Renewable Diesel

DEER

August 2007

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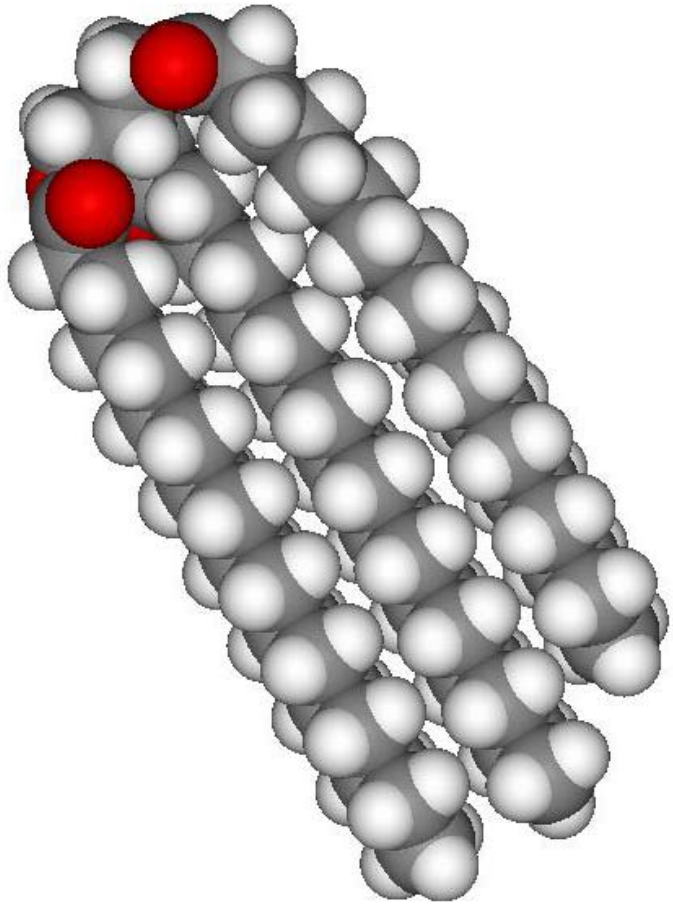
What Are Fats/Oils?

- Fats & Oils Have the Same Chemistry
  - Fats are solid
  - Oils are liquids
- Triglycerides
  - 3 Carbon tri-alcohol, glycerin
  - 3 Long-Chain (typically C_{16}-C_{18}) fatty acids attached to glycerin – ester linkage



Animal Fat

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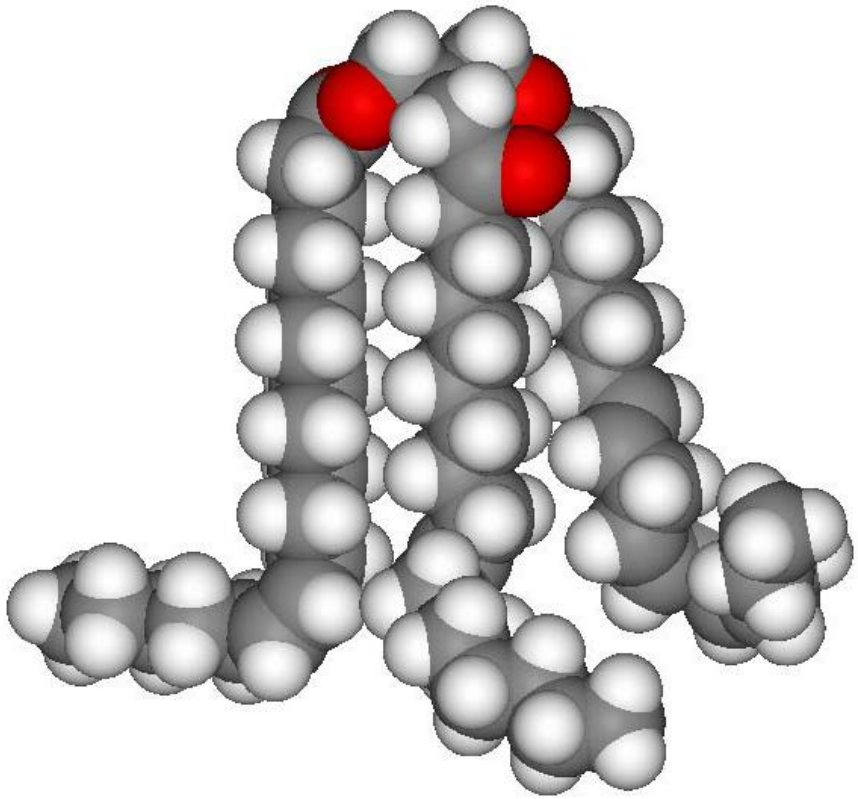
Animal Fat vs. Vegetable Oil

- Animal Fat
  - More highly saturated
- Vegetable Oil
  - More unsaturation (>50% di & poly)
  - Lower melting point



Soy Oil

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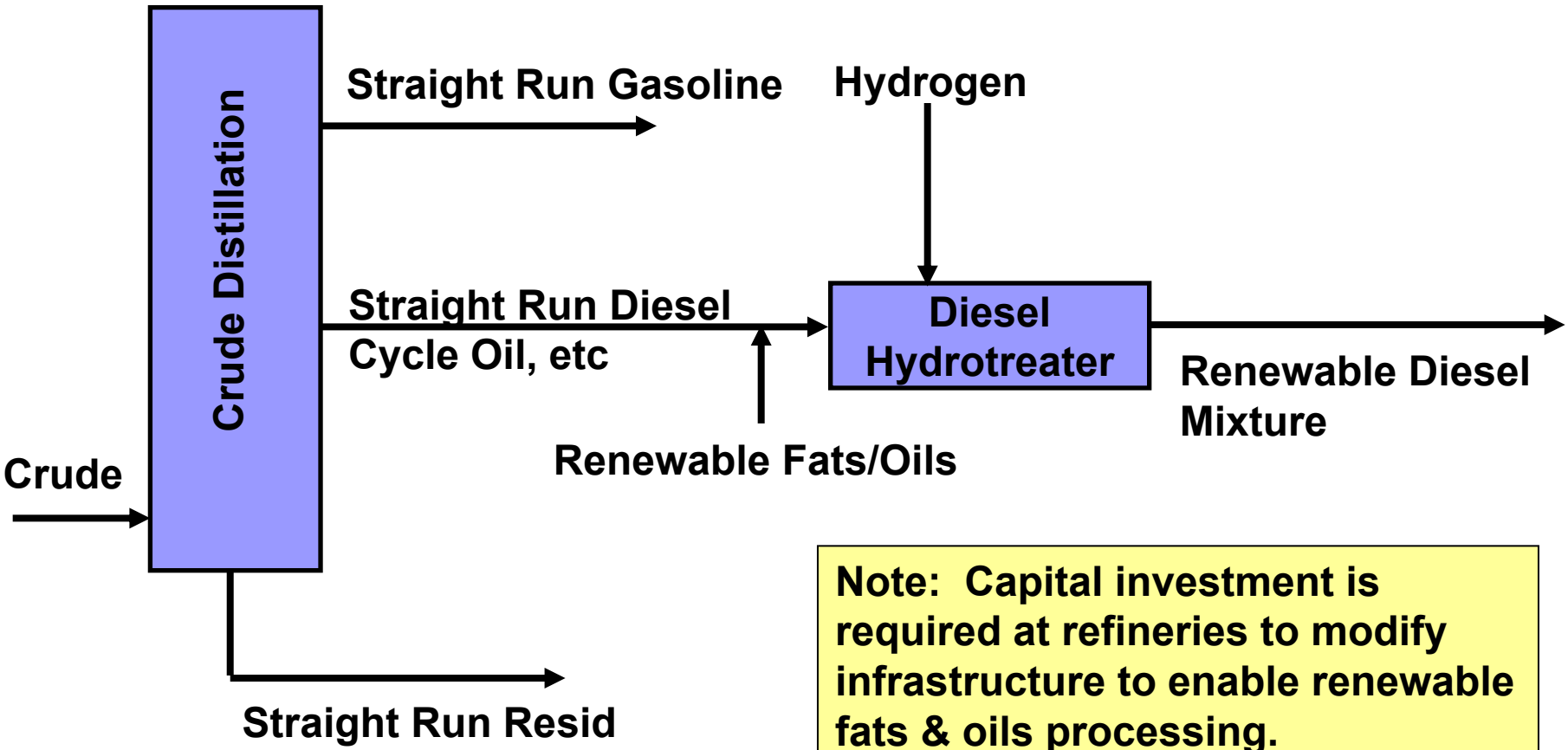
Renewable Diesel Process



Note: Capital investment is required at refineries to modify infrastructure to enable renewable fats & oils processing.

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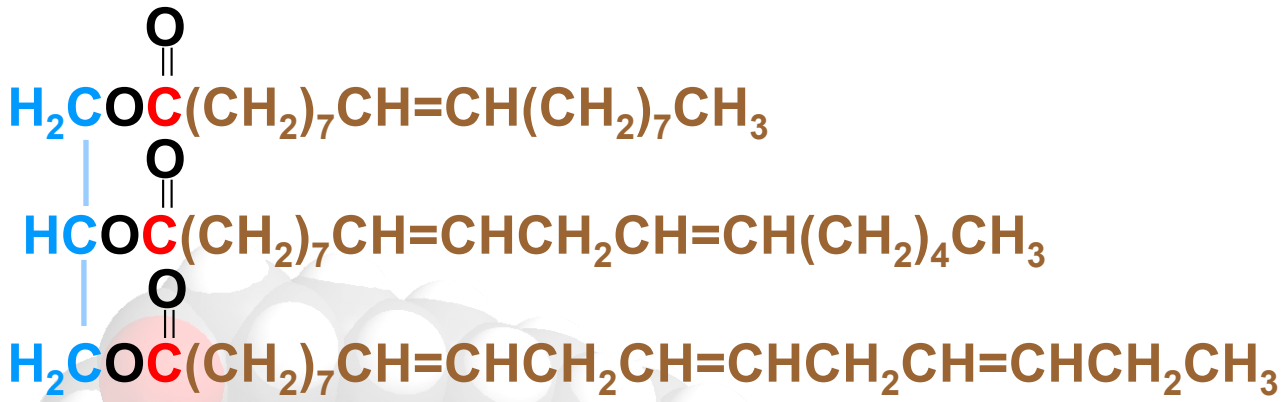
Renewable Diesel Chemistry

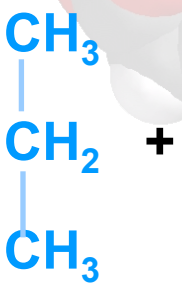
Fat or Oil

(Triglyceride)



Hydrotreating — **Heat, Hydrogen, Catalyst**

Renewable Diesel



+

$CH_3(CH_2)_{16}CH_3$ **+** $2H_2O$

$CH_3(CH_2)_{15}CH_3$ **+** CO_2

n-Paraffins

Propane

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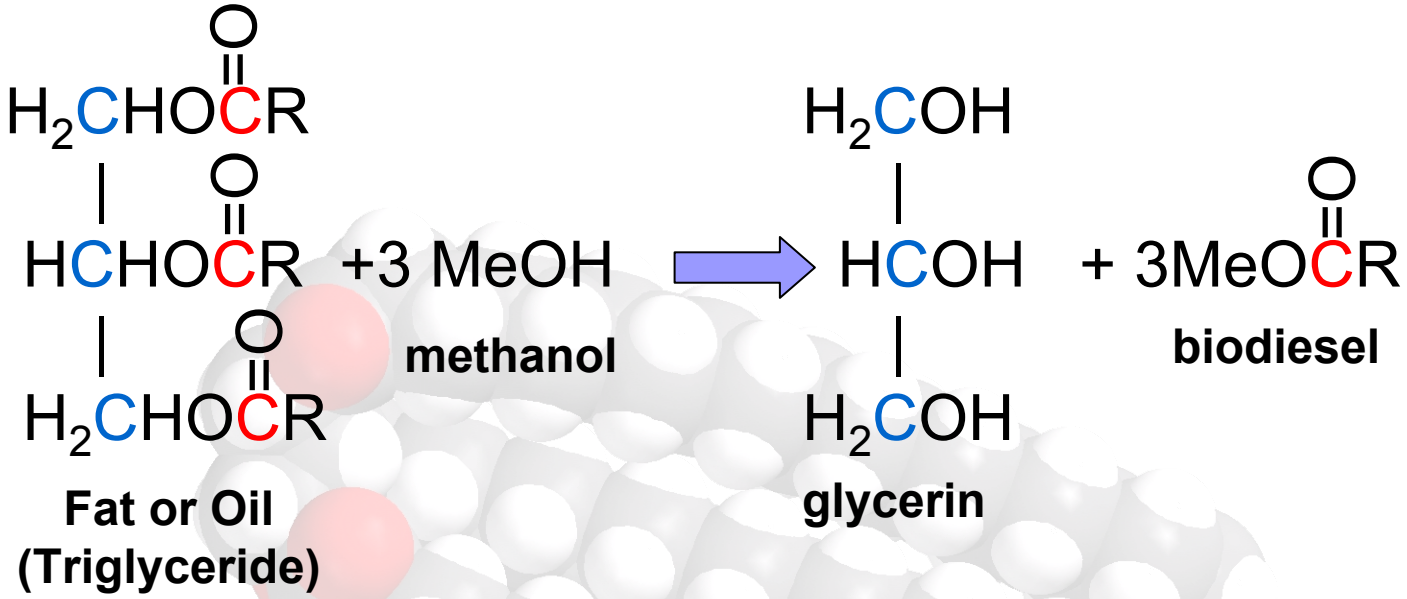
Biodiesel Chemistry



$R = C_{17}H_{31}$ (typical)

Works Best With Virgin Vegetable Oils

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Renewable Diesel Process

- Co-feed Renewable Oils to Diesel Hydrotreater
  - 150-2400 psi Hydrogen, 600-800°F
  - Normal reaction is sulfur removal (HDS)
- At HDS Conditions Fat Or Oil Conversion To Renewable Diesel Is 100%
  - Glycerin converted to propane, glycerin is not a co-product of renewable diesel
  - Oxygen converted to H_2O or CO_2

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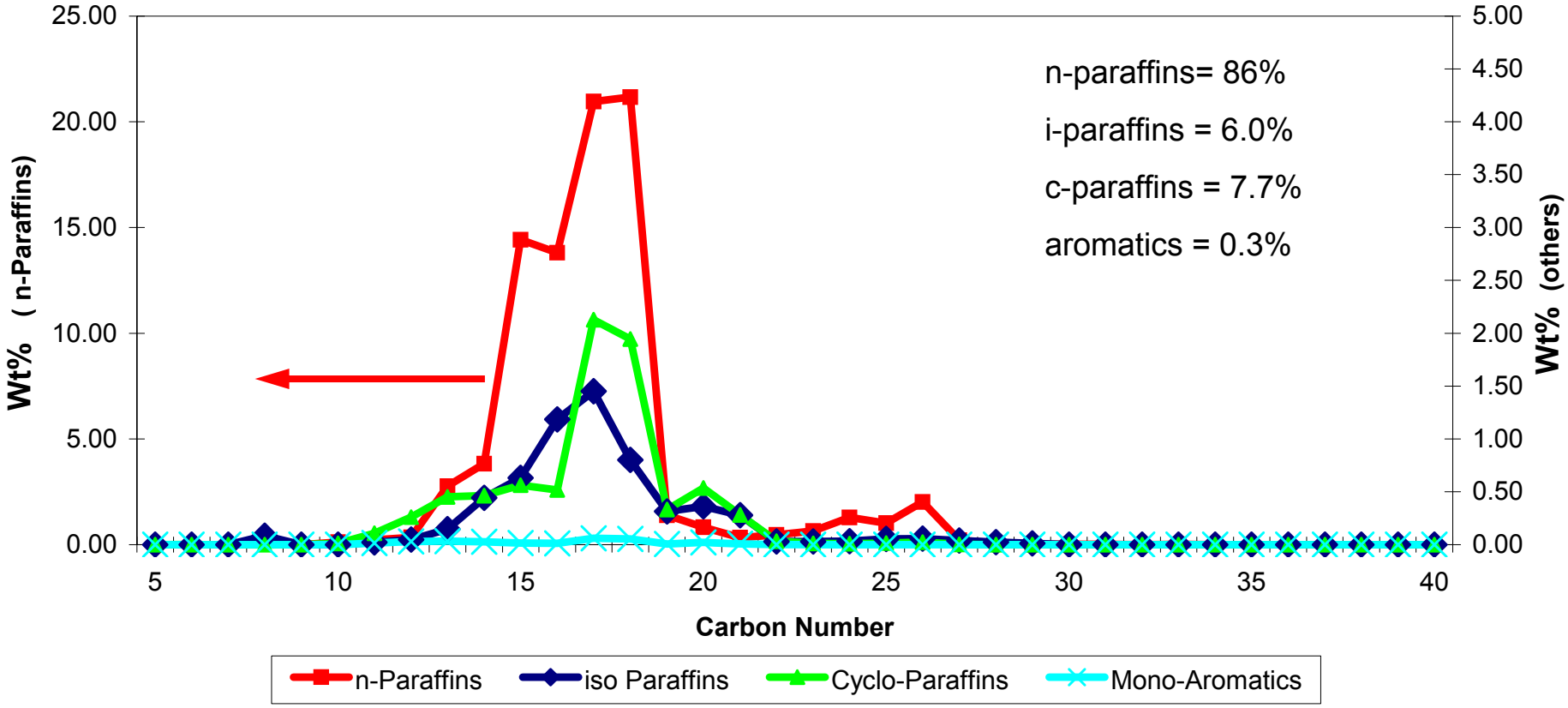
100 % Renewable Diesel From Beef Tallow



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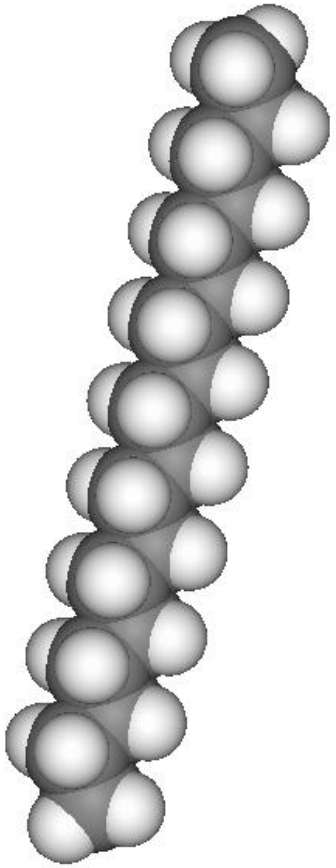
Typical Renewable Diesel

- Paraffinic (C_{13}-C_{18})
- No Oxygen
- No Double Bonds
- In Heart of Diesel Fuel (C_{10}-C_{22})
- High Cetane
- Feedstock Independent
- Cold Flow Issues



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Low Concentration Renewable Diesel Content Effects

Property	ASTM D975	Base Fuel	5% Ren Content	10% Ren Content	20% Ren Content	30% Ren Content
T90, F	540-640°F	559	565	568	571	577
Visc. (mm^2/s at 20C)	1.9-4.1	2.3	2.3	2.4	2.4	2.4
Ash, mass %	0.01 max	<0.001	<0.001	<0.001	<0.001	<0.001
Sulfur (ppm)	15 max	5	6	6	8	5
Copper Strip Corrosion	3 max	1A	1A	1A	1A	1A
Ramsbottom Carbon	0.35 %max	<0.1	<0.1	<0.1	<0.1	<0.1
Cetane number	40 min.	41.2	45.8	47.4	51.2	54.2
Lubricity	520μ max.	591	598	603	597	586
Cloud Point, F	Seasonal/Regional	-9	3	8	14	17
Pour Point, F	Seasonal/Regional	-24	-6	0	6	9

Note 1: Renewable diesel fuels shown here are not commercially optimized - for illustration only
Note 2: Feedstock is soy oil; results for non-soy feedstocks are similar

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Renewable Diesel Compatibility

- No New Molecules
- Meets ASTM D 975
- High Level of Quality Control
- No Transportation Limitations
  - Use existing pipeline & trucking infrastructure
- Reduces Emissions & CO_2

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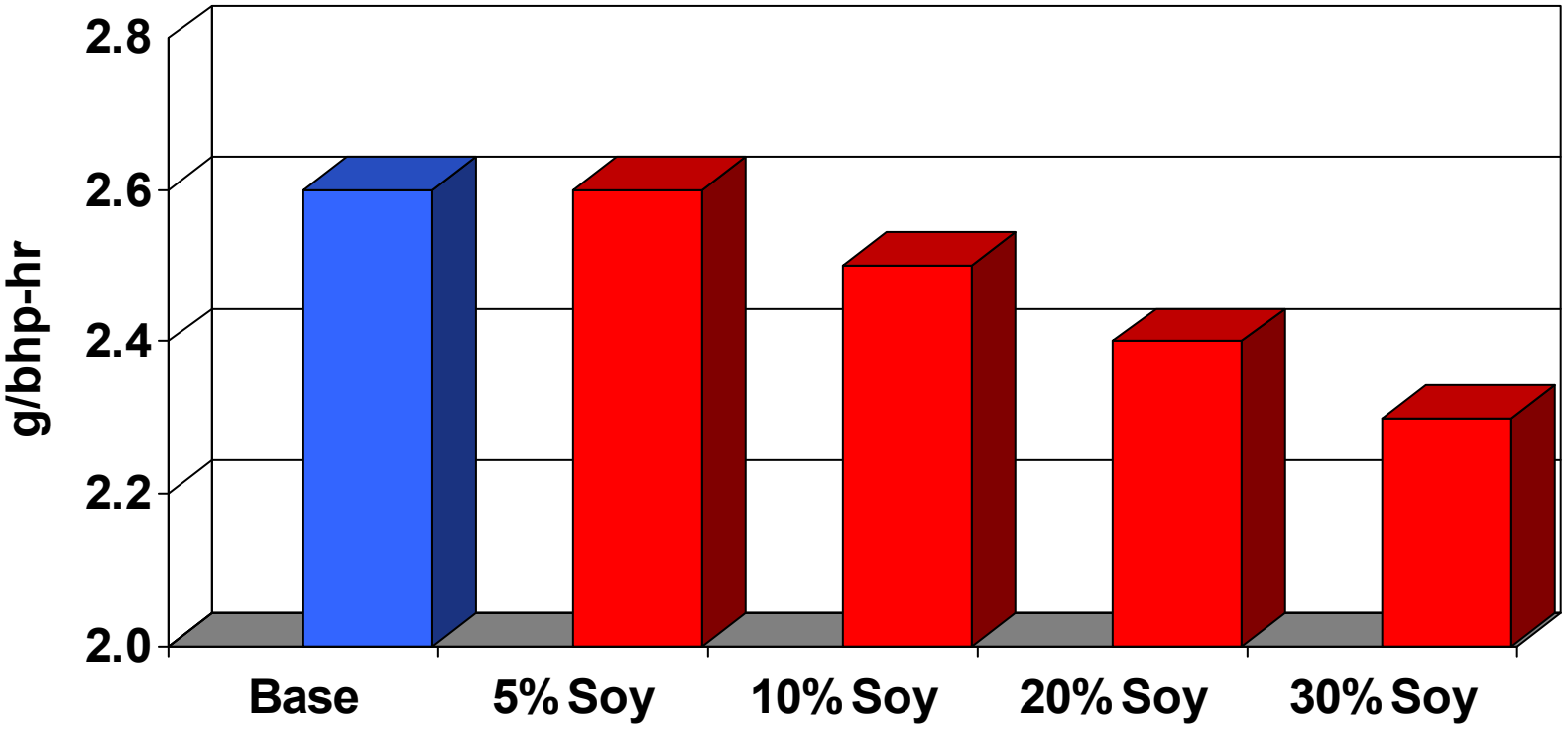
Low Concentration Renewable Diesel NOx



Note: Renewable diesel fuels tested are not commercially optimized

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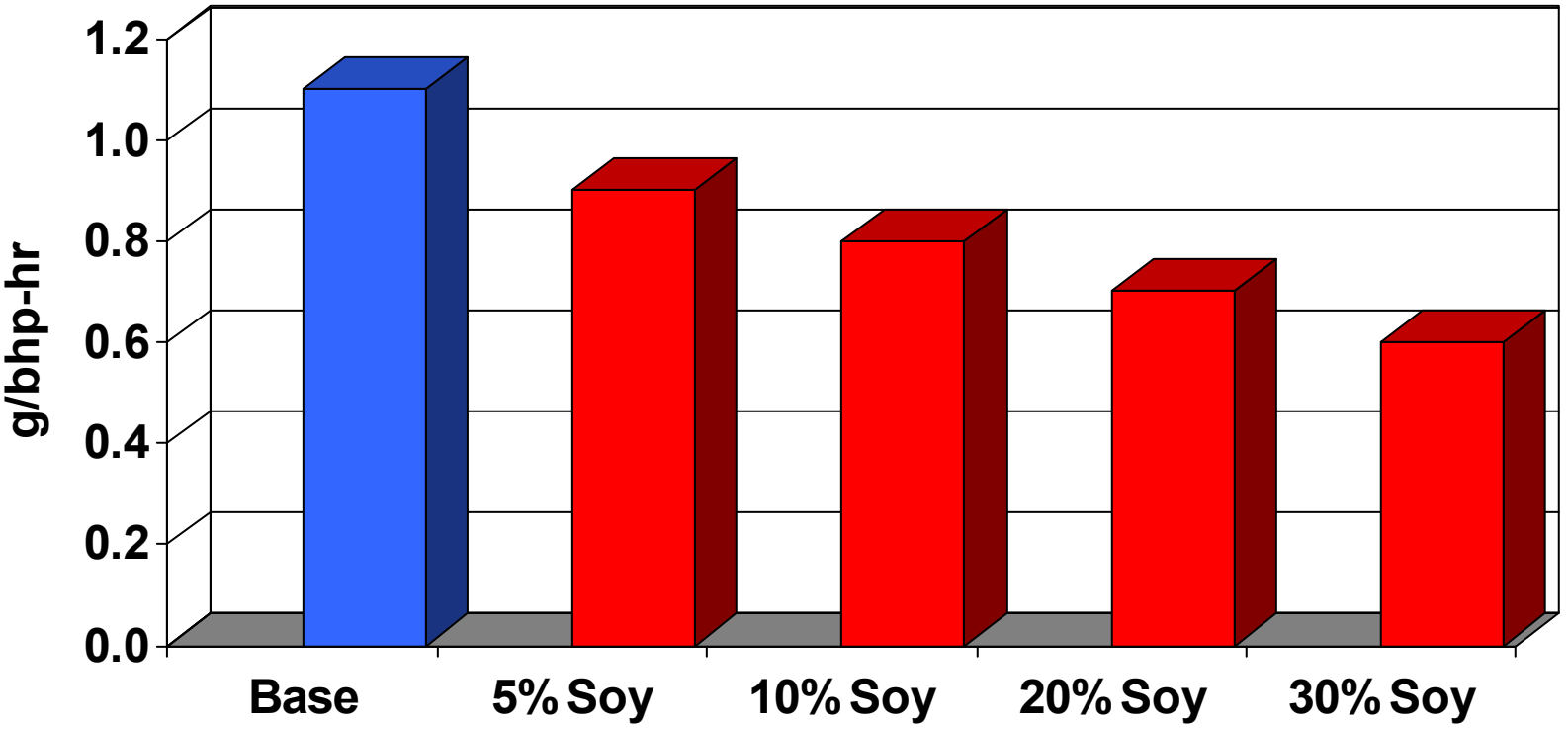
Low Concentration Renewable Diesel CO



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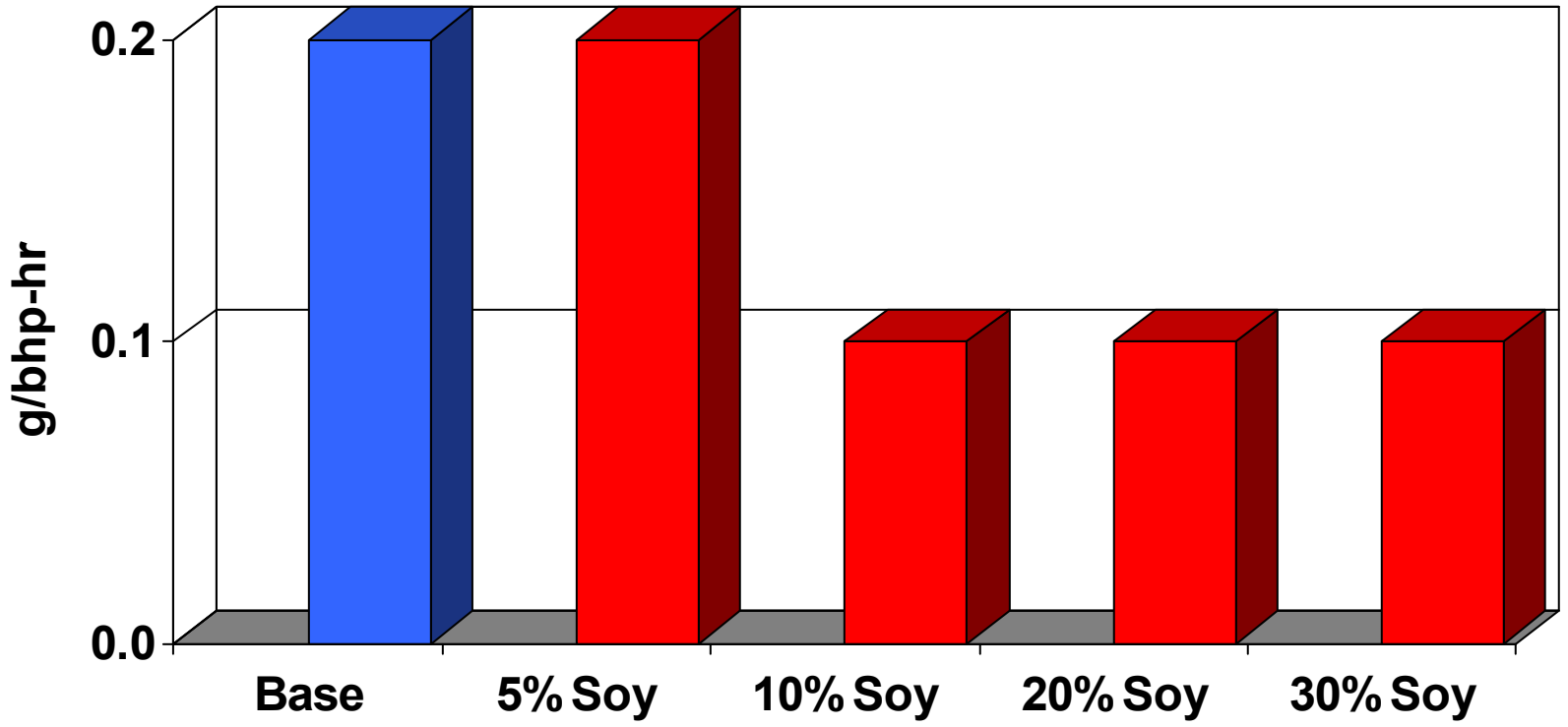
Low Concentration Renewable Diesel NMHC



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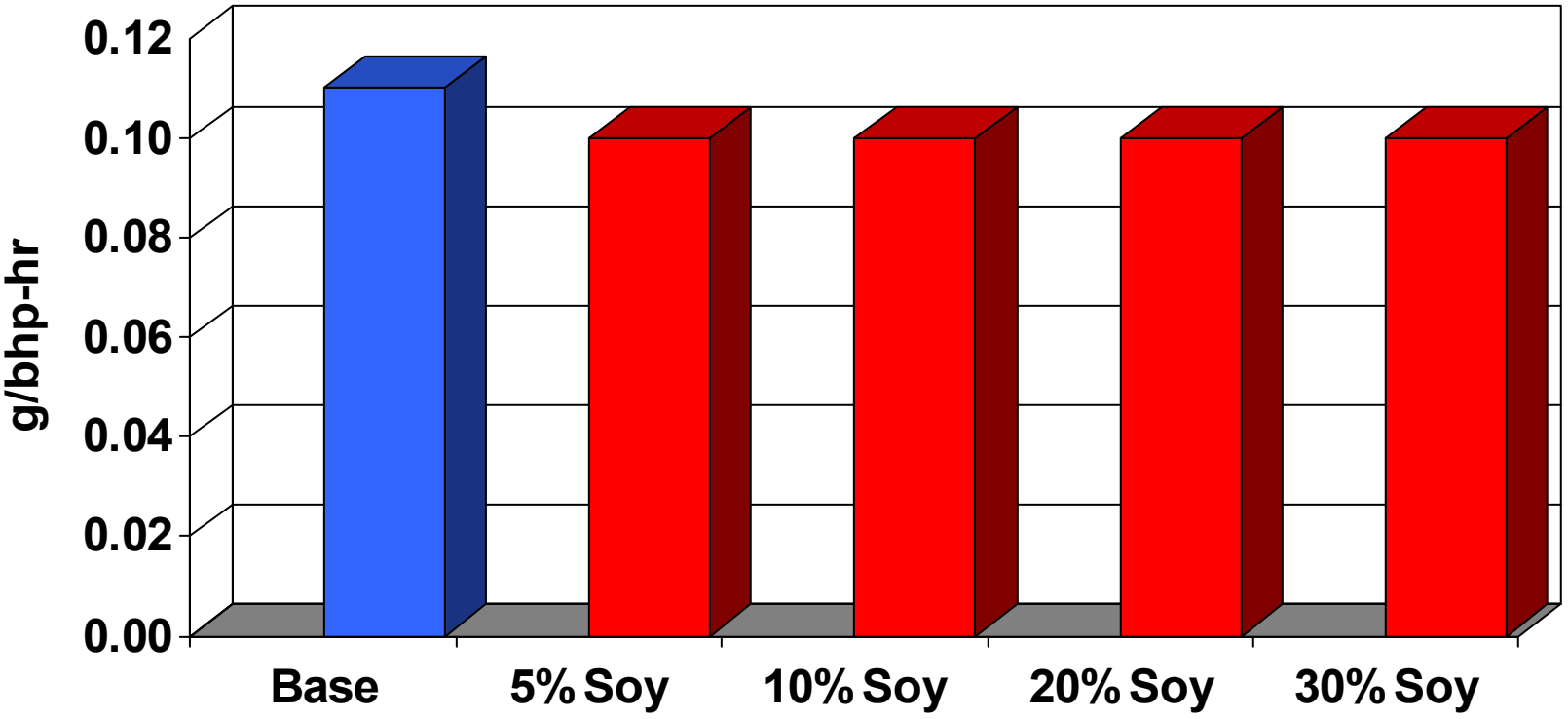
Low Concentration Renewable Diesel PM



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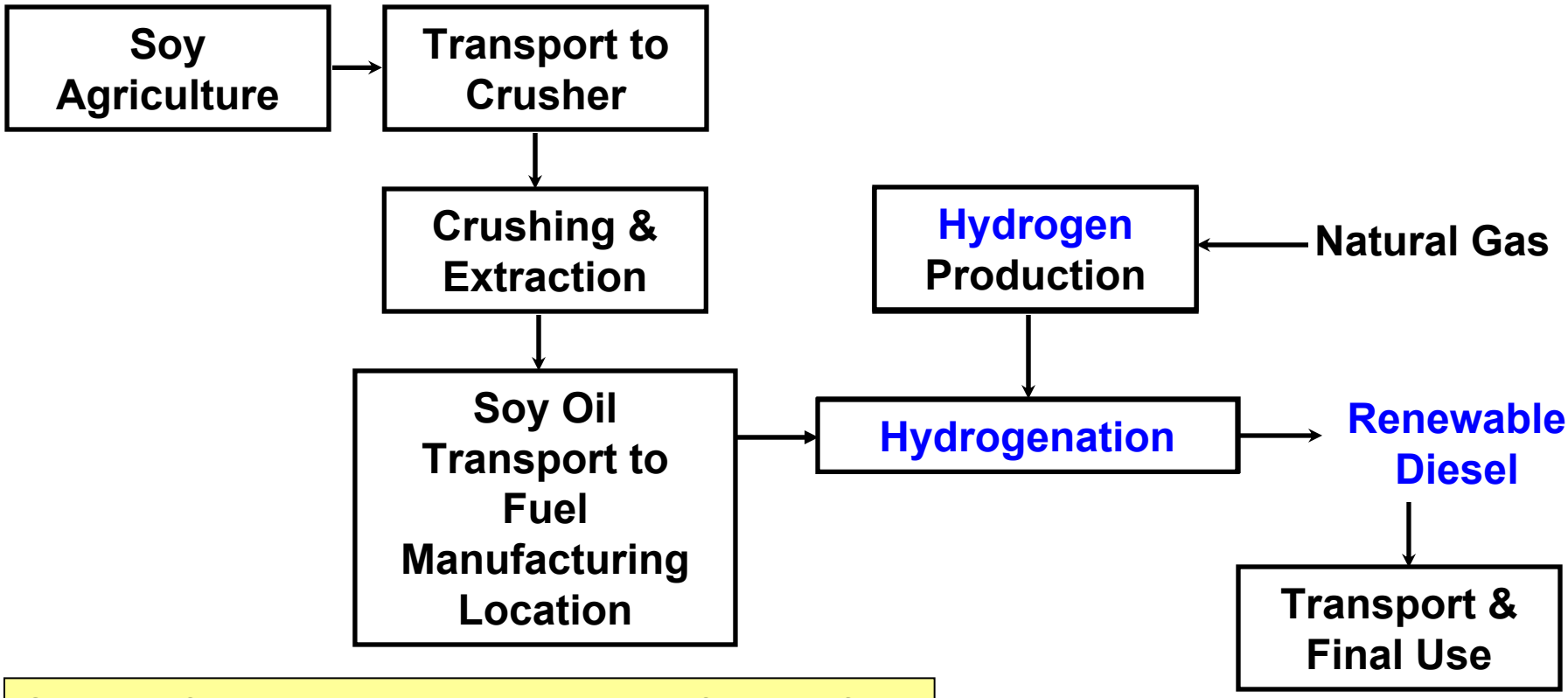
Bio/Renewable Diesel Lifecycle



Similar life cycle analysis can be performed for other renewable diesel feedstocks including beef tallow, canola (rapeseed), poultry fat and yellow grease.

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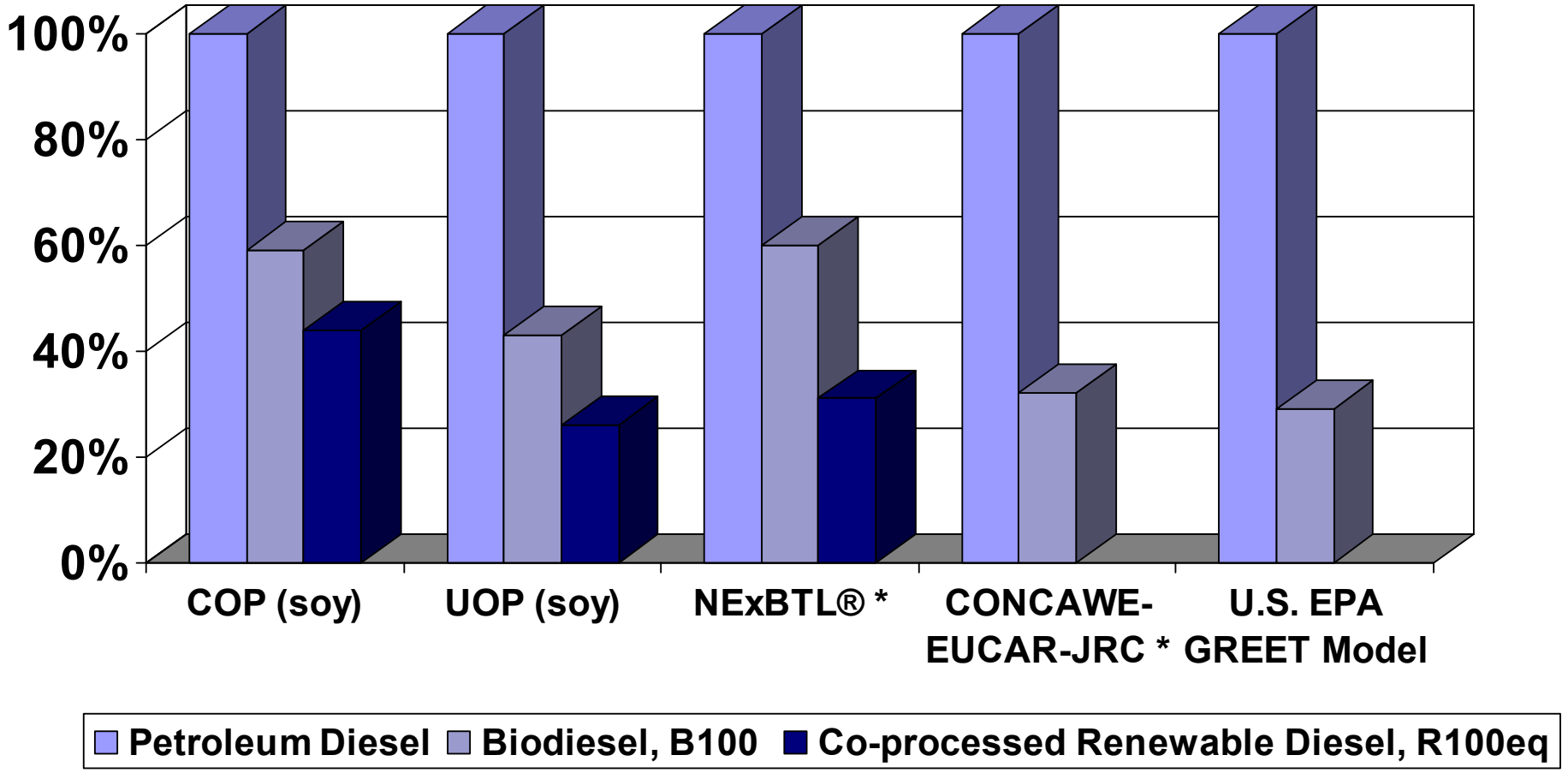
Relative CO_2 Life Cycle Emissions



* Rapeseed Feedstock

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Renewable Diesel Summary

- Excellent Way To Incorporate Renewable Fats & Oils Into Diesel Fuel
- Feedstock Flexible
  - Converts Any Fat/Oil to Normal Diesel Fuel
- High Level Of Quality Control
- Meets ASTM D 975 Diesel Specification
- Transparent To Users
- Expands Opportunities For Farm Community

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