Biodiesel Technology and Use

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Rocky Mountain Biodiesel

Biomass Opportunity and Challenges in Indian Country

Denver, CO

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Rocky Mountain Biodiesel

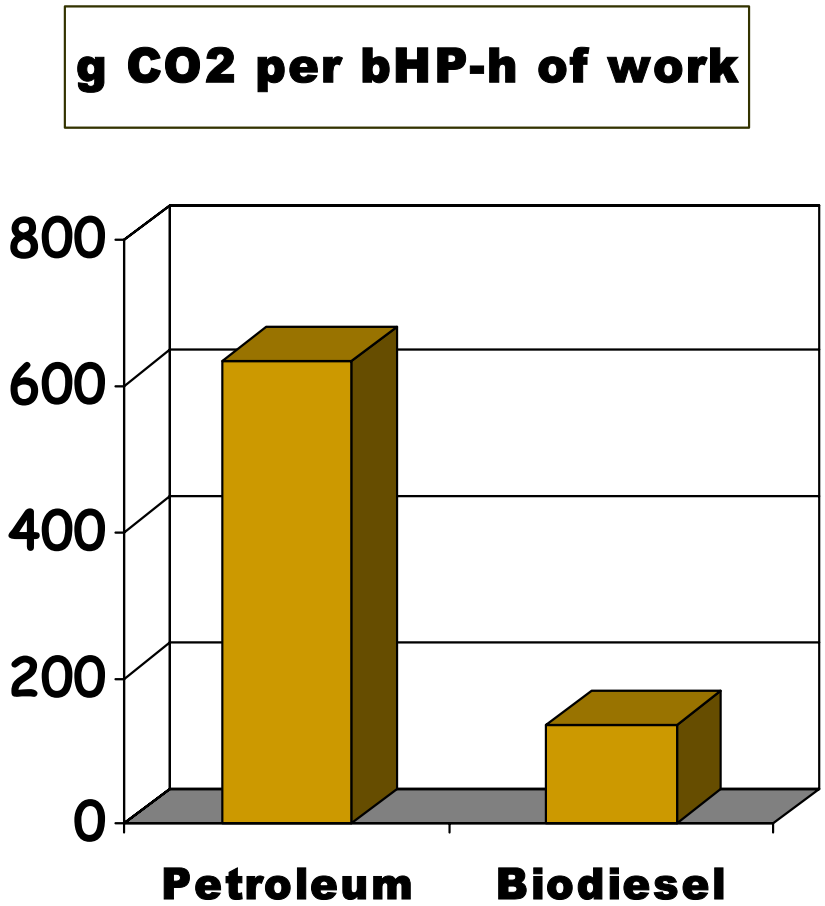
What is Biodiesel ?

- A clean burning renewable fuel made from agricultural products
  - Soy bean oil
  - Sunflower oil
  - Canola and rapeseed oil
  - Animal fats
  - Recycled cooking oil (yellow grease or WVO)

Benefits of Biodiesel

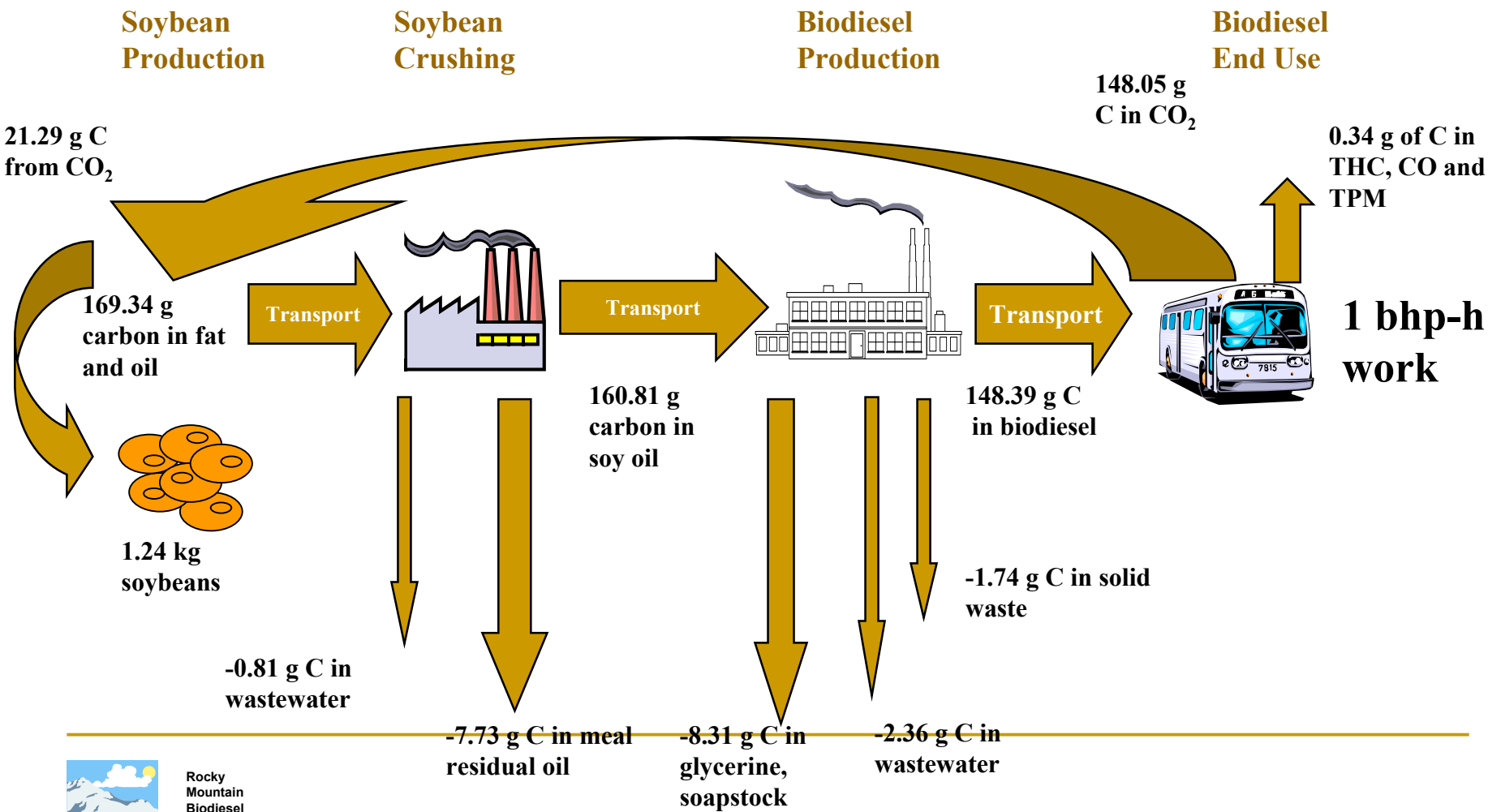
- Renewable
- Supports agriculture
- Supports recycling
- Displaces petroleum
- Adds value to petroleum fuels
- Environmental benefits

Recycles CO_2



- Biodiesel emits 78.5% less CO_2 than petroleum diesel
- Blends exhibit proportionate benefits
  - B20 emits 15.66% less CO_2 than petroleum diesel

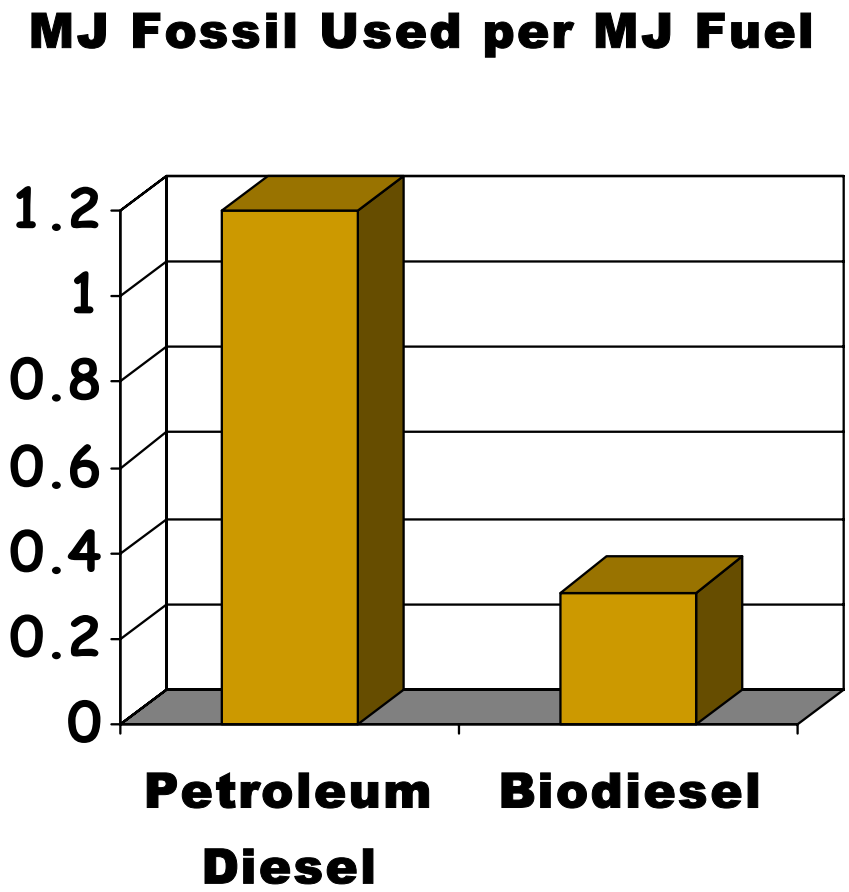
Biodiesel emits 78.5% less CO_2 than petroleum diesel



Rocky Mountain Biodiesel

Energy Efficient

- Biodiesel yields 3.2 units of fuel energy for every unit of fossil fuel consumed in its life cycle.
- Petroleum diesel yields 0.83 units of fuel energy per unit of fossil energy consumed.

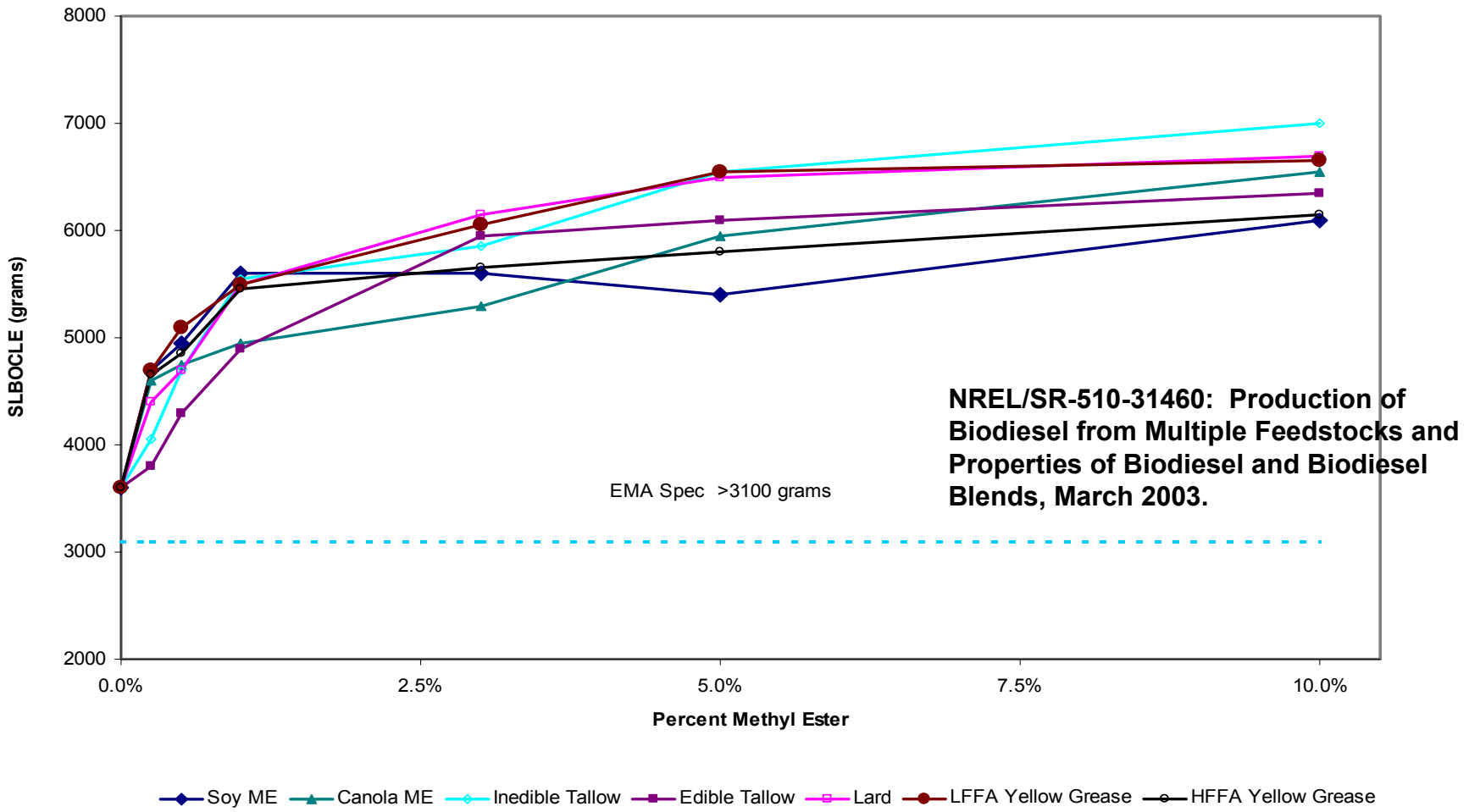


Energy Content

- B100 energy content averages 121,000 BTU/gal
  - Diesel No. 2 averages 131,000
  - Diesel No. 1 averages 126,000

- B20 reduces fuel economy, power and torque by 1-2%
- B5 has 99.5% of the energy content of diesel fuel

Biodiesel is a Lubricant



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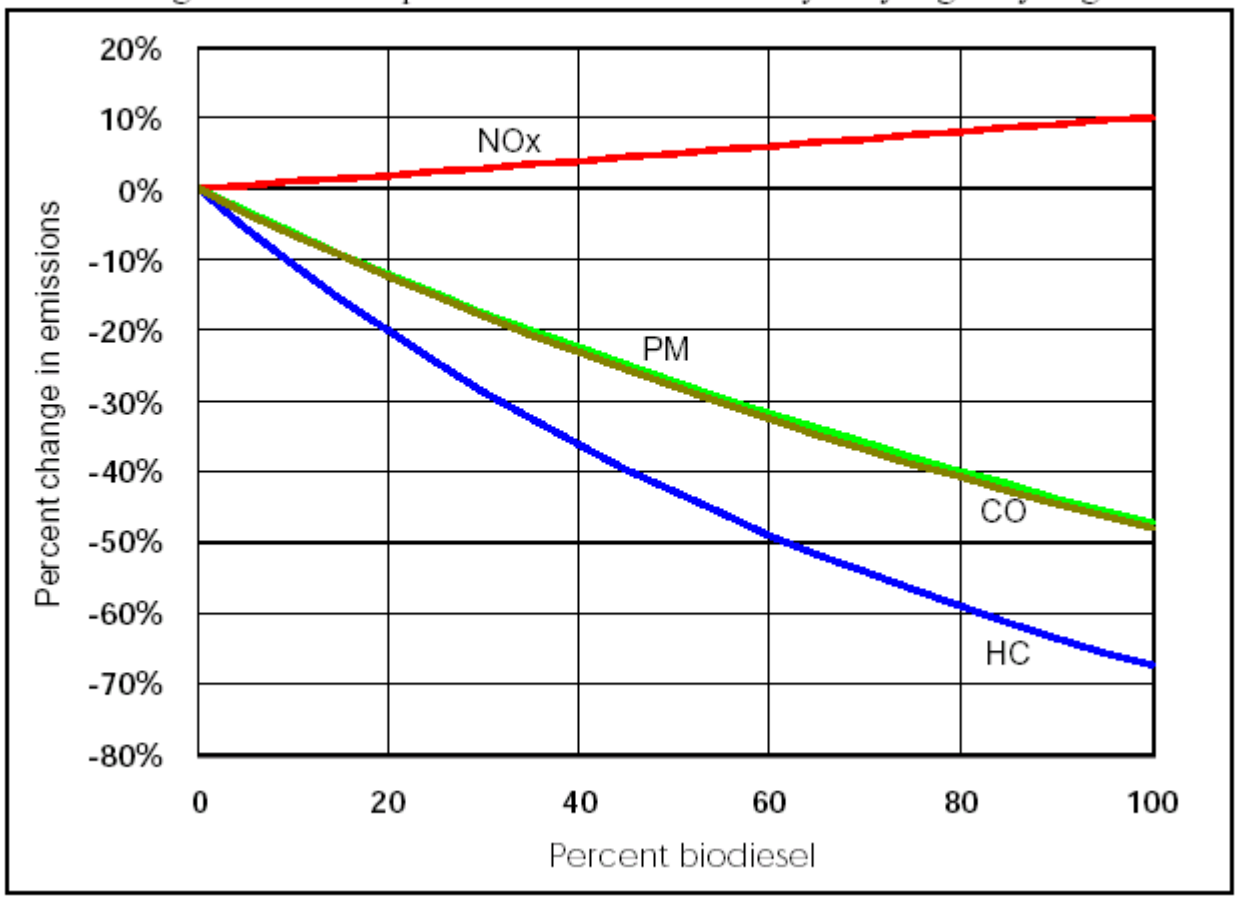
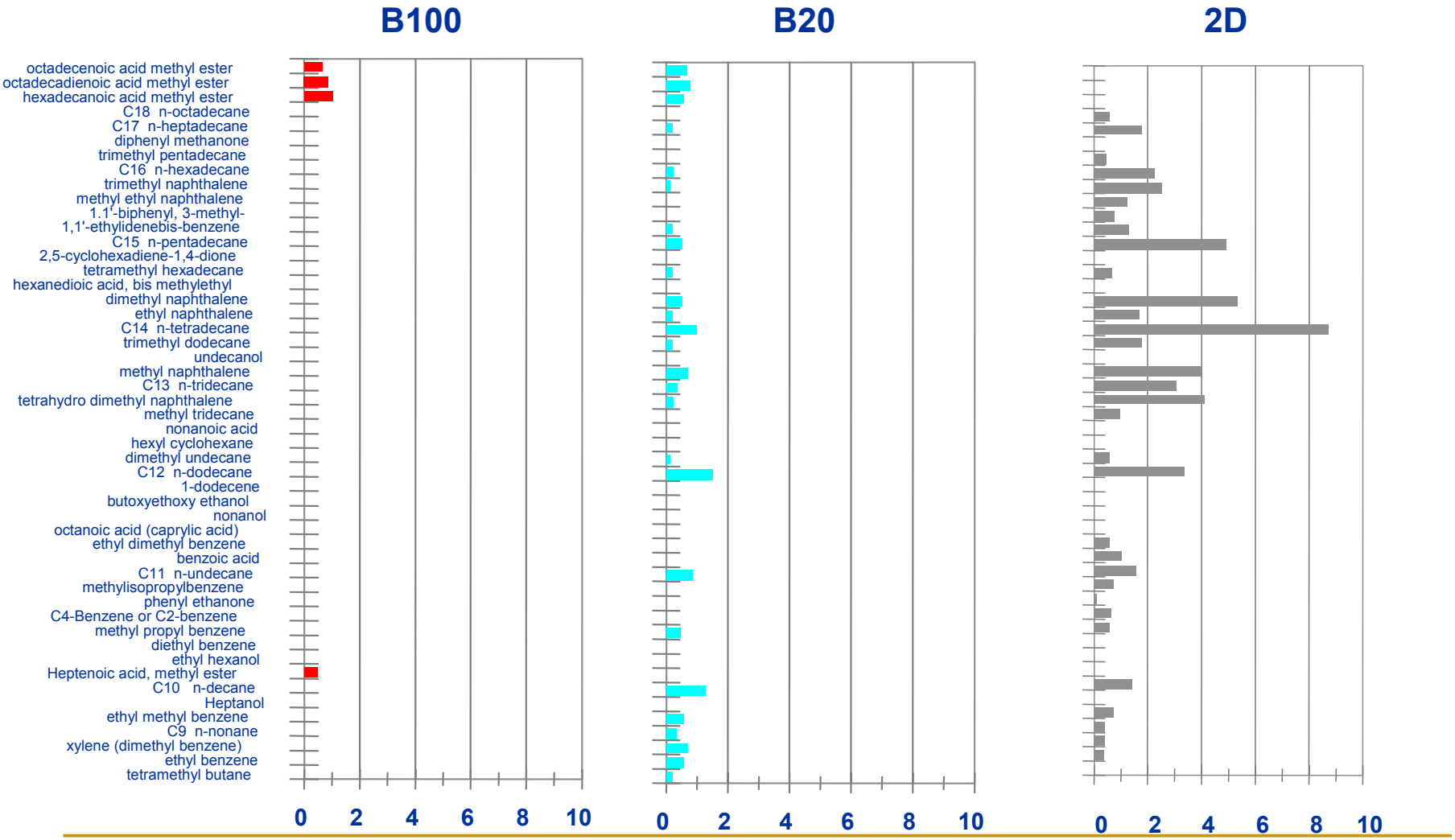
EPA Emission Analysis

Figure ES-A
Average emission impacts of biodiesel for heavy-duty highway engines



HEAVY HC SPECIATION
- CUMMINS N14 ENGINE



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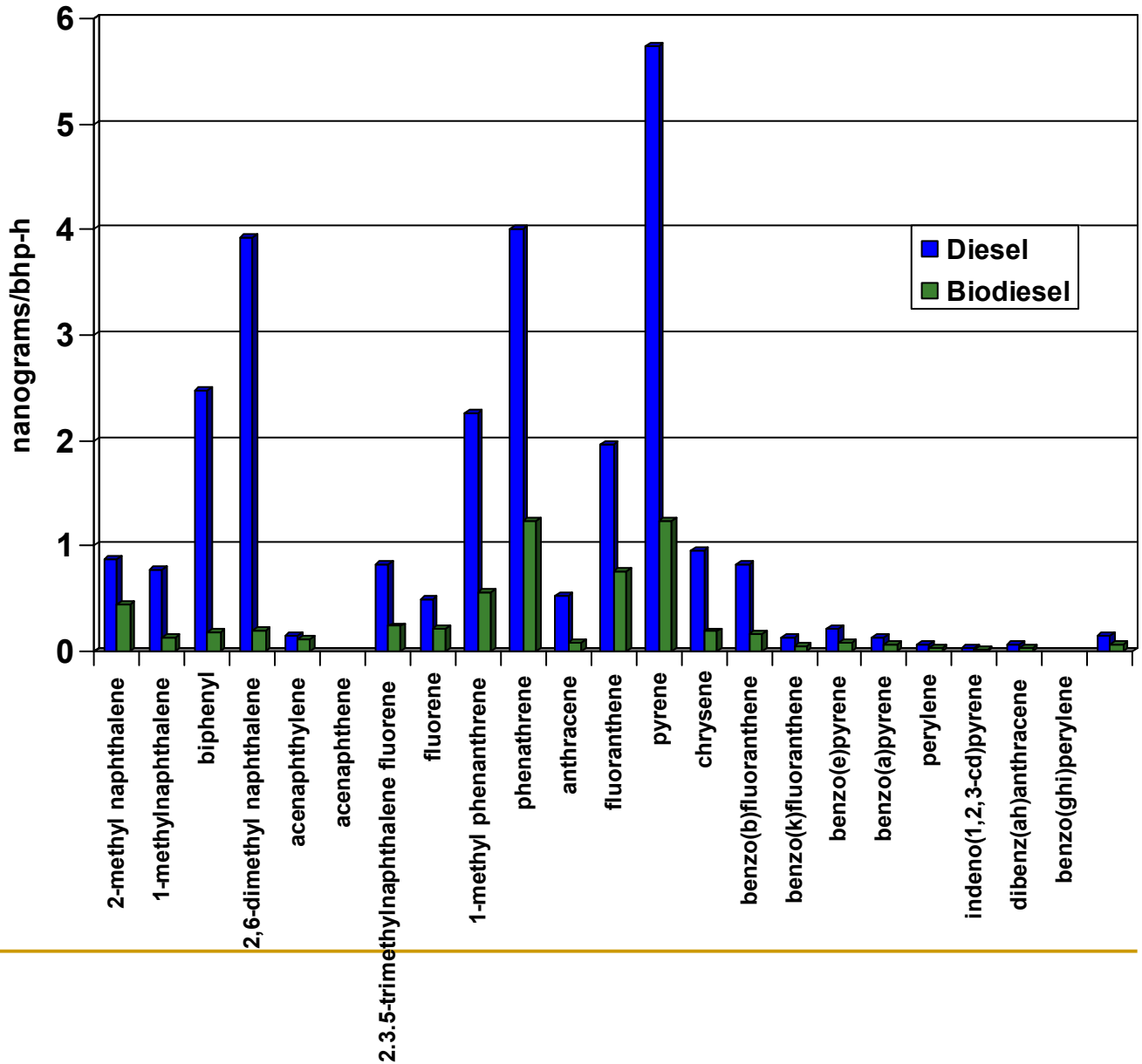
RELATIVE EMISSION RATE (MG/HP-HR)

Tier I Health Effects Data supplied by SWRI, 1997-8

PAH in Semi Volatile PM



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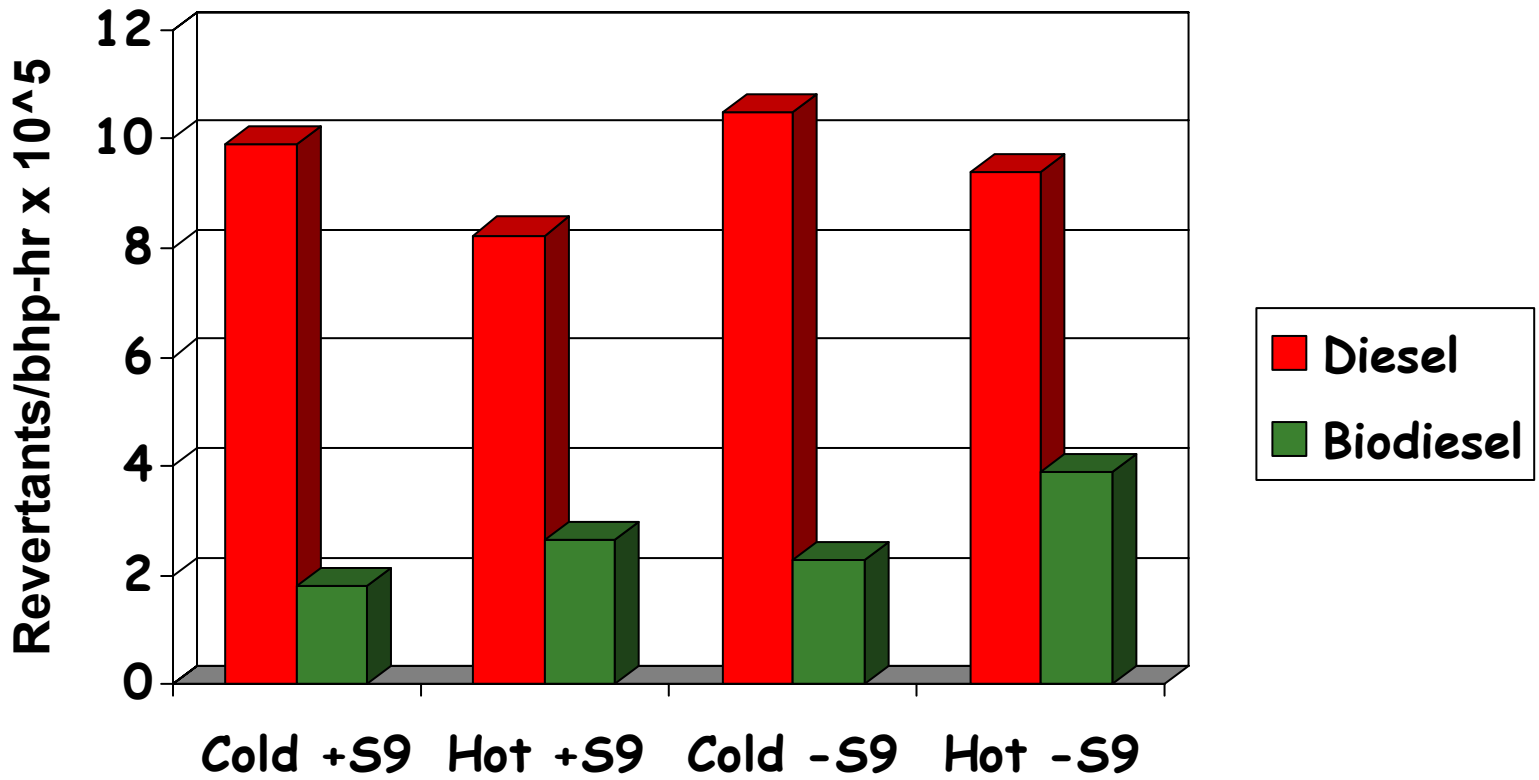
Mutagenicity Testing



Rocky Mountain Biodiesel

EPA Required Tier II Health Effects

- Testing at Lovelace Respitory Research Institute, 1999
- Exposed 10 wk old F & M F344 rats
  - 6 hrs/day, 5 days/wk for 13 weeks
  - Whole diluted emissions, 1998 Cummins B5.9
  - 100 % biodiesel produced from soybean oil
  - 3 levels (H, M, L) plus negative control

LRRI Health Evaluations

- General Toxicity:
  - Body Weight & Feed Consumption, Clinical Observation, Mortality, Hematology (cell counts), Clinical Chemistry (liver & kidney function)
- Pathology (gross and histopathology, all organs)
- Ophthalmology
- Neuropathology
  - Histopathology of brain, spinal cord, nerves
  - Brain glial fibrillary acidic protein
- Reproduction
- DNA Damage:
  - Micronucleus in bone marrow red blood cells
  - Sister chromatid exchange in lymphocytes

Tier II Results

- No Significant Exposure-Related Effects On:
  - Feed Consumption, Clinical Condition, Mortality, Ophthalmology, DNA (Micro-nucleus, Sister Chromatid), Neural Parameters, Reproduction (Fertility, Teratology)
- Minor Exposure Effects Deemed Not Biologically Significant
  - Body and Organ Weights:
    - Lower liver weight, Higher relative lung weight in F, Higher relative testis weight in M
  - Clinical Chemistry:
    - 4 Liver-related parameters decreased, Glucose increased

Tier II Results cont.

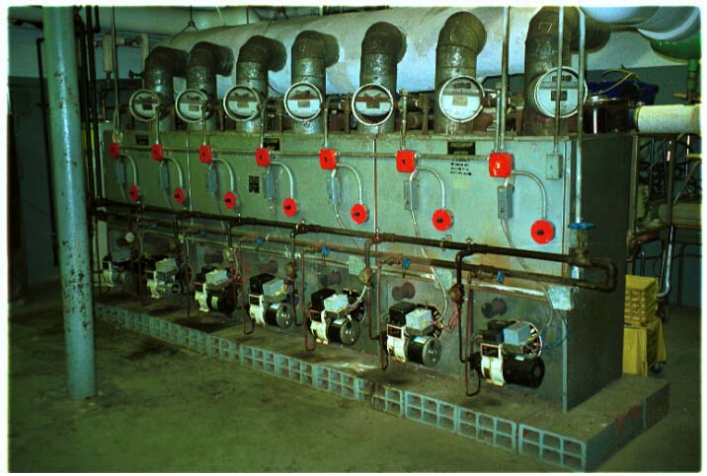
- Minor Exposure Effects:
  - Lung Histopathology:
    - Dose-related increase in macrophages containing particulate matter
    - Minor alveolar cell changes in 4/30 females in the high level group
    - Caused by particles, but not toxic effect
    - Effect diminished after 28 days non-exposure
- Only Biologically Significant Biodiesel Exhaust Exposure Effect was a Small Effect in Lungs at the High Exposure Level:
  - Increased macrophages in M & F
  - Slight increase in F lung weight
  - Cellular changes in a few F
- Based on this, the No Observable Adverse Effects Level (NOAEL) was the Medium Level

Biodiesel—The Healthy Alternative

- Based on the health benefits established for biodiesel emissions, many groups are using biodiesel to reduce health risks
  - Miners
  - School bus fleets
- Some people think the exhaust smells good too! Even B20 exhaust has a more pleasant odor than diesel No. 2.

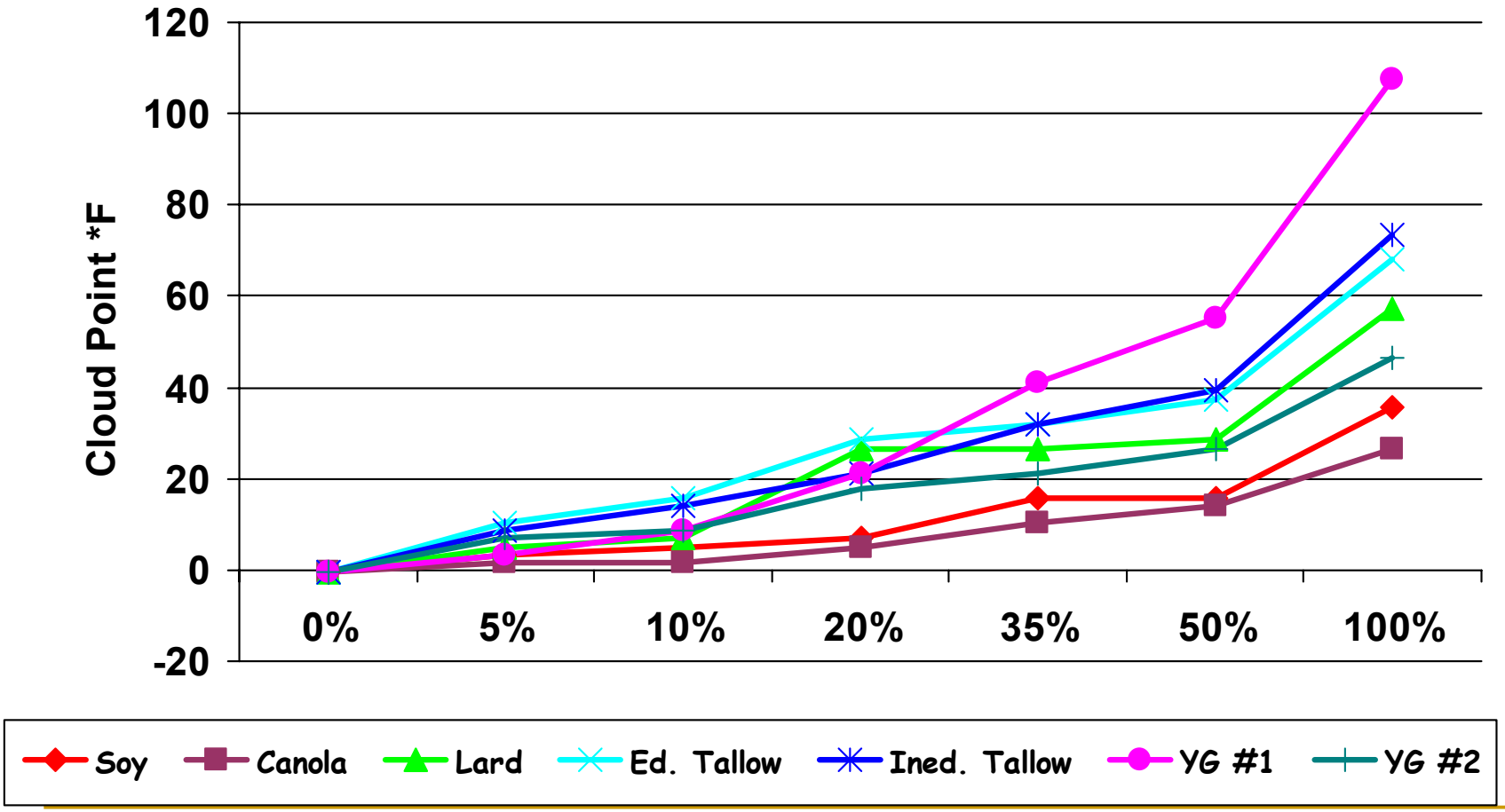
Benefits of Biodiesel

- Blends with petroleum diesel
- Blends up to 20% biodiesel can be used in any diesel equipment with out modification
  - Vehicles
  - Storage
  - Off-road
  - Heating oil
  - Boiler fuels



- No new investments required

Cloud Point Rises as Biodiesel Fraction Increases



Rocky Mountain Biodiesel

ASTM Biodiesel Definition

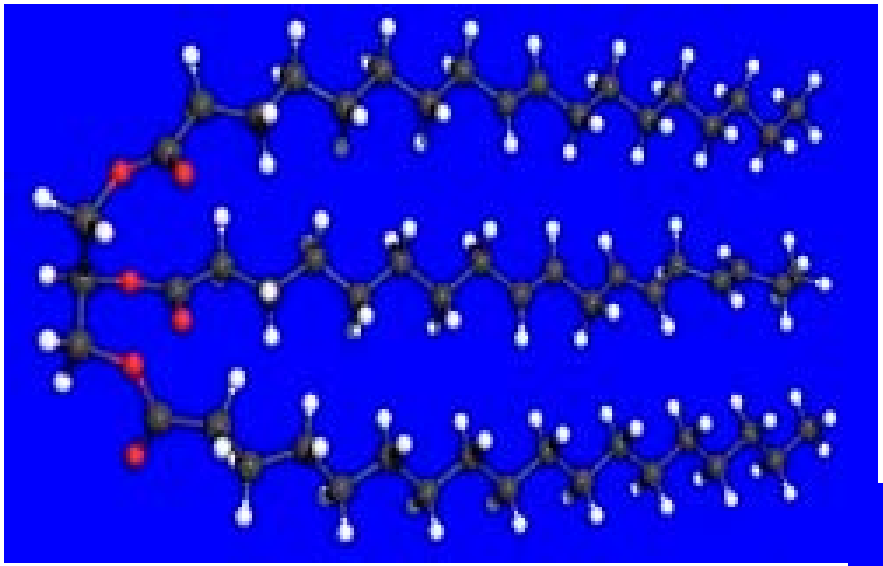
- *biodiesel,* n. -- a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.

- *biodiesel blend,* n. -- a blend of biodiesel fuel with petroleum-based diesel fuel designated BXX, where XX is the volume percent of biodiesel.

Biodiesel Ingredients

- Oil or fats +
  - Soy
  - Corn
  - Sunflower
  - Canola
  - Rapeseed
  - Mustard
  - Cottonseed
- Alcohol +
  - Methanol
  - Ethanol
- Catalysts
  - Sodium hydroxide
  - Potassium hydroxide
- Plus
  - Heat
  - Mixing

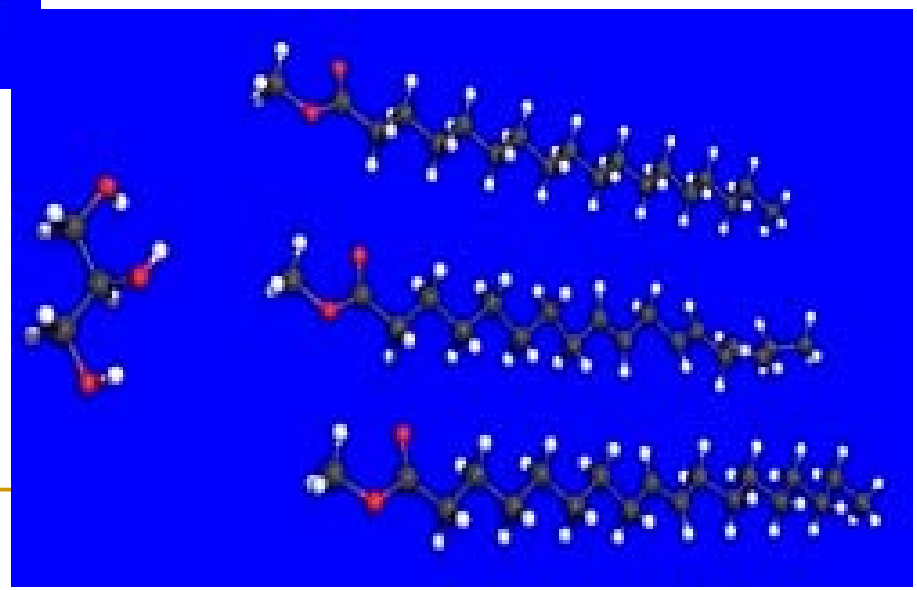
What are fatty acid alkyl esters?



Triglyceride:
Fat or Oil
molecule

Biodiesel
molecules

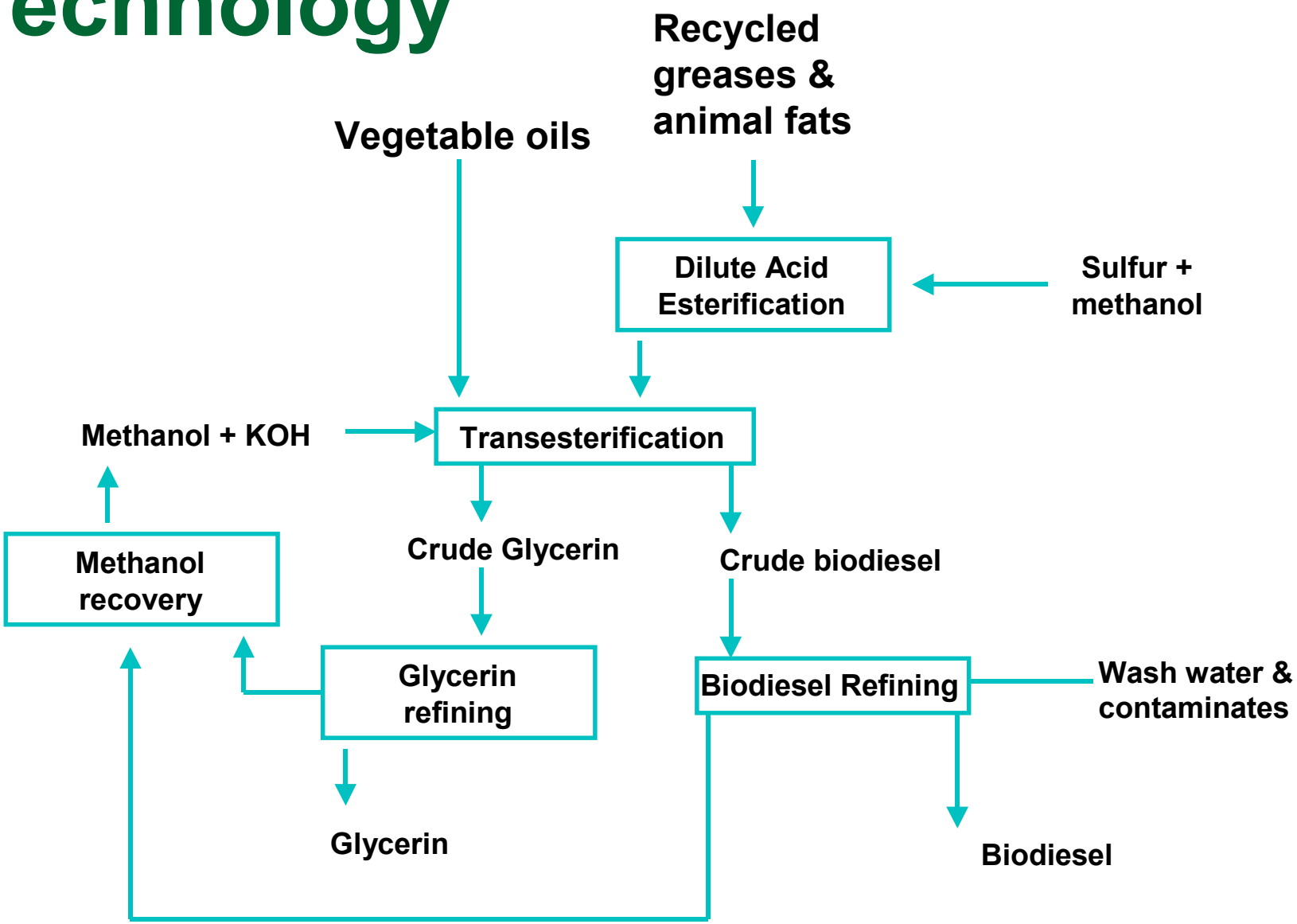
Glycerin
molecule



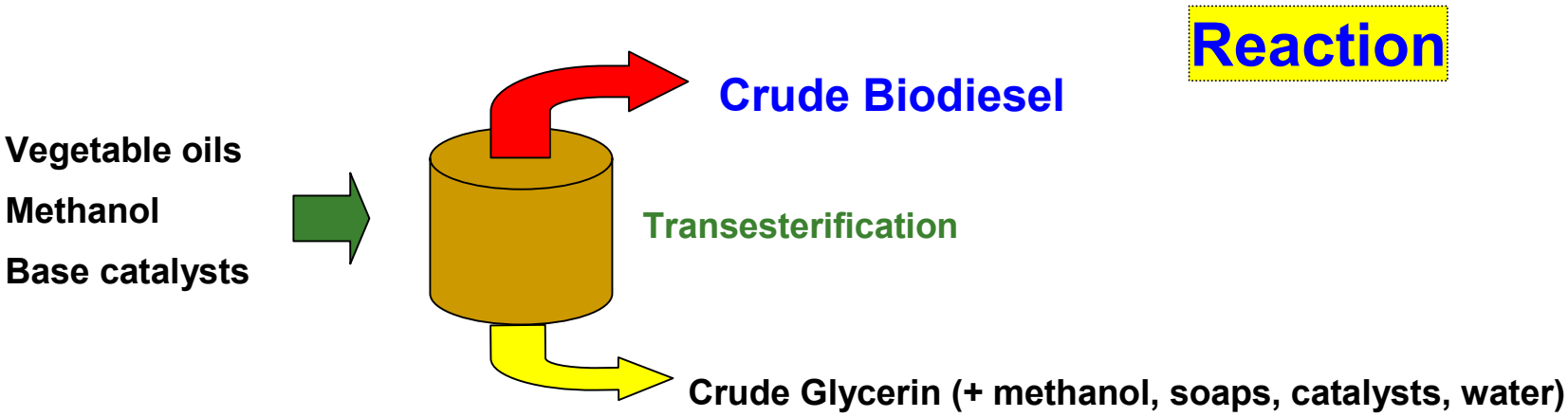
Pictures courtesy of

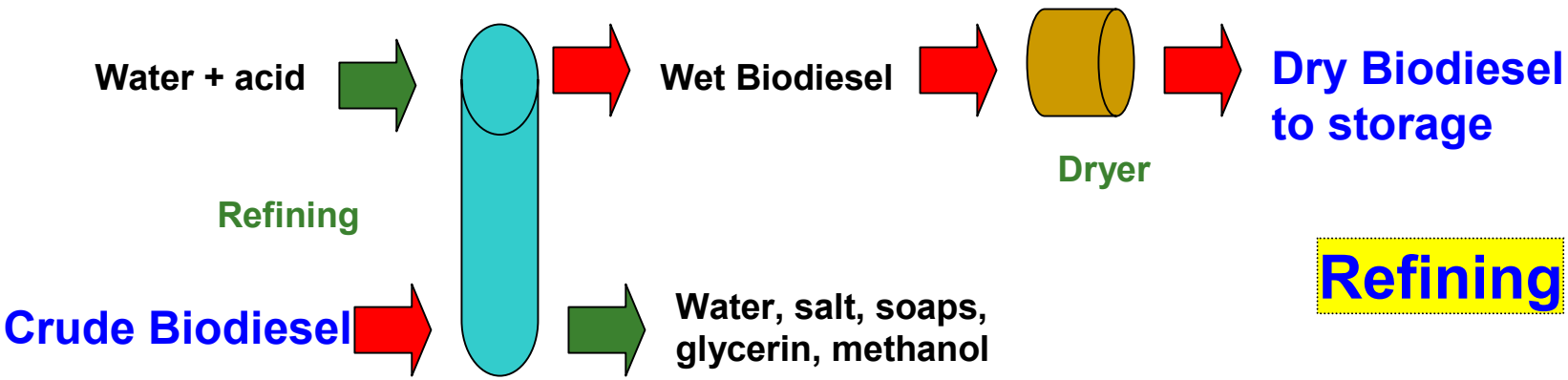
Campa® als Kraftstoff

Technology


Recycled greases & animal fats
Vegetable oils
Dilute Acid Esterification
Sulfur + methanol
Methanol + KOH
Transesterification
Methanol recovery
Crude Glycerin
Crude biodiesel
Glycerin refining
Biodiesel Refining
Wash water & contaminates
Glycerin
Biodiesel

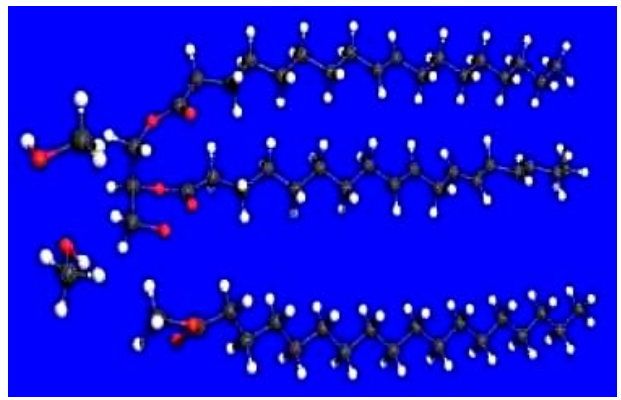
Quality Processing





Good Production Technology

- Reaction
  - Transforms 99% (or more) of fats and oil molecules to fatty acid esters
  - Minimizes unreacted or partially reacted fatty acids
- Refining removes
  - Neutralized catalysts
  - Methanol
  - Glycerin
  - Soaps
  - Water



ASTM D 6751 -- B100 for Blending

Property	ASTM Method	Limits	Units
Flash Point	93	130.0 min.	degree C
Water & Sediment	2709	0.05 max.	vol.%
Carbon Residue (100% sample)	4530	0.050 max.	wt. %
Sulfated Ash	874	0.020 max.	wt. %
Kinematic Viscosity, 40C	445	1.9-6.0	$mm^2/sec.$
Sulfur	5453	0.05 max.	wt. %
Cetane	613	47 min.	
Cloud Point	2500	By Customer	degree C
Copper Corrosion	130	No. 3 max.	
Acid Number	664	0.80 max.	mg KOH/g
Free Glycerin	6584	0.020	wt. %
Total Glycerin	6584	0.240	wt. %
Phosphorus	4951	0.0010 max	wt, %
Vacuum distillation	1160	T-90 $\leq$ 360	^oC max

Commercial Technology

- Century old technologies
- Numerous patents
- Dozen + technology vendors
- 99% + yields
- Any feedstock
- Sizes from 0.5 million gal/yr to 60 mil gal/yr
- With and without crushing technology

Vendor Qualifications

- Existing facilities operating in good standing
- Performance guarantees
  - Quality guarantees (ASTM)
  - Cost guarantees
  - Yield guarantees
- Technical support
- Training
- Feedstock optimization

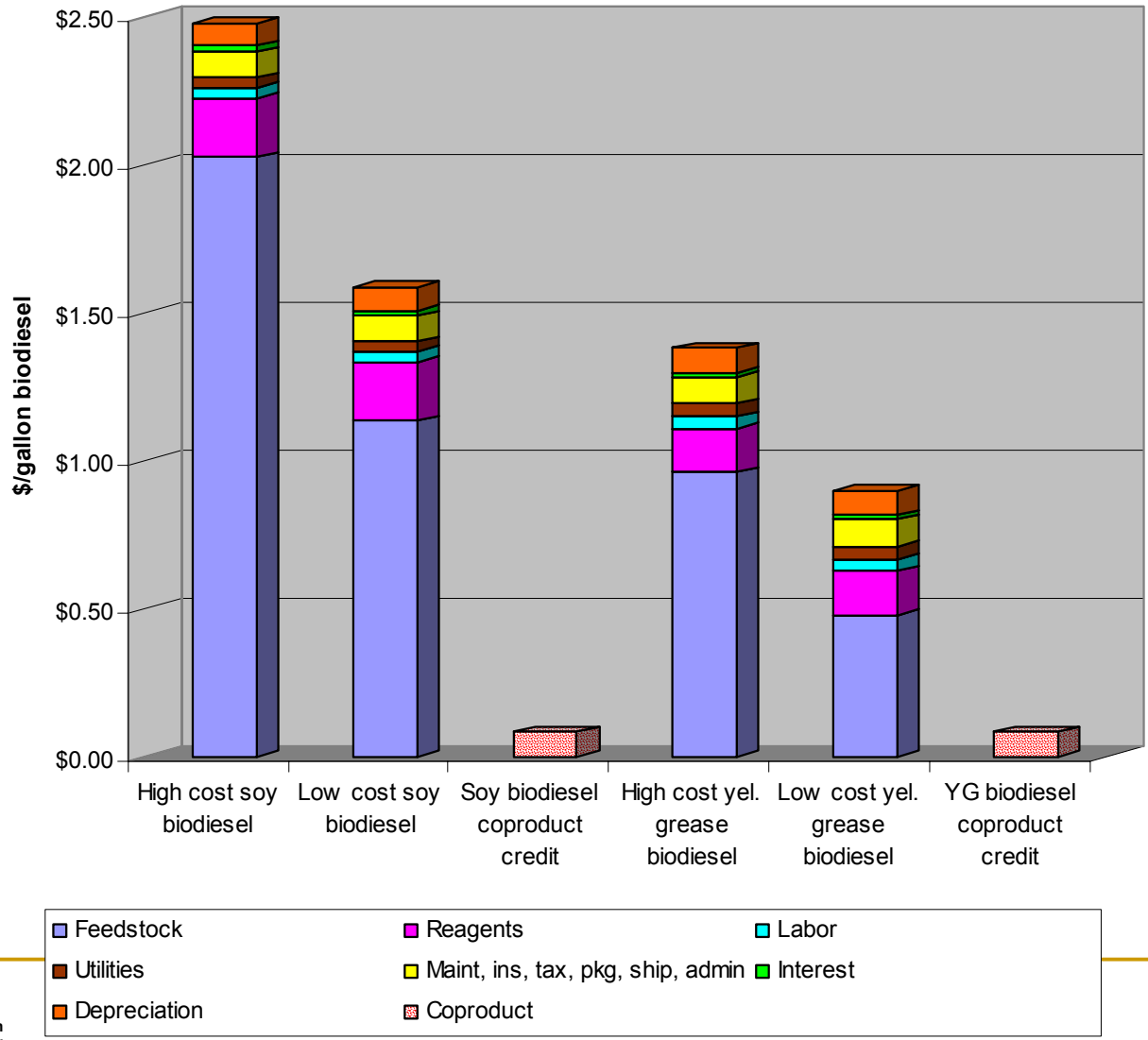
Feedstock Variables

- What kind of feedstock
  - Free fatty acid content
  - Price
  - Cold flow characteristics
  - Supply volumes
- Mixing feedstocks
  - Controls price
  - Controls properties
  - Complicates USDA payments
  - Complicates potential excise tax incentives

Scaling up “home brew”

- Home brewers’ DO NOT make ASTM quality biodiesel on a consistent basis
  - Generally using low temperatures, no pressure
- You can invest in scale up development
  - Include extra costs for
    - Engineering
    - Longer shakedown period
    - Equipment replacement
    - Technical assistance
    - Higher working capital

Production Costs



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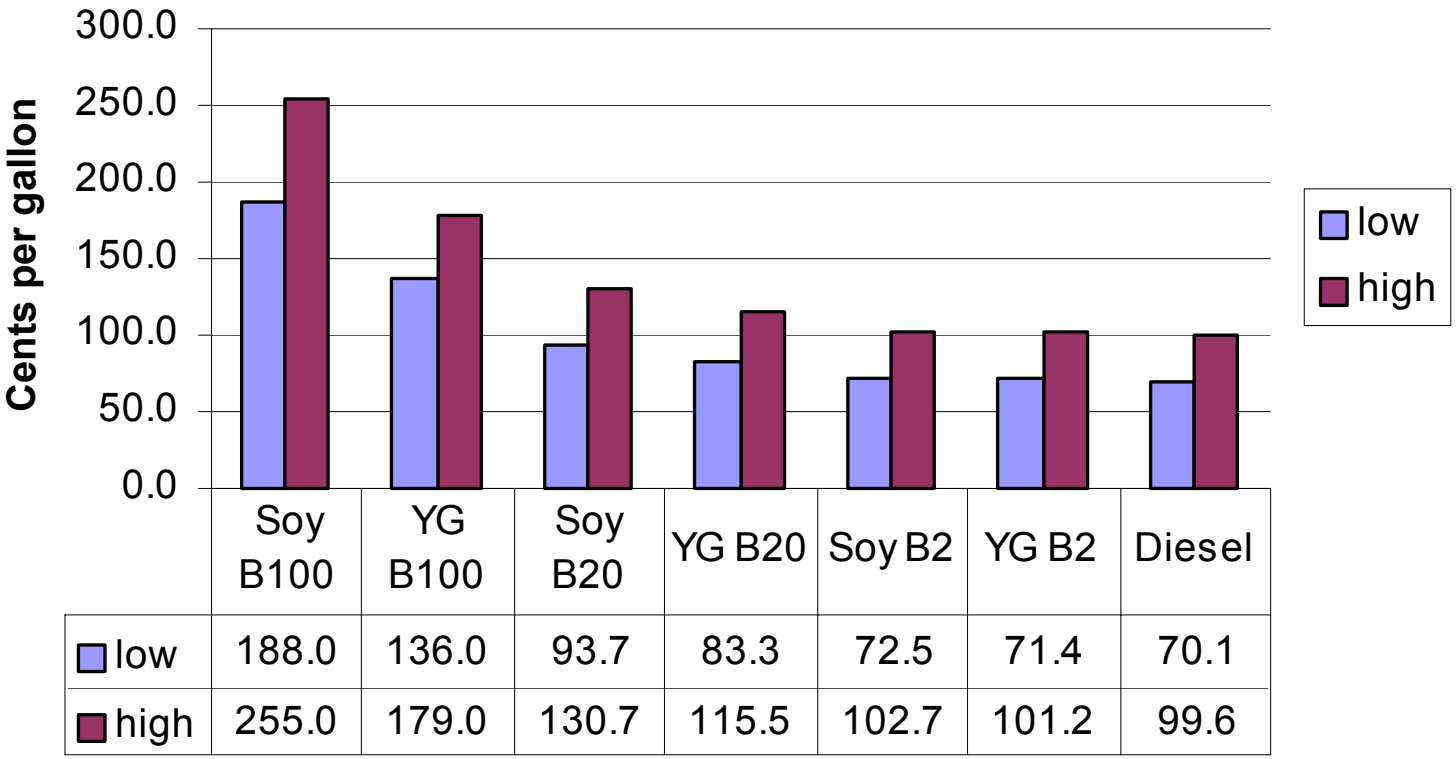
B2 to B20 Can be Affordable Premium Fuels



	Soy B100	YG B100	Soy B20	YG B20	Soy B2	YG B2	Diesel
low	188.0	136.0	93.7	83.3	72.5	71.4	70.1
high	255.0	179.0	130.7	115.5	102.7	101.2	99.6

Biodiesel Markets

- B100
  - Expensive, technical limitations, not recommended
- B20
  - Bulk fuel fleets, primarily government, some retail
  - High cost offset by emission benefits
- B2
  - Commercial as premium diesel
  - Lubricity value, fuel diversity

Market Issues

- What markets are available?
  - B20, who are they
  - B2, which petroleum distributors?
- What volumes will move
  - In the first six months
  - By the second year
- What will you have to do to compete?
  - Vis-à-vis other biodiesel distributors/producers
- How will you build your markets?

Potential Incentives

- Federal Excise Credit
  - Reduces on road taxes paid by Blenders
  - 1 cent per 1 percent vegetable oil biodiesel
  - 0.5 cent per 1 percent WVO biodiesel
- Blenders' Income Tax Credit
  - Same as above except for OFF-road uses
  - Limited by income tax obligations
- States offering a variety of incentives

Renewable Fuel Standard

- X% of (on road gasoline + on road diesel) must be renewable by 2012/2015
  - Not passed into law yet
  - Ethanol is cheaper per gallon than biodiesel
  - Refiners will use ethanol
  - Some refiners will use biodiesel
    - Farm belt
  - Won't create big markets for biodiesel without the excise tax credit

Near Term Biodiesel Supplies

Current Supplies equivalent to using 5.5% biodiesel in all on-road diesel markets in the U.S. in 2003

	Million Lbs/yr	Million Gal Oil Per year	Million Gal B100 Per year
Soy	2,250	292	304
Corn	1,130	147	153
Sunflower	465	60	63
Canola[1]	0	0	0
Cottonseed	140	18	19
Peanut, Safflower, Linseed	190	25	25
Edible tallow	465	60	63
Lard	85	11	11
Inedible tallow & greases	2,837	368	383
Other fats & oils	399	52	54
Poultry fat	221.5	29	30
Fish oils	27.9	4	4
Yellow grease	406	53	55
Trap grease	3,808	495	514
Total biomass oils	13,424	1,614	1,677

Summary

- Feedstocks are available
- Feedstock cost generally higher than petroleum diesel wholesale cost
- Production technology available for most feedstocks/scales
- Environmental, health benefits creating demand
- B2 & B20 markets growing
- Off-road uses growing
- Without incentives, economics not strong
- Incentives could create a boom