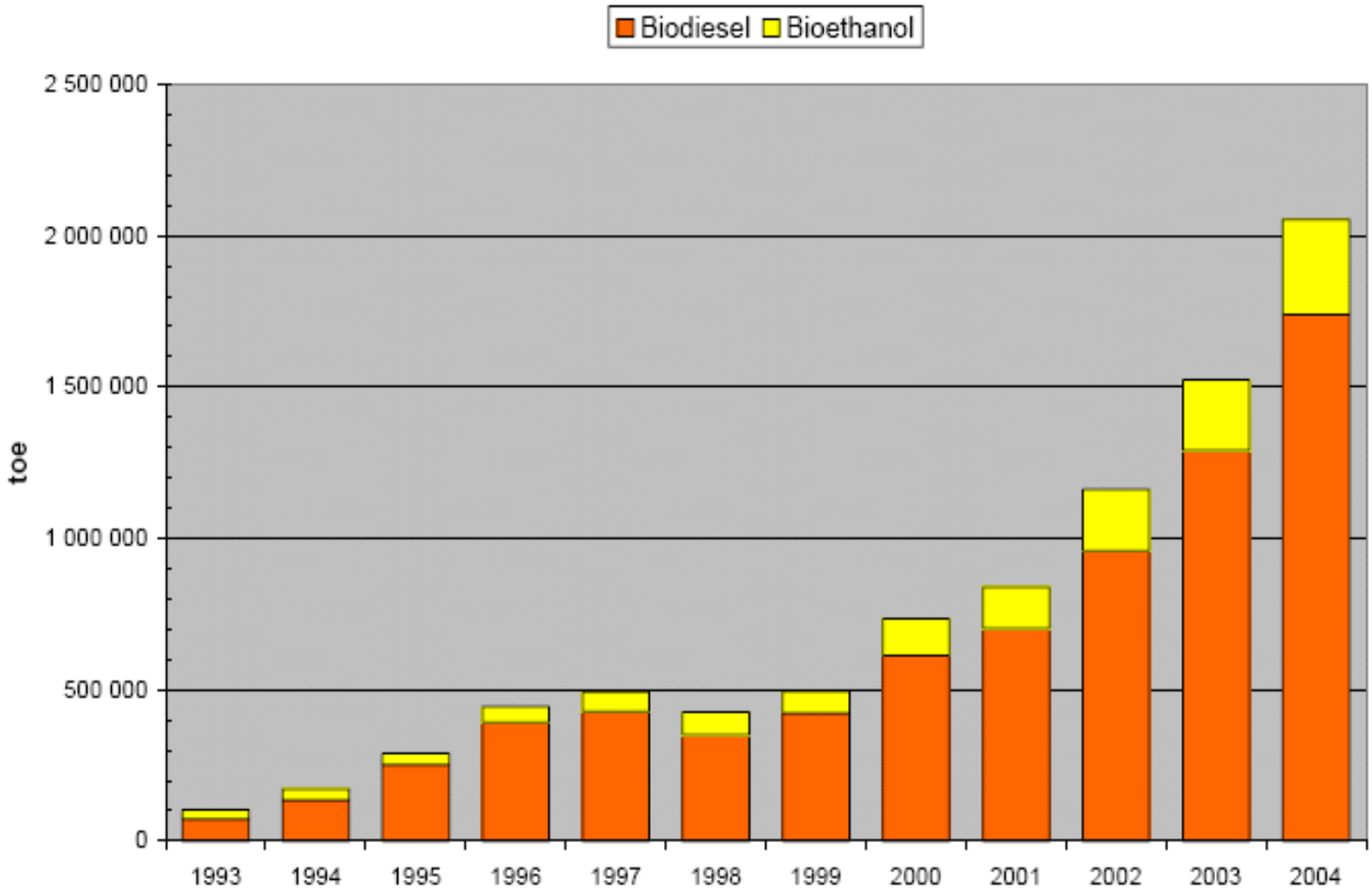


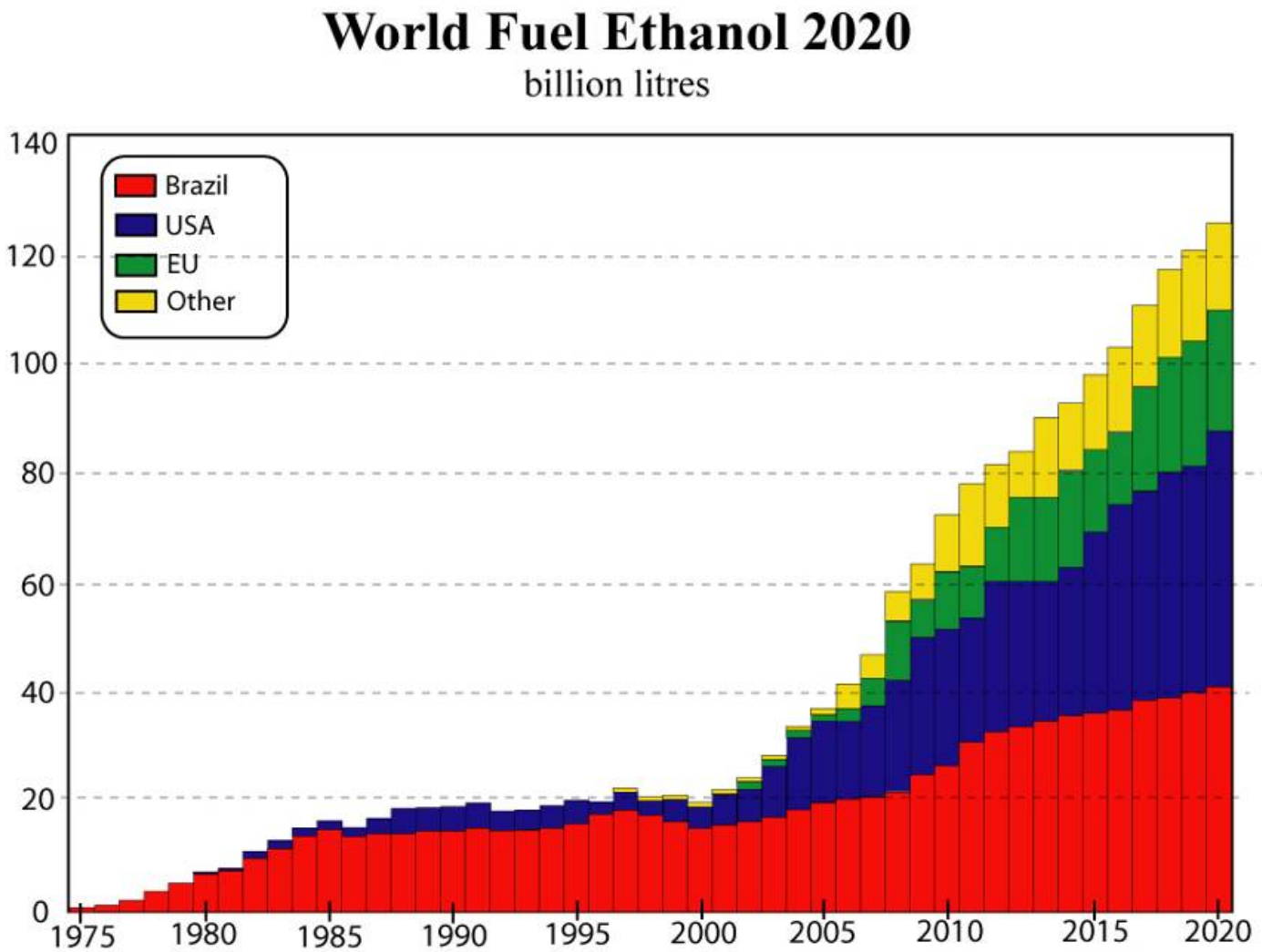
Figure 2.1: Biofuel production in the EU since 1993. (2004: EU25). Source: Eurobserv'er 2005.

Top ethanol producing countries

	2004	2005
U.S.	3,535	4,264
Brazil	3,989	4,227
China	964	1,004
India	462	449
France	*219*	*240*
Russia	198	198
South Africa	110	103
U.K.	*106*	*92*
Saudi Arabia	79	32
Spain	*79*	*93*
Thailand	74	79
Germany	*71*	*114*
Ukraine	66	65
Canada	61	61

Europe total ~450 mil gal

The world is going towards biofuels…



F.O. Licht's World Ethanol and Biofuels Report
Vol. 4, No. 5, Nov. 11, 2005

Future US Ethanol Production?

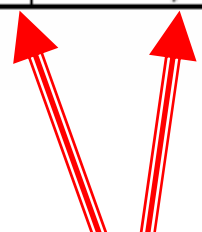
Excerpt from EPA Renewable Fuel Standard NPRM, Sept. 2006

obtaining contractor agreements. Other projects have been proposed or announced, but have not entered the formal planning process. If all these plants were to come to fruition, the combined domestic ethanol production could exceed 20 billion gallons as shown in Table VI.A.2-2.

Table VI.A.2-2
Potential U.S. Ethanol Production Projects

	2006 Baseline + UC[a]		Planned		Proposed		Total ETOH Potential	
	MMGal/yr	Plants	MMGal/yr	Plants	MMGal/yr	Plants	MMGal/yr	Plants
PADD 1	0.4	1	250	3	1,005	21	1,255	25
PADD 2	7,010	128	1,940	15	7,508	90	16,458	233
PADD 3	60	2	108	1	599	9	767	12
PADD 4	155	5	0	0	815	14	970	19
PADD 5	124	5	128	2	676	18	928	25
Total	**7,349**	**141**	**2,426**	**21**	**10,603**	**152**	**20,378**	**314**

[a]Under Construction



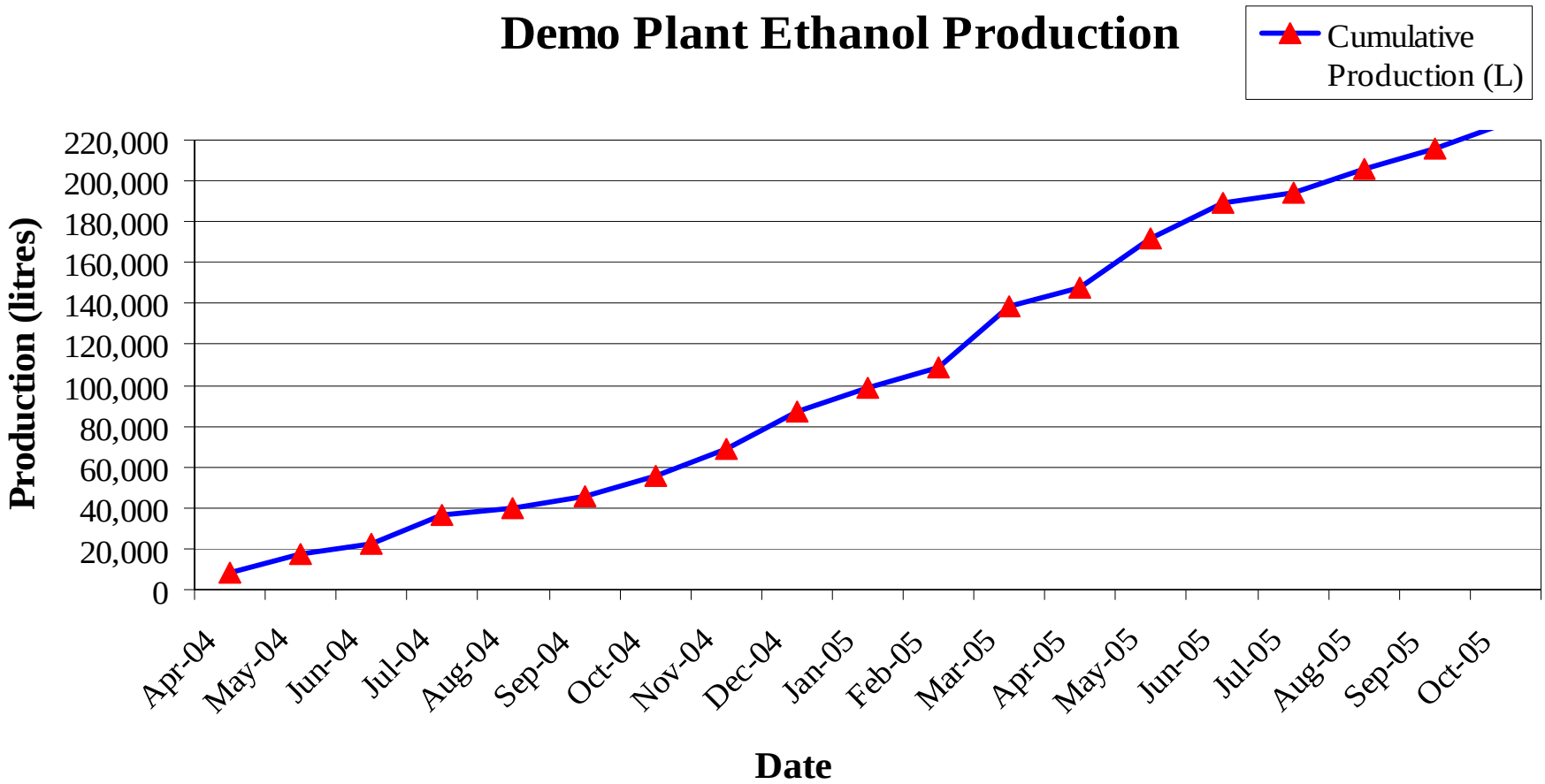
The Iowa Renewable Fuels Standard (RFS)

- Calls for renewable fuels to displace 25% of all gasoline sold 2019. The RFS program begins in 2009 with 10% of all gasoline being a renewable product. The program ramps up annually until 2019 when the full 25% standard becomes effective.
- More than 450 million gallons of ethanol could be utilized to meet the new demand created by the Iowa RFS.

Minnesota Biofuels Mandates

- E-20 bill signed into law in May 2005, passed by House (91-43 vote) and Senate (54-12 vote)
- E-20 ethanol requirement will take effect in 2013 unless ethanol has already replaced 20 percent of the state's motor vehicle fuel by 2010
- $500,000 allocated to assist stations in converting to E-85—over 150 stations online.
- $200,000 to study ethanol combustion (E20)
- Biodiesel (B2) statewide requirement

Cellulosic ethanol: Production at logen Ontario Canada Plant (only one in world)



Second Generation Biofuels may be much better fuel alternatives

Cellulosic Ethanol

Biobutanol

Fischer-Tropsch Diesel

Synthetic biofuels

Biogas

Biohydrogen

Others . . .

Key Factors for Fuel Choices

- Safety
- Fuel stability, storage and handling
- Engine, vehicle and materials compatibility
- Engine, vehicle and materials compatibility
- Vehicle emissions
- Fuel Economy
- Health effects
- Life Cycle ‘Costs / Impacts’

Good Reading:

EPA NPRM on Renewable Fuel Standard, Sept 2006

Major reasons stated for biofuel benefits:

Energy Security / Independence

Environmentally Friendly - renewable, decreases GHG)

Stimulates Rural Economies - send $$ to Midwest, not Middle East

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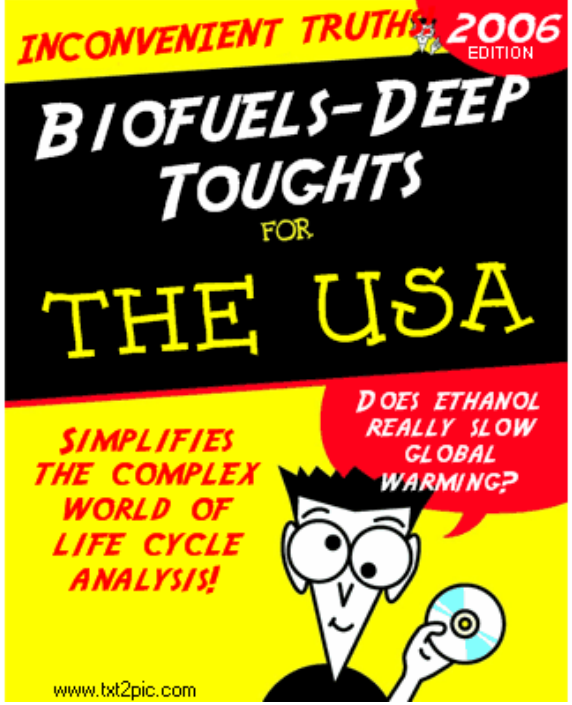
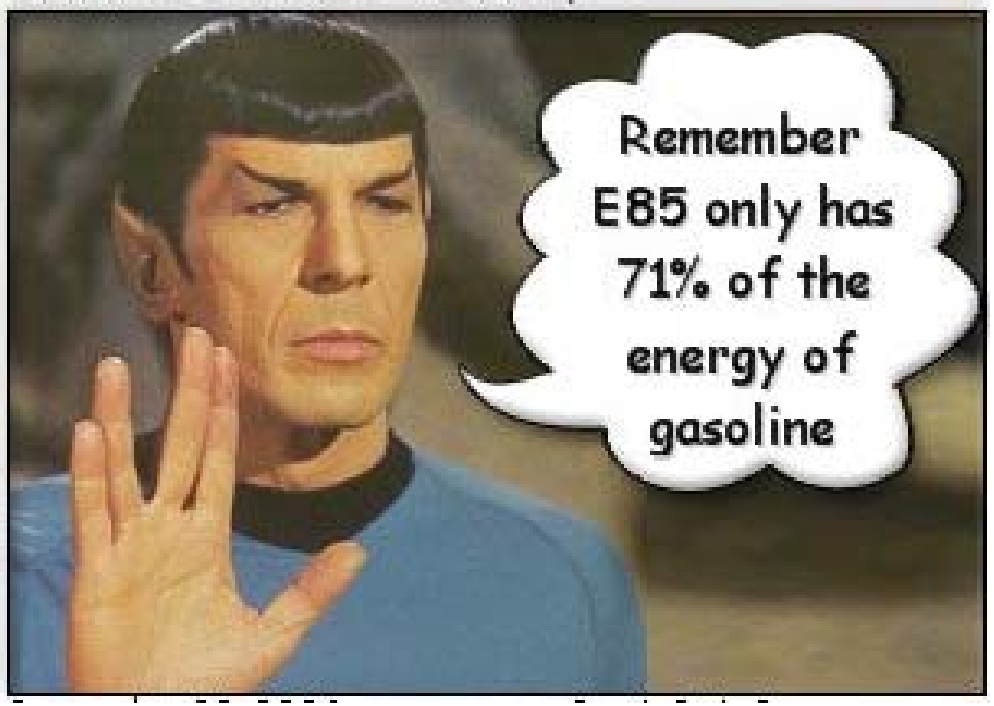
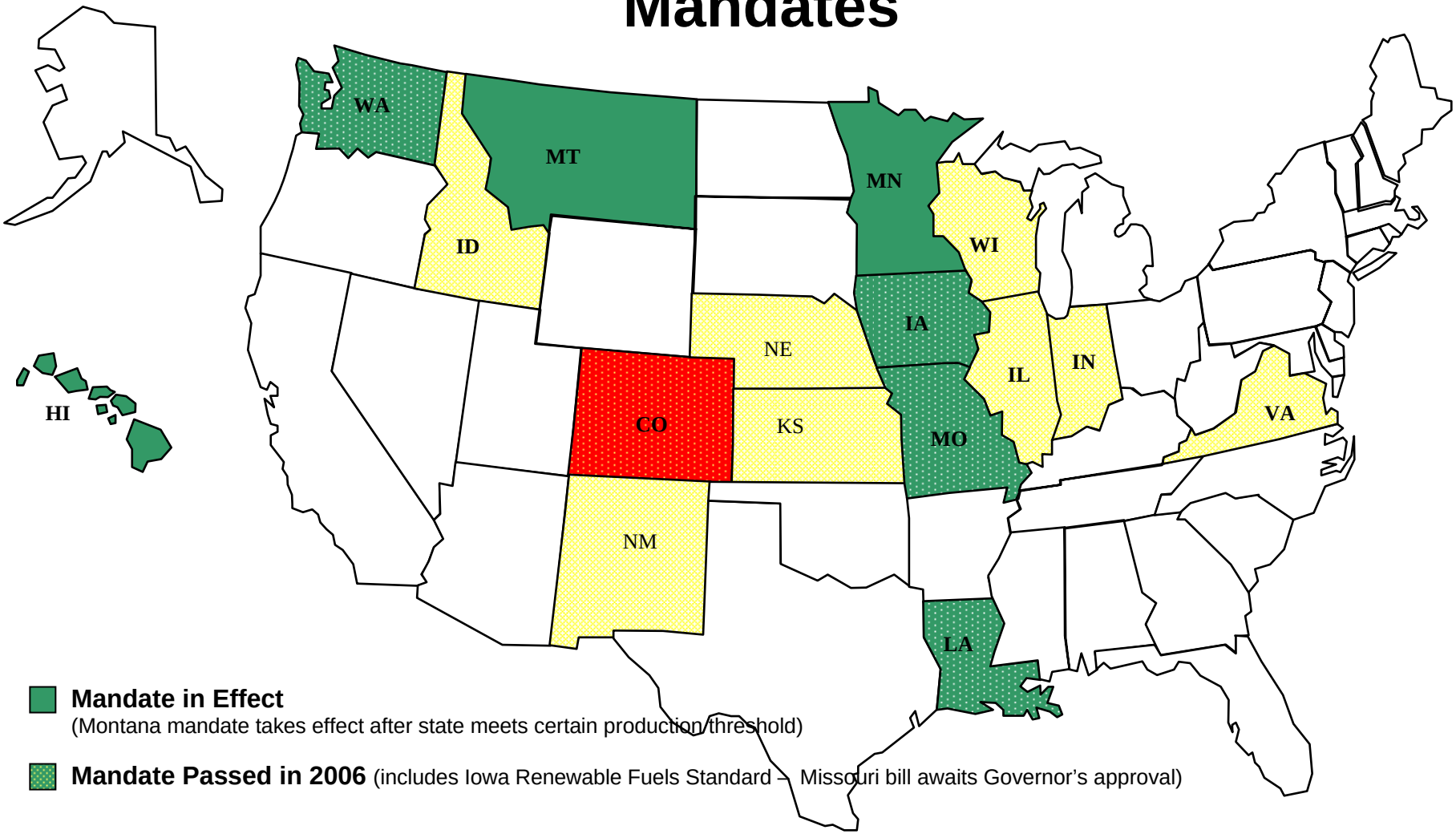




- **If entire US were E85, would need about 1/3 more deliveries of fuel to gas stations (1/3 more overfills?)**
- **About 1/3 more frequent vehicle fillups (or 1/3 larger gas tanks)**
- **Or reduce mileage penalty by modifying vehicles to take advantage of higher octane of ethanol**

State Ethanol Mandates



Mandate in Effect
(Montana mandate takes effect after state meets certain production threshold)

Mandate Passed in 2006 (includes Iowa Renewable Fuels Standard – Missouri bill awaits Governor's approval)

Vetoed (Colorado Governor vetoed ethanol legislation 5/26)

Legislation Considered and Failed in 2006 (Indiana was Renewable Fuels Standard)

6/15/06

EPA Blue Ribbon Panel on Gasoline Oxygenates (1999)

Recommendations for Evaluating and Learning From Experience

. . . .**The unanticipated effects of RFG on groundwater highlight the importance of exploring the potential for adverse effects in all media (air, soil, and water), and on human and ecosystem health, before widespread introduction of any new, broadly-used, product.**

16. In order to prevent future such incidents, ... EPA should:

a. Conduct a full, multi-media assessment (of effects on air, soil, and water) of any major new additive to gasoline prior to its introduction;

b. Establish routine and statistically valid methods for assessing the actual composition of RFG and its air quality benefits, . . . field monitoring and emissions characterization techniques to assess "real world" effects of different blends on emissions;

c. Establish a routine process . . . . for reporting on the air quality results from the RFG program; and

d. . . . . measure the broader impact (both beneficial and adverse) of changes in gasoline formulations on public health and the environment.

Ethanol Fuels – Health Effects

- **Very few studies on the relevant mixtures / exposure scenarios**
- **Work in progress (EPA 211b & HPV testing programs)**
- **None on E85**

EPA IRIS Ethanol Assessment

- Draft is in agency review
- External review expected March 2007

NESCAUM Reviews (2001)

- "Low-level ethanol contamination of groundwater (i.e., less than 400 ug/L, . . .) is not expected to substantially alter blood alcohol concentrations or produce a significant health risk." NEIWPCC 2001
- "Generally reviews of the literature have concluded that ethanol inhalation from RFG has little public health significance." NESCAUM 1999

Ethanol is Safe in Soil and Groundwater

http://www.ncga.com/ethanol/environment/soilGroundwater.asp

According to the National Corn Growers Association:

- Ethanol is non-toxic, water soluble and is the most harmless and biodegradable component of gasoline. In fact, ethanol occurs naturally during the fermentation of organic matter.

- When gasoline is spilled on land or in water, ethanol is the first component to quickly, safely and naturally degrade. More important, the presence of ethanol in gasoline means the reduced presence of other more toxic components such as benzene—so gasoline spills are less threatening to the environment.

API- U. Waterloo Controlled Release Ethanol study

- Injected 50 L E95 and E10 below water table
- At 230 days, at 15.5 m from the injections ethanol concentrations of about 560 mg/L from the E10 source and about 5030 mg/L from the E95 source were detected after about 230 days.
- These were only three times lower than the highest early concentrations of 1390 mg/L in the E10 gate and about 15700 mg/L in the E95 gate.

Ethanol in Motor Fuels: Ground Water

- Subsidies & MTBE phaseout will increase future use 2-3X in next 5-10 yrs (from 1.6 BGY)
- Neat EtOH?? E-85 use increase? 'Biodiesel'???
- Field experience of fate - transport limited despite localized long term use
- Direct exposures to EtOH not of likely concern
- Secondary effects on BTEX transport or other HC? On existing BTEX and MTBE plumes? NAPL?
- Other secondary effects of interest? (methane, metals equilibria, taste/odor) and the "U-I-C Effect"?
- Cleanup criteria and effects and water treatment $???
- Ongoing research limited: lab column studies; benzene plume studies; field controlled releases

API RPs and Reports Addressing Ethanol Fuels

- API 1626: Storing and Handling Ethanol and Gasoline-Ethanol Blends at Distribution Terminals and Service Stations (April, 1985; reaffirmed June 2000)
- API 1642: Alcohols, Ethers and Gasoline-Alcohol and –Ether Blends: A report on Fire-Safety Considerations at Petroleum Marketing Facilities
- API 939-D: Stress Corrosion Cracking Of Carbon Steel In Fuel Grade Ethanol: Review And Survey
- API Ethanol Study - Literature Review - Impact Of Gasoline Blended with Ethanol On Long Term Structural Integrity Of Liquid Petroleum Storage System & Components
- *Alcohols and Ethers: a Technical Assessment of Their Application as Fuels and Fuel Components*, API Publication 4261, Third edition, June 2001.

Other API Biofuel issues materials at:

www.factsonfuel.org

Other Key Biofuel Resources

- **API Ground Water Research**

See www.api.org/groundwater

- **CD Materials**
- **LUSTLine 52**
- **PEI Alternative Fuel Compatibility Guide**
- **DoE Handling & Storage Reports for E85 and Biodiesel**
- **NESCAUM: July 2001**
  Health, Environmental, and Economic Impacts of Adding Ethanol to Gasoline in the Northeast
- **LLNL / CalEPA Ethanol Assessments 1999-2001**

2004/2005 U.S. Gasoline Composition Study

- 2004/2005 study of U.S. gasoline composition
- Report Available:
  - http://www.epa.gov/athens/publications
  - Weaver et al., 2005, Predicted Ground Water, Soil and Soil Gas Impacts from US Gasolines, 2004

LUSTLine 52, May 2006

Inside

PEI Alternative Fuels Equipment Guide

http://www.pei.org/altfuels/guide.asp

Alternative Fuels Equipment Compatibility Guide

presented by the Petroleum Equipment Institute.

This guide provides information on equipment for storing, dispensing, metering and transporting alternative fuels. When viewing details for each item click the company name to view the manufacturer's contact information and web site.

Search for Equipment

search

Enter keywords or phrases that describe the equipment you're trying to locate

Equipment by Fuel
Select an alternative fuel to view compatible equipment

Items by Company
View companies that have listed compatible equipment

All entries and data are provided by the manufacturer. For comprehensive supplier listings for all types of petroleum marketing and liquid handling equipment refer to **Source: PEI**

: **Manufacturer Login**

alt.fuels
Alternative Fuels Information Center

Resources

- Alternative Fuels Equipment Compatibility Guide
- The Fuels
- Alt Fuel Links

New DoE Publications

Handbook for Handling, Storing, and Dispensing E85

Second edition July 2006

Biomass

BIODIESEL Handling and Use Guidelines

DOE/GO-102006-2358
Third Edition
September 2006

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

ASTM Biofuel Specifications

- **Fuel Grade Ethanol**: **D4806-06a** Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel
- **Gasohol: ASTM D4806-04a** "Standard Specification for Automotive Spark-Ignition Engine Fuel"
- **E85**: **D5798-06** Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines

- **100% Biodiesel: ASTM D 6751**
  Standard for (B100) Blend Stock for Distillate Fuels (does not address quality of blends like B2, B5, B20)

- Bronze pentagon is used to identify E85 tanks – fill pipe cover or box

Responding to Incidents Involving Ethanol and Gasoline Fuel Mixtures

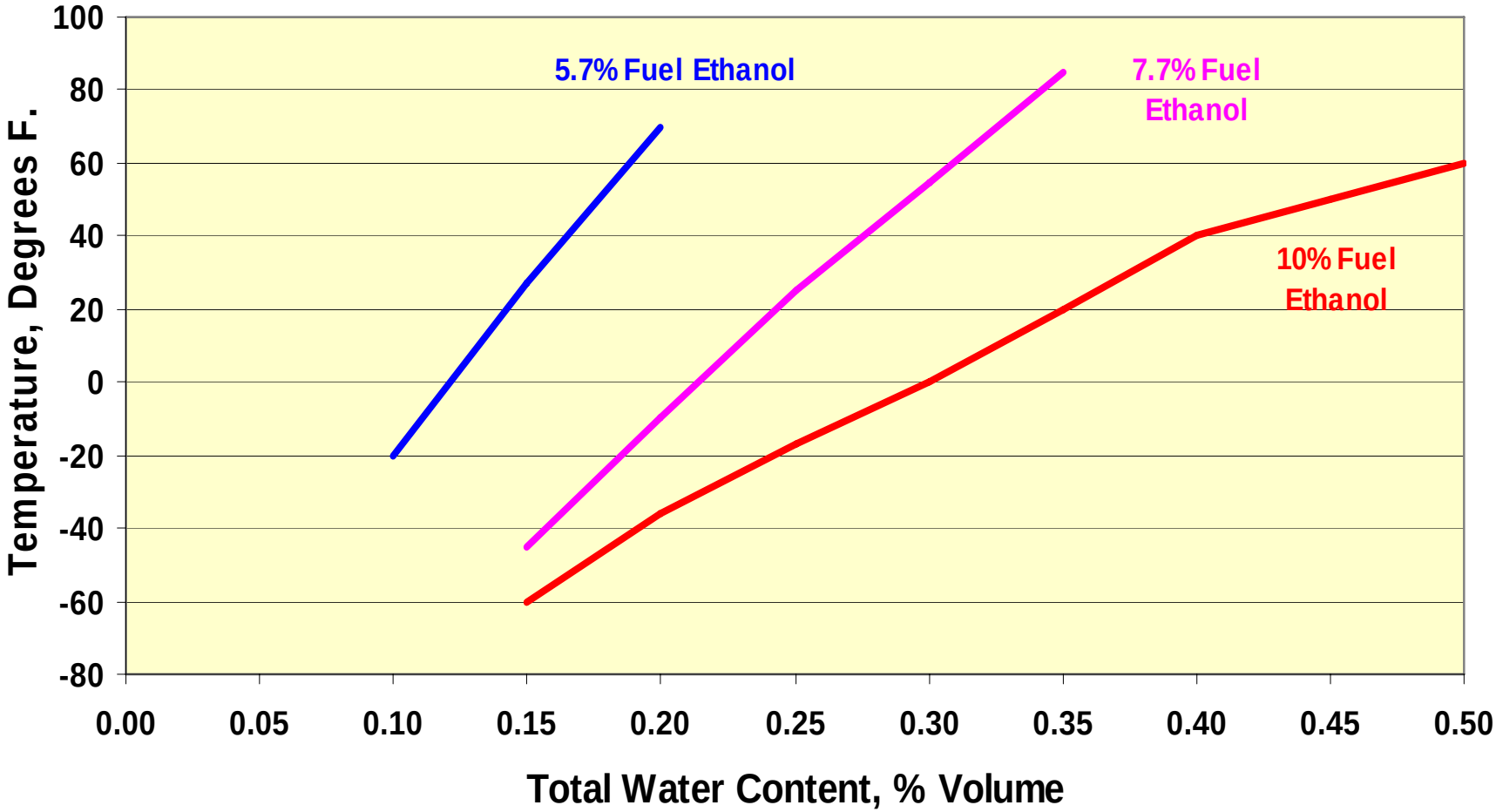
The Pipeline and Hazardous Materials Safety Administration (PHMSA) is alerting emergency responders to appropriate emergency response guidance for responding to incidents involving fuel mixtures composed of ethanol (or "ethyl alcohol") and gasoline in various concentrations. The most common of these fuels, designated E85 (85% ethanol and 15% gasoline), recently has begun to be used in volume in the Midwest, primarily in the states of Illinois and Minnesota.

Fires involving E85 and other ethanol/gasoline mixtures containing more than 10% ethanol should be treated differently than traditional gasoline fires because these mixtures are polar/water-miscible flammable liquids (i.e., they mix readily with water) and will degrade the effectiveness of fire-fighting foam which is not alcohol-resistant. For this reason, PHMSA recommends use of alcohol-resistant foam to fight fires involving these fuel mixtures. Properties of ethanol/gasoline fuels that may be of interest to emergency responders are provided in the chart below.

Properties of Fuel Ethanol

Property	Comment
Vapor density	Ethanol vapor, like gasoline vapor, is denser than air and tends to settle in low areas. However, ethanol vapor disperses rapidly.
Solubility in water	Fuel ethanol will mix with water, but at high enough concentrations of water, the ethanol will separate from the gasoline.
Flame visibility	A fuel ethanol flame is less bright than a gasoline flame but is easily visible in daylight.
Specific gravity	Pure ethanol and ethanol blends are heavier than gasoline.
Conductivity	Ethanol and ethanol blends conduct electricity. Gasoline, by contrast, is an electrical insulator.
Toxicity	Ethanol is less toxic than gasoline or methanol. Carcinogenic compounds are not present in pure ethanol; however, because gasoline is used in the blend, E85 is considered to be potentially carcinogenic.
Flammability	At low temperature (32°), E85 vapor is more flammable than gasoline vapor. However at normal temperatures, E85 vapor is less flammable than gasoline, because of the higher autoignition temperature of E85.

Water Tolerance of Gasoline / Fuel Ethanol Blends



10% Ethanol blends can hold 0.5%v water at 60 F, and 0.4% at 40 degrees F before phase separation occurs

Ethanol Denaturants

- **Usually blended into alcohol at 5 gal per 100 gal (4.76% vol.)**
- **From the ATF "Alcohol Fuel" web page:**

http://www.ttb.gov/pdf/authorized_denaturants_fuel_alcohol.pdf

Natural gasoline, ETBE, Raffinate, Naptha,

Also:

Bureau of Alcohol Tobacco & Firearms (BATF)- A denaturant is...

"A material authorized by this part (27 CFR Ch.1) to be added to spirits in order to make those sprits unfit for beverage or internal human medical use"

Gasoline or automotive gasoline **Kerosene**
Deodorized kerosene **Rubber hydrocarbon solvent**
Methyl isobutyl ketone **Mixed isomers of nitropropane**
Heptane

API Fuel Tank Vapor Flammability Study (1996)

- **API Pub. 4646 -** Evaluation of Fuel Tank Flammability of Low RVP Gasolines
- Evaluated Ethanol and MTBE blends

Fuel / compound	**10% EtOH ppmv**	**15% MTBE ppmv**
Benzene	**720-1300**	**600-1300**
Toluene	**1500-3200**	**1800-3100**
Ethylbenzene	**200-400**	**150 - 450**
Xylenes	**800-1400**	**700-1400**
IsoPentane	**8-29,000**	**6-25,000**
N-butane	**3 - 30,000**	**3-27,000**
Ethanol	**16-32,000**	
MTBE	**--**	**11-18,000**

"Summary of the Study of E85 in the US" CRC, August 2006

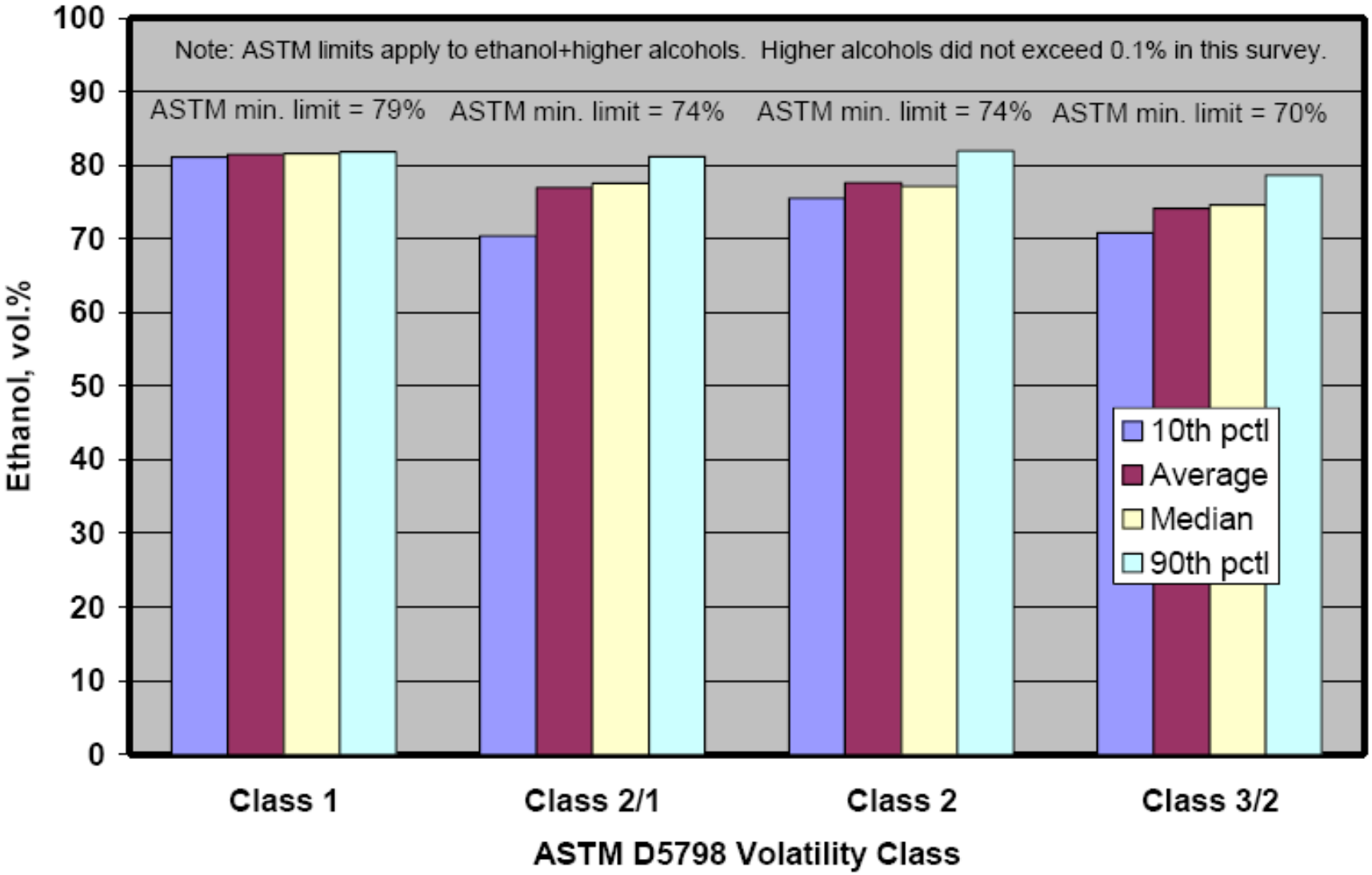
Table 1. Statistical Data for E85 Fuels in Volatility Class 1

			Volatility Class 1			
Property	Units	Test Method	10th pctl	average	median	90th pctl
Vapor pressure	kPa	ASTM D 5191	39.9	41.8	41.7	43.7
Vapor pressure	psi	ASTM D 5191	5.8	6.1	6.0	6.3
Ethanol	vol.%	ASTM D 6729 mod	81.1	81.5	81.6	81.8
Higher alcohols	vol.%	ASTM D 5599	0.08	0.09	0.08	0.10
Ethanol+higher alcohols	vol.%		81.2	81.6	81.7	81.9
Methanol	vol.%	ASTM D 5599	<0.01	<0.01	<0.01	<0.01
Sulfur	mg/kg	ASTM D 5453, D 6334	11	12	11	13
Unwashed gum	mg/100 mL	ASTM D 381	5.2	6.0	5.2	7.6
Solvent washed gum	mg/100 mL	ASTM D 381	<1.0	<1.0	1.0	1.2
Acidity as acetic acid	mg/L	ASTM D 1613	8	11	11	13
pHe		ASTM D 6423	7.2	7.3	7.4	7.6
Water	mg/kg	ASTM E 1064	5357	5817	5685	6409
Lead	mg/L	ASTM D 5059	<0.1	<0.1	<0.1	<0.1
Total chlorine	mg/kg	ASTM D 4929/B	0.5	0.7	0.6	1.0
Inorganic chloride	mg/kg	Ion Chromatography	<0.2	0.2	<0.2	0.6
Sulfate	mg/kg	Ion Chromatography	0.8	1.0	0.8	1.4
Number of Samples	3					
Percent of fuels not meeting ASTM D 5798: 0%						

Note: mg/kg = ppm (mass)

CRC E85 Fuel Quality Survey, Results

Figure 2. Ethanol Content of E85 Fuels



E-65-3 - Project Description

- Five vehicle fuel system test rigs (2000 – 2005 MY)
  - 2000 Honda Odyssey enhanced evap system (Rig 2 – E-65)
  - 2001 Toyota Tacoma enhanced evap system (Rig 1 – E-65)
  - 2004 Ford Taurus LEV II "near zero" evap system (Rig 11)
  - 2004 Chrysler Sebring PZEV evap system (Rig 12)
  - 2005 Chevrolet Tahoe FFV system (Rig 14)
- Five test fuels (vapor pressures targeted at 7.0 psi)
  - E0 non-oxygenated base fuel
  - E6 5.7 vol% ethanol (26 vol% aromatics)
  - E6Hi 5.7 vol% ethanol (39 vol% aromatics)
  - E10 10 vol% ethanol
  - E85 85 vol% ethanol
- Order of testing: E0, E6, E6Hi, E10, E85

E-65-3 - Typical Test Rig

2004 Chrysler Sebring PZEV Fuel System

FUEL PERMEATION FROM AUTOMOTIVE SYSTEMS: E0, E6, E10 AND E85

Interim Report
CRC Project No. E-65-3

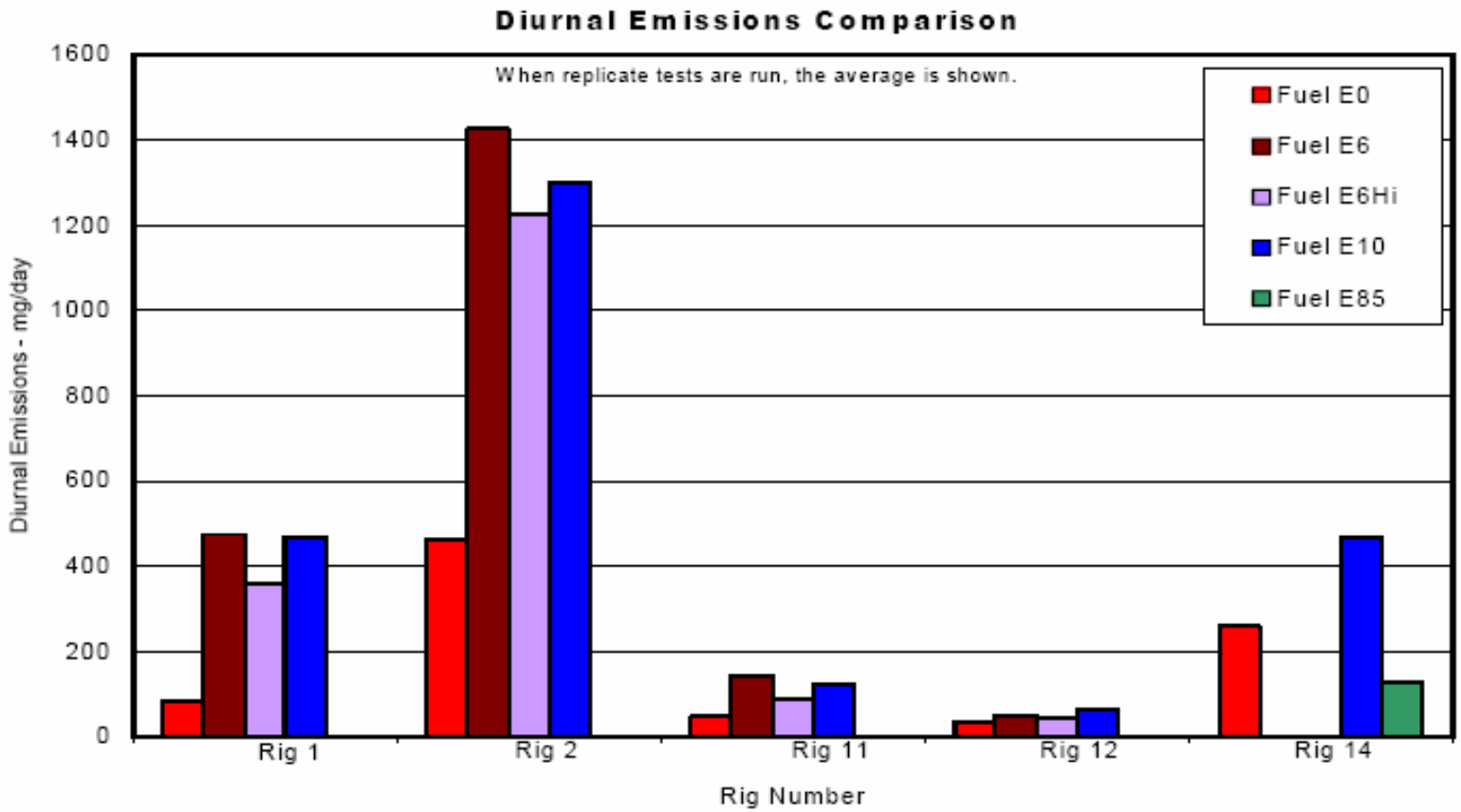
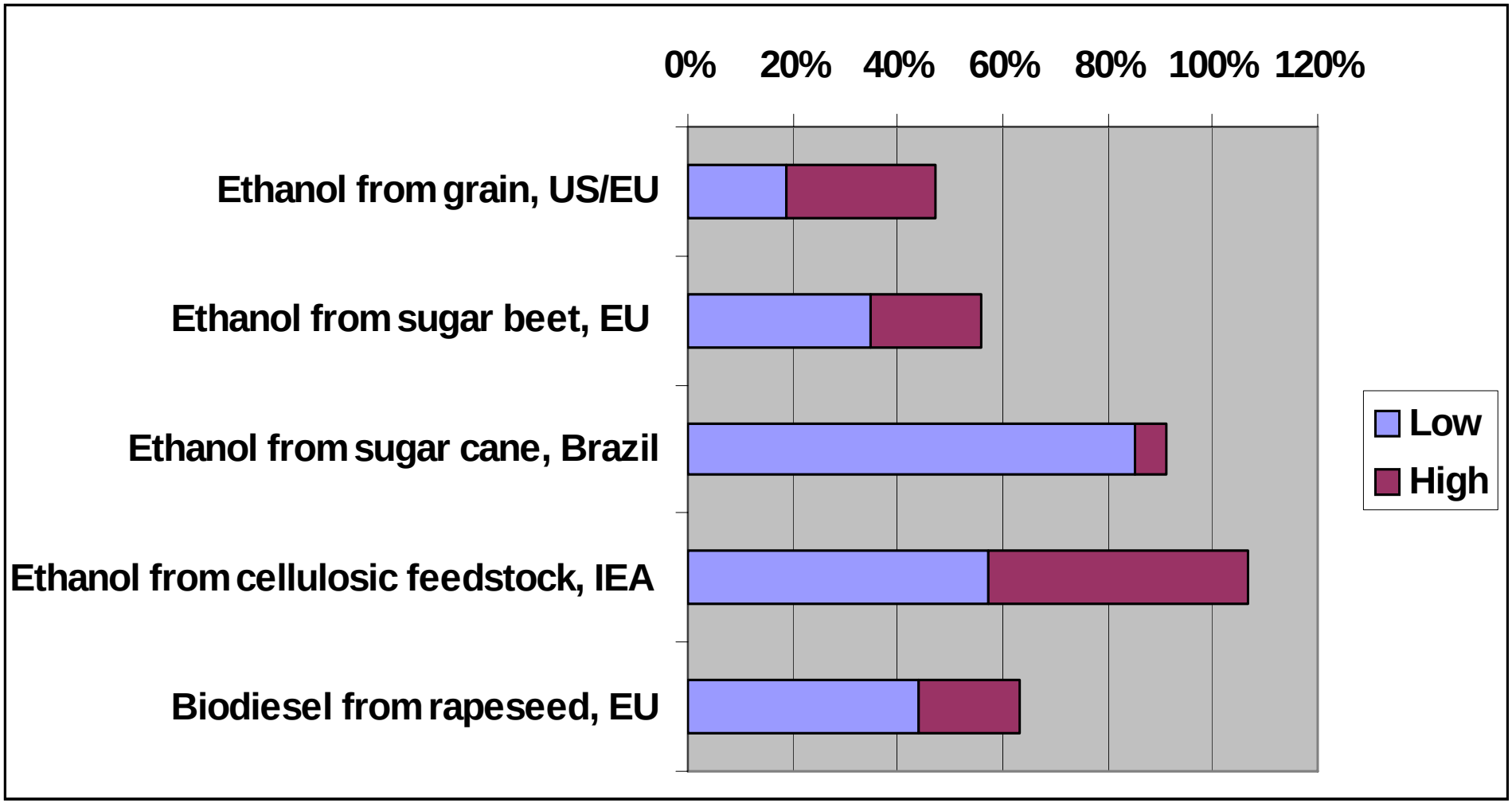


Figure 15

E-65-3 - Results

Diurnal Permeation Rates, mg/day								
	Test Fuel					Differences from E0, mg/day		
Rig	**E0**	**E6**	**E6Hi**	**E10**	**E85**	**E6**	**E6Hi**	**E10**
1	84	475	361	468	-	391	277	385
2	463	1426	1227	1301	-	963	764	838
11	48	144	89	123	-	96	41	75
12	35	50	45	64	-	15	10	29
Avg.	**158**	**524**	**430**	**484**		**366**	**272**	**326**
14	260	-	-	466	128			

Biofuels - Reductions in CO_2- equivalent GHG emissions per km



Source: IEA. Compared to gasoline (for ethanol) and diesel fuel (for biodiesel)

Health and Environmental Effects of Ethanol Use in Gasoline
(API, 2006)

- There is no independent scientific consensus that blending ethanol in gasoline provides a net benefit to human health and the environment.
- Ethanol impacts will be different, but not necessarily less than those of MTBE or other gasoline formulations. For example, ethanol use may increase drinking water well impacts from benzene.
- Oxygen is not required for cleaner burning gasolines. Gasoline without oxygenates will have the least impact on air and water quality.

Biofuels, USTs & Ground Water Quality

- **Biofuels are, like gasoline, complex mixtures**
- **Solubility and biodegradability will be primary properties of interest**
- **Presumably, future UST release scenarios are less likely to be large, long term releases**
- **Presumably, small releases would not likely create major groundwater impacts**
- **“Rapid” biodegradation can be can have positive or negative on overall plume behavior**
- **Will need to evaluate effects on the gasoline or diesel phase of the biofuel (e.g., effects on benzene transport)**
- **Fate / transport in groundwater will need to be evaluated both by lab and field studies at real world sites**
- **If additives are used, their properties and behavior must also be taken into consideration.**

What is Biodiesel?

- **Also sometimes referred to as “FAME” – fatty acid methyl ester**
- **Biodiesel is a methyl ester mixture made from a wide range of vegetable oils, animal fats and tallow, used cooking oils, and yellow and trap greases.**
- **Biodiesel is made through a conventional chemical process -- “transesterification.”**
- **A fuel or fuel additive, bio-degradable, nontoxic**
- **No significant changes needed in infrastructure or engines**

Biodiesel Raw Materials

Oil or Fat Options

Recycled cooking oils
Rapeseed Oil
Cottonseed oil
Soybean oil
Sunflower oil
Corn oil
Beef tallow
Pork lard

Alcohol feeds

Methanol
Ethanol

Catalysts

Potassium Hydroxide
Sodium hydroxide

ASTM D 6751

Standard for (B100) Blend Stock for Distillate Fuels

Property	ASTM Method	Limits	Units
Flash Point	**93**	**130 min.**	**degree C**
Water & Sediment	**2709**	**0.05 max.**	**vol.%**
Carbon Residue (100% sample)	4530	0.05 max.	wt. %
Sulfated Ash	874	0.02 max.	wt. %
Kin. Viscosity, 40C	445	1.9 - 6.0	$mm^2/sec.$
Sulfur S500	5453	0.05 max.	wt. %
S15		15 max	ppm
Cetane	613	47 min.	
Cloud Point	**2500**	**Report**	**degree C**
Copper Corrosion	130	No. 3 max.	
Acid Number	**664**	**0.50 max.**	**mg KOH/g**
Free Glycerin	**6854**	**0.020**	**wt. %**
Total Glycerin	**6854**	**0.240**	**wt. %**
Phosphorous	4951	10 max	ppm
Distillation, T90 AET	1160	360 max	degree C
Na/K	UOP 391	5 max combined	ppm

BOLD = BQ-9000 short list

Properties of Diesel and Biodiesel

Table 1. Selected Properties of Typical No. 2 Diesel and Biodiesel Fuels.

Fuel Property	Diesel	Biodiesel
Fuel Standard	ASTM D975	ASTM D6751
Lower Heating Value, Btu/gal	~129,050	~118,170
Kinematic Viscosity, @ 40°C	1.3-4.1	4.0-6.0
Specific Gravity kg/l @ 60°F	0.85	0.88
Density, lb/gal @ 15°C	7.079	7.328
Water and Sediment, vol%	0.05 max	0.05 max
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, by dif. Wt %	0	11
Sulfur, wt %*	0.05 max	0.0 to 0.0024
Boiling Point, °C	180 to 340	315 to 350
Flash Point, °C	60 to 80	100 to 170
Cloud Point, °C	-15 to 5	-3 to 12
Pour Point, °C	-35 to -15	-15 to 10
Cetane Number	40-55	48-65
Lubricity SLBOCLE, grams	2000-5000	>7,000
Lubricity HFRR, microns	300-600	<300

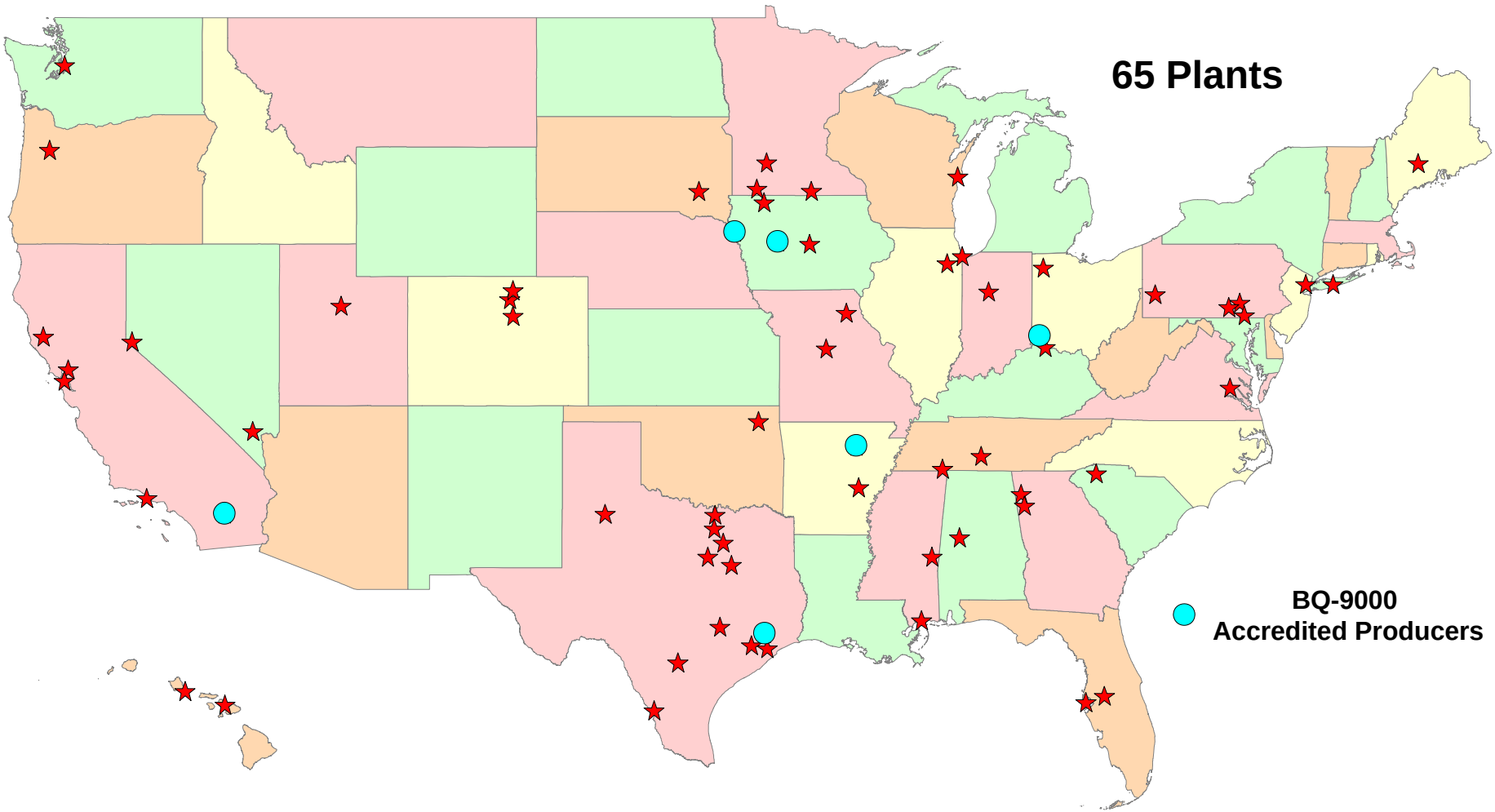
*Sulfur content for on-road fuel will be lowered to 15 ppm maximum in 2006.

Biodiesel…..

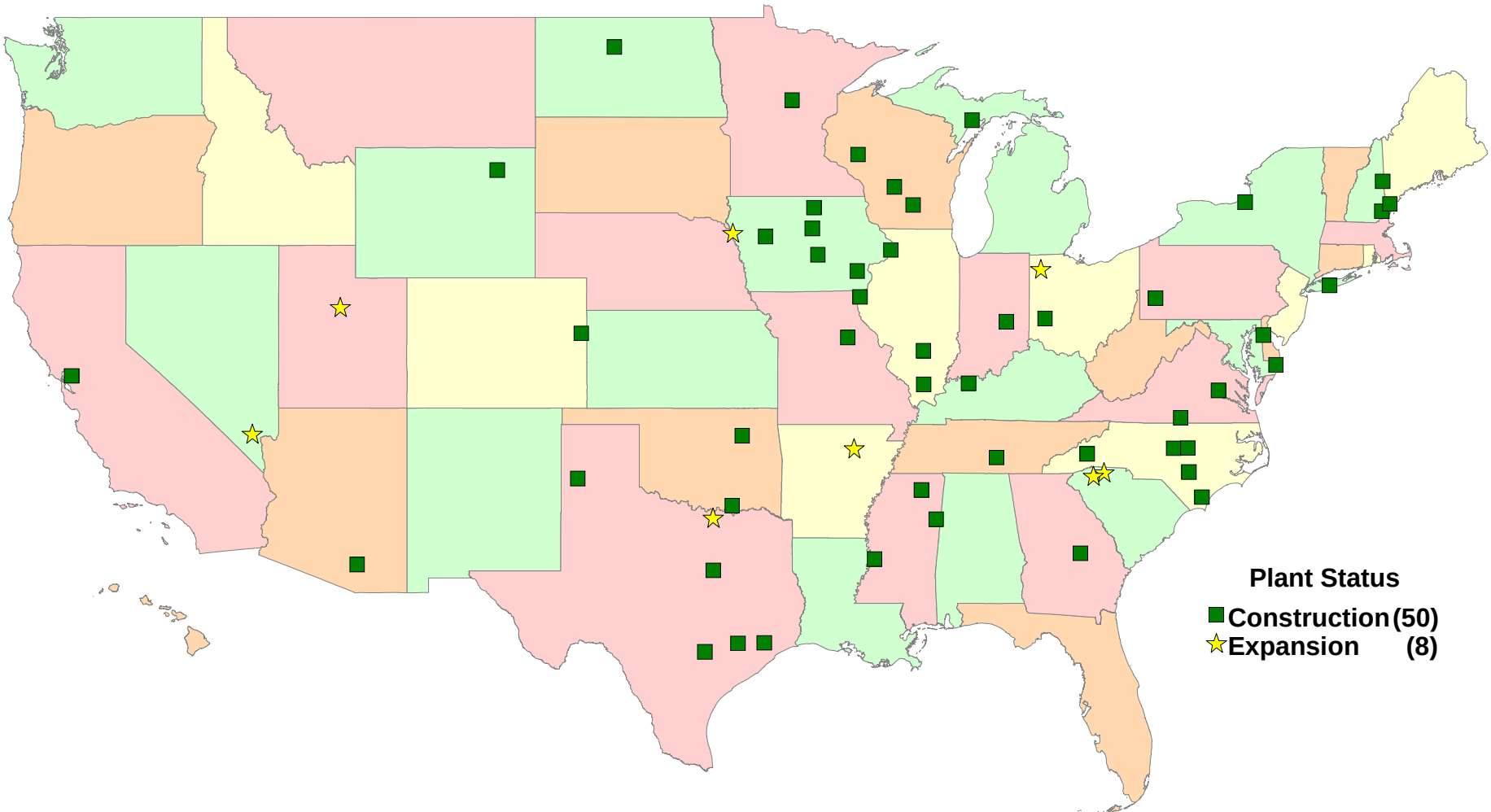
- No negative impact on fuel economy
- Reduces knocking in diesel engines (higher cetane value)
- Produced to ASTM 6751 specifications
- Won’t void engine warranty
- Safer to handle than diesel
- Has a positive energy balance (1 unit of energy in; 3.24 units of energy gained)
- Only alt fuel to complete EPA health effects testing -- no health threats and a 90% reduction in air toxins. Reduces potential risks of cancer and birth defects.

Biodiesel Production Locations

(4/28/06)



Biodiesel Plants Under Construction & Expansion (4/28/06)



Biodiesel Emissions
(compared to #1 or #2 Diesel)

Emissions	B20
Carbon monoxide	-12%
Hydrocarbon	-20%
Particulates	-12%
Nitrous oxides	+2%
Air toxics	-12%-20%

B20 = Mixture of 20% Biodiesel with 80% Diesel

Table 2. Requirements for Biodiesel (B100) Blend Stock as Listed in ASTM D6751-03

Property	ASTM Method	Limits	Units
Flash Point	D93	130.0 min.	°C
Water and Sediment	D2709	0.050 max.	% vol.
Kinematic Viscosity, 40°C	D445	1.9 - 6.0	mm^2/s
Sulfated Ash	D874	0.020 max.	% mass
Sulfur*	D5453	0.0015 max. (S15) 0.05 max. (S500)	% mass
Copper Strip Corrosion	D130	No. 3 max.	
Cetane Number	D613	47 min.	
Cloud Point	D2500	Report to Customer	°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	D4951	0.001 max.	% max.
Distillation Temperature, 90% Recovered (T90)***	D1160	360 max.	°C

*Sulfur content of on-road diesel fuel to be lowered to 15 ppm in 2006

**Carbon residue shall be run on the 100% sample

***Atmospheric equivalent temperature

Variability in Biodiesel Feedstocks

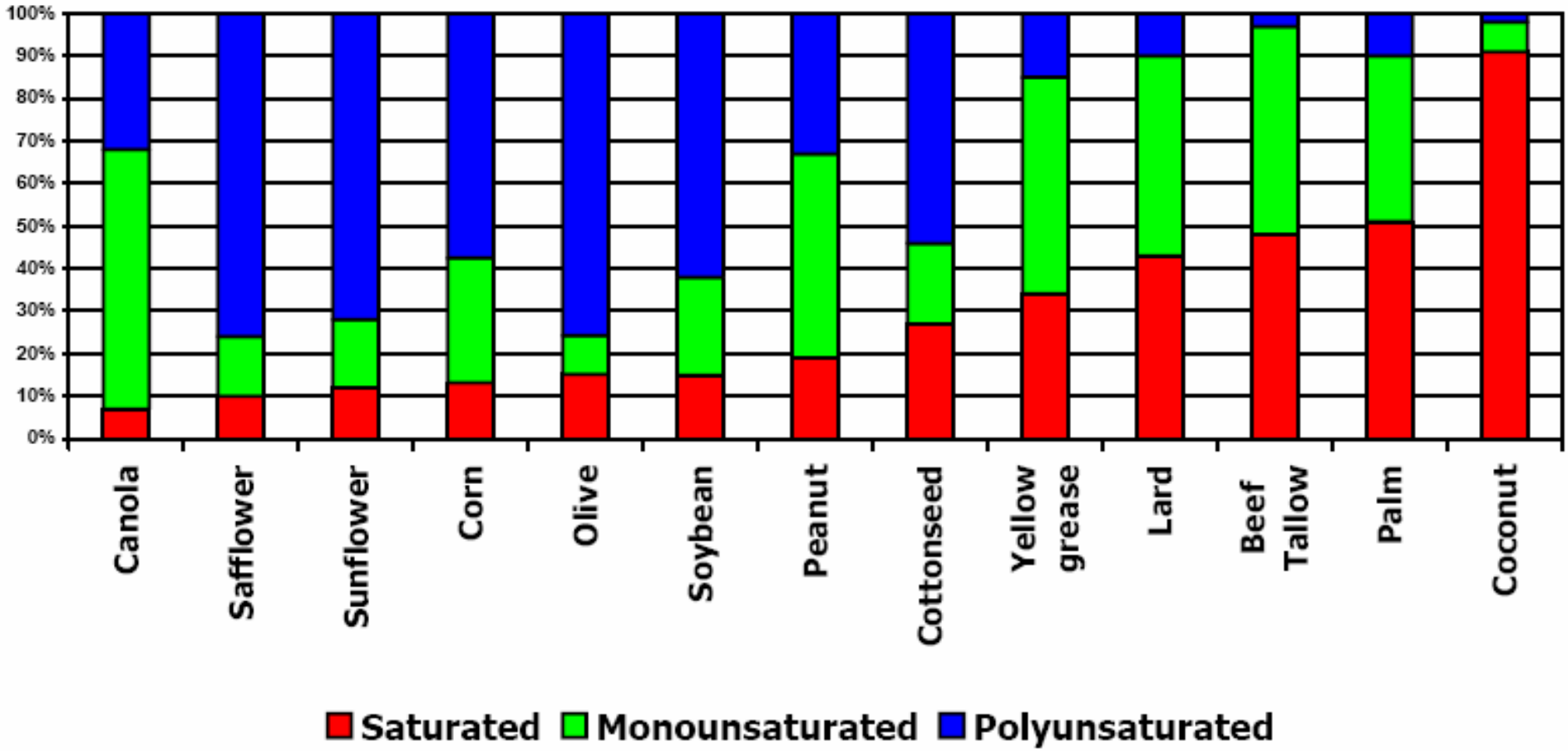


Figure 2. Composition of various biodiesel feedstocks

Source: DoE Biodiesel Handling & Storage, 2006

Biodiesel: Health, Environmental & Safety

From DoE Biodiesel Handling and Storage, 2006:

7. SAFETY, HEALTH, AND ENVIRONMENTAL ISSUES

"Biodiesel contains no hazardous materials and is generally regarded as safe to use. Like any fuel, certain fire safety precautions must be taken. Appendix III contains a Material Safety Data Sheet (MSDS) with details on concerns in these areas."

"A number of studies have found that biodiesel biodegrades much more rapidly than conventional diesel. Users in environmentally sensitive areas such as wetlands, marine environments, and national parks have taken advantage of this property. "

E-diesel

http://www.e-diesel.org/fuel.htm

- Currently considered experimental. Can be used legally in off-road applications but for on-road use EPA must provide permission
- Several demonstration programs in progress with buses
- Comprised of No. 2 diesel fuel and up to 15v% ethanol.
- Typical blend levels for ethanol are 7.7v% and 10v%.
- Proprietary additives are used to help keep the ethanol emulsified in the blend, typically at 0.2v% to 5.0v%

What is E-Diesel (O^2Diesel™) ?

A diesel fuel with:

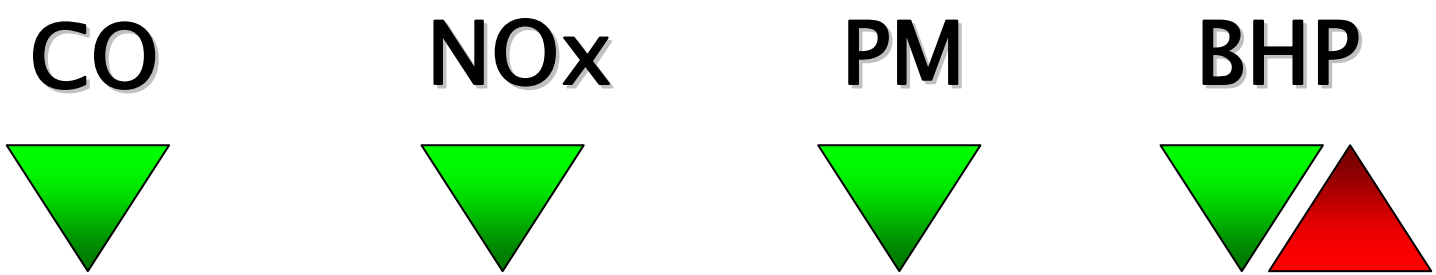
- **Up to 15% Ethanol,**
- **Stabilized with ~1.0vol% proprietary additive -- Cetane enhancement where required**
- **Premium Diesel performance: lubricity, stability, conductivity**
- **Little or no infrastructure or engine changes required**
- **Can be used in heavy-duty on- & off-road diesel engines now!**
- **Currently restricted to fleet operations (flameability)**

O^2Diesel™ Emissions Benefits

"Typical" E-Diesel Emissions Test Results

Colorado School of Mines: Nov. '99 - Dec. '00

EPA No.2 Diesel vs. No.2 O^2Diesel™ (7.7vol% ethanol)



EPA 13-mode Transient Cycle Engine Tests (1991 DDC Series 60)

E-Diesel

- Fuel stability requires the use of cosolvents like ethyl acetate or tetrahydrofuran
- Material compatiblity issues?

Nellis Air Force Base Triples Use of O2Diesel E-Diesel; Company Developing New Fuel for Military

9 September 2006

Nellis Air Force Base (Las Vegas, Nevada) will triple the number of vehicles currently operating exclusively on O2Diesel's ethanol-diesel fuel blend, O2Diesel and extend the demonstration program.

O2Diesel is a blend of 7.7 vol% renewable ethanol, 0.6% of the company's patented and proprietary fuel technology and 91.7% of regular diesel fuel. The ethanol-diesel blend, significantly reduces emissions from diesel-powered equipment, with no loss of power performance or driveability.

The Department of Defense (DoD) is the largest single consumer of diesel and distillate fuels in the United States, and the Air Force consumes the largest amount of alternative fuel within DoD.

E-diesel – flammability limits

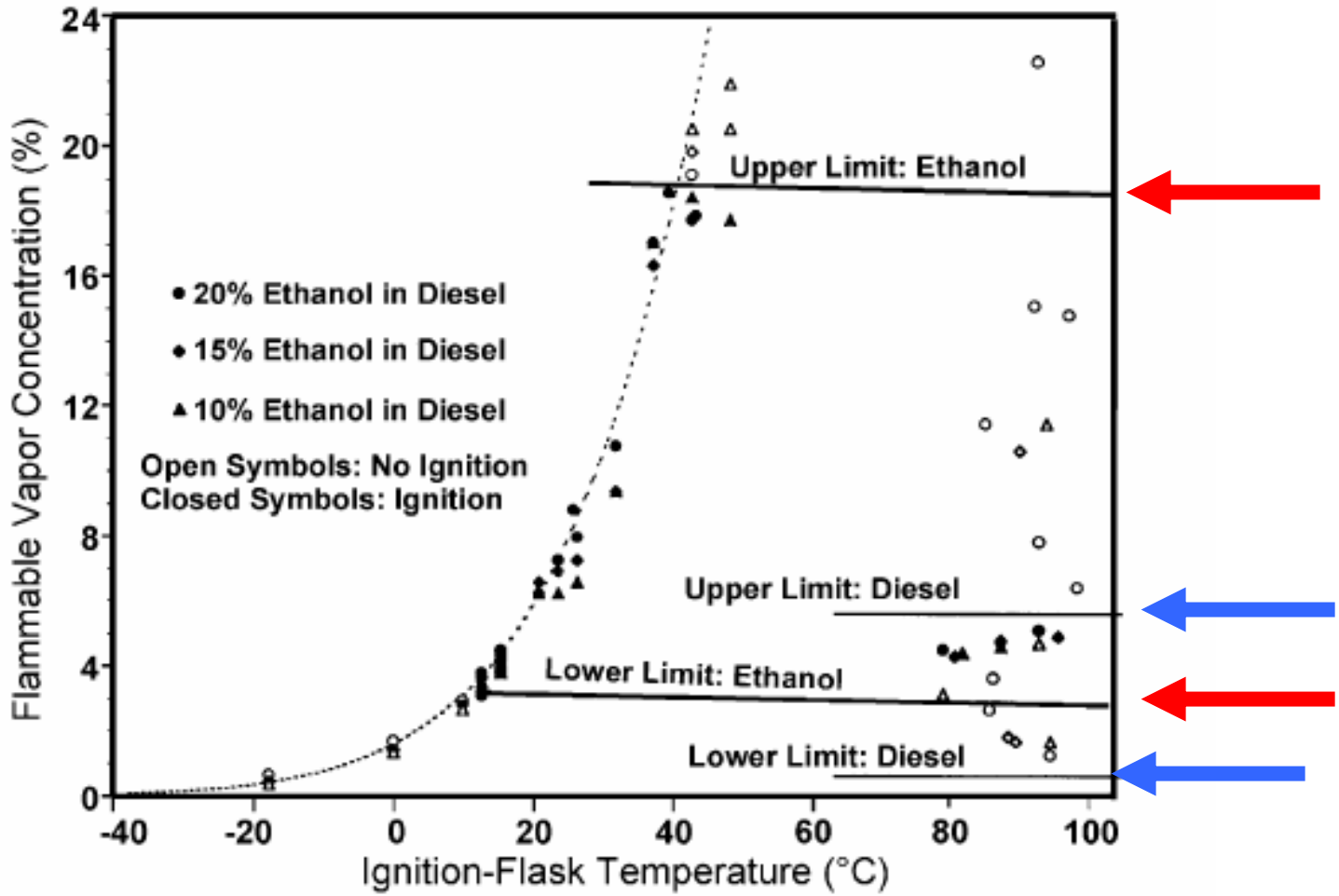


Fig. 4. Flammability characteristics of ethanol–diesel fuel blends (after Battelle, 1998).