National Renewable Energy Laboratory

Biodiesel: Emissions & Health Effects

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Treasure Valley Air Quality Workshop

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- Wind & Hydropower
- Geothermal
- Distributed Energy, Electric Infrastructure & Reliability
- **Biomass**
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- Freedom Car & Vehicle Technology
- Hydrogen & Infrastructure
- Building Technologies
- Weatherization & Intergovernment Grants
- FEMP

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National Renewable Energy Laboratory
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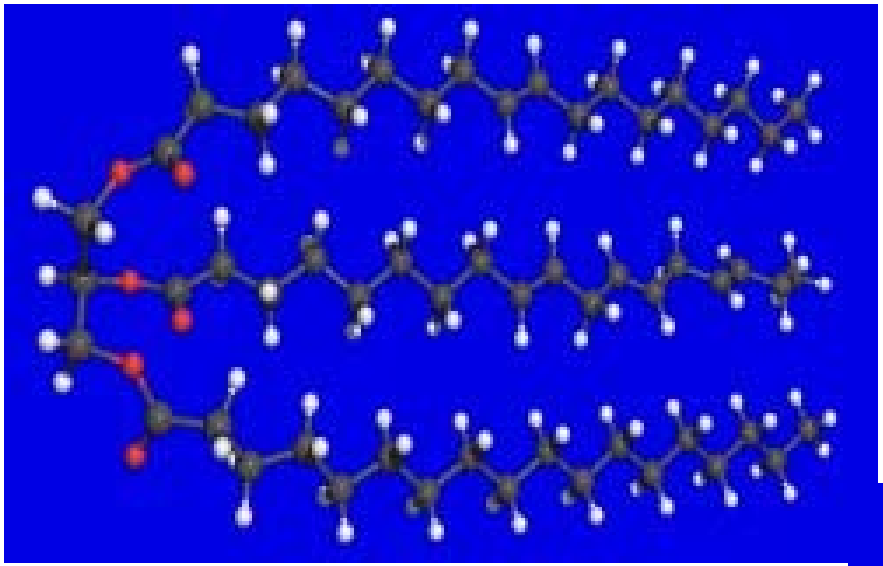
What is Biodiesel

- **Defined by ASTM, EPA and DOE and by each State's Weights and Measures Agency or State Regulations**
  - "A fuel consisting of long-chain fatty acid alkyl esters made from renewable vegetable oils, recycled cooking greases, or animal fats " that meets ASTM standards
  - ASTM D 6751 - 02

Biodiesel Terminology

- **Pure biodiesel or 100% Biodiesel (B100)**
  - Also called NEAT Biodiesel
- **Biodiesel Blend**
  - BXX for XX% biodiesel
  - B20 is 20% biodiesel and 80% petro diesel fuel
  - B50 is 50% biodiesel and 50% petro diesel fuel
- **Avoid calling blends "biodiesel" because it can lead to a lot of confusion!**
  - What is true for B100 may not be true for B20
  - And visa versa

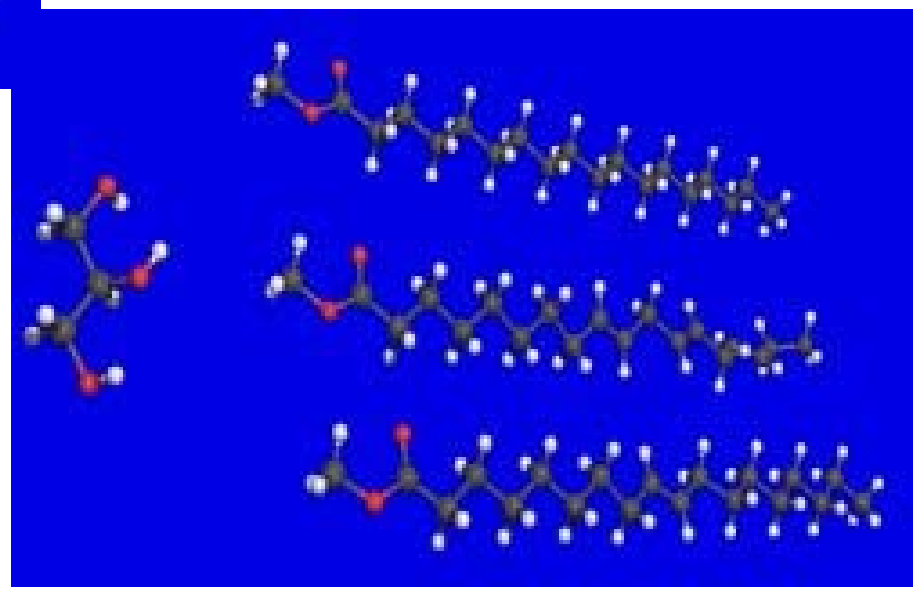
Biodiesel Manufacturing



Triglyceride: Fat or Oil molecule

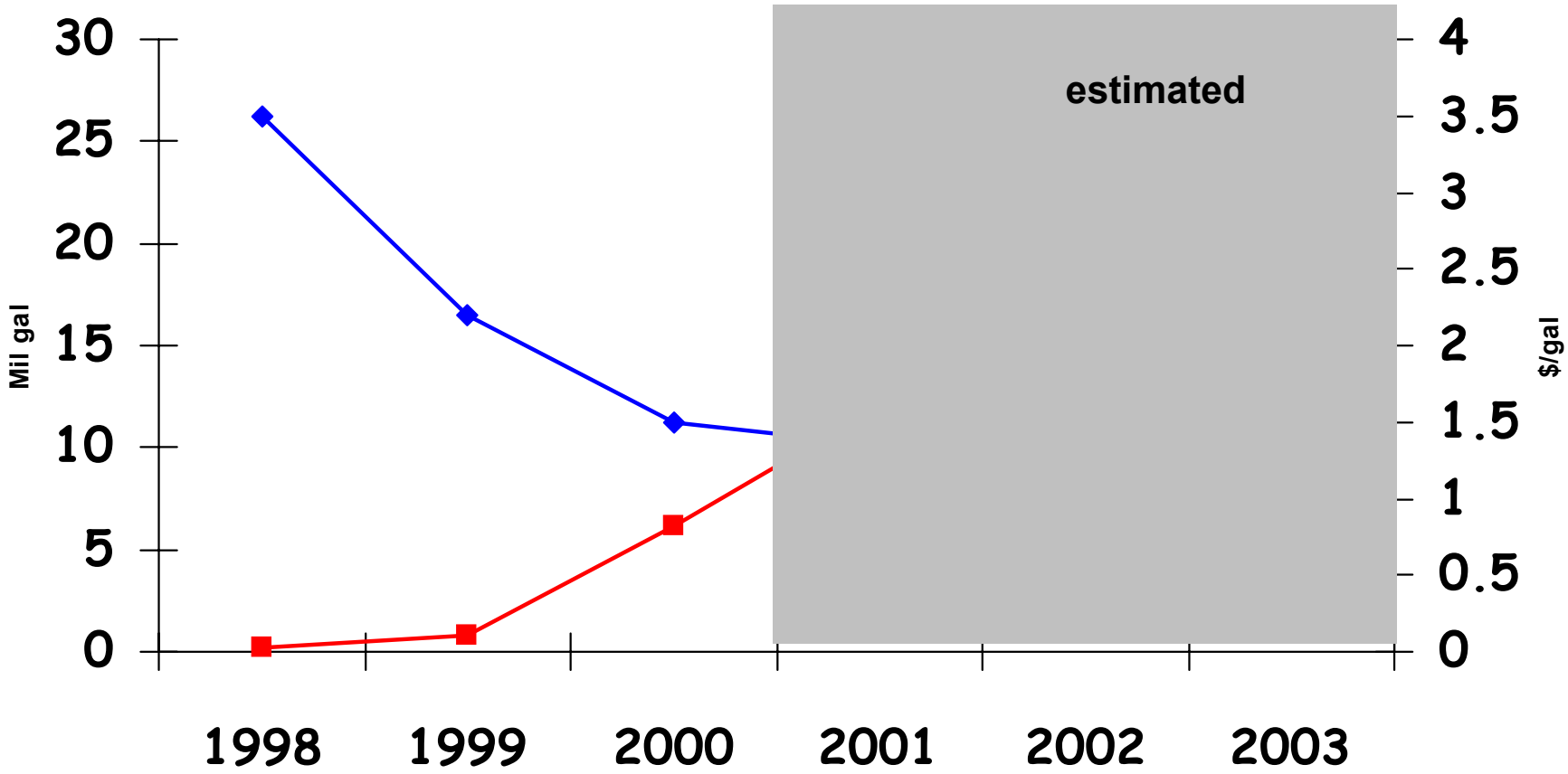
Biodiesel molecules

Glycerin molecule



Pictures provided by Campa® als Kraftstoff

Sales Volume and Price Trends



2001-2003 Prices incorporate effect of USDA subsidy for soy biodiesel ranging between $0.85 and $1.30/gal B100. Assumed extended through 2003.

Benefits of Biodiesel

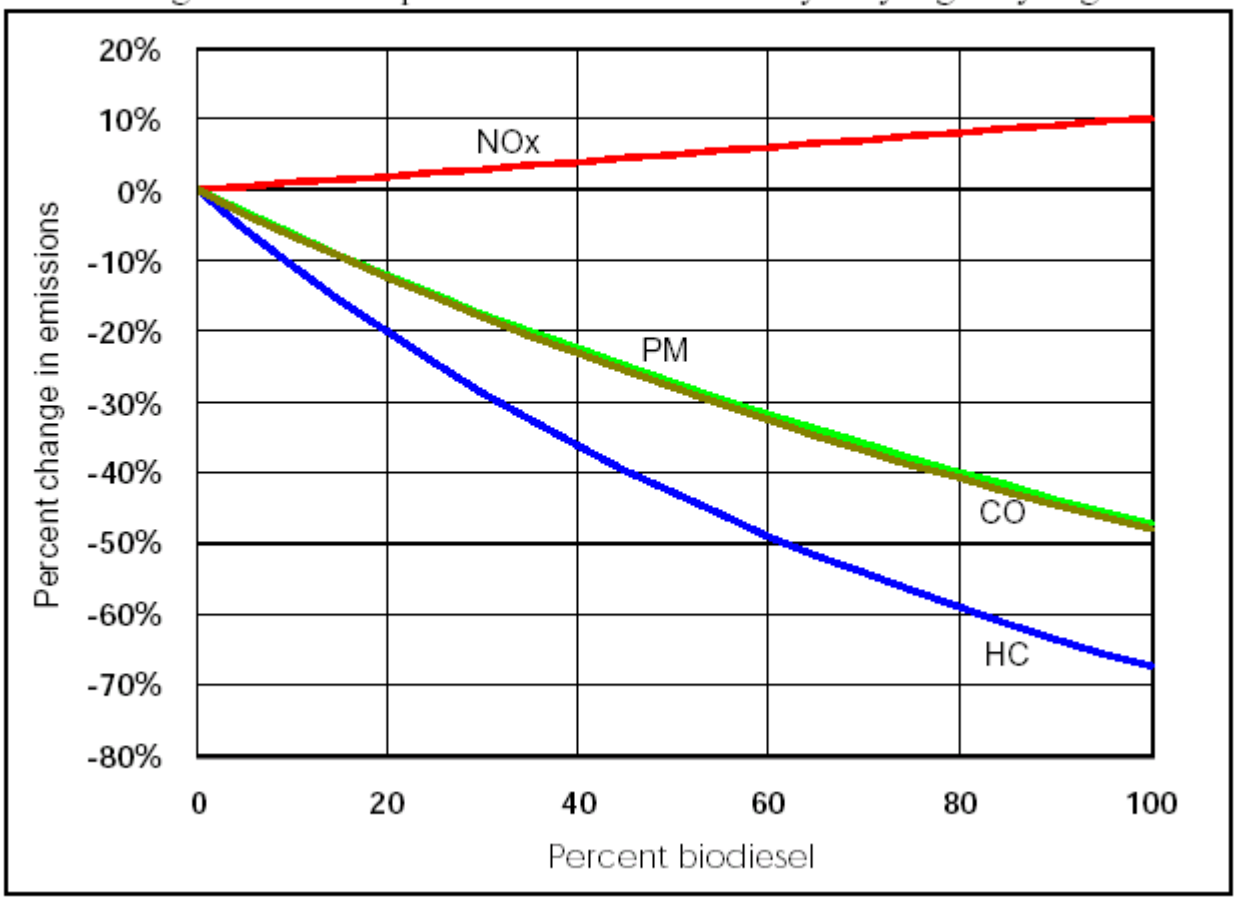
- **Use just like No. 2 diesel fuel in existing equipment with no modifications in most cases**
- **On-road and off-road transportation**
  - B20 is a drop in technology, no changes to equipment or infrastructure
  - B100 requires careful management, but few changes to equipment
- **Electric generators similar to transport issues**
- **Heating oils**
  - Blends up to 20% with heating oil No. 2

Benefits of Biodiesel

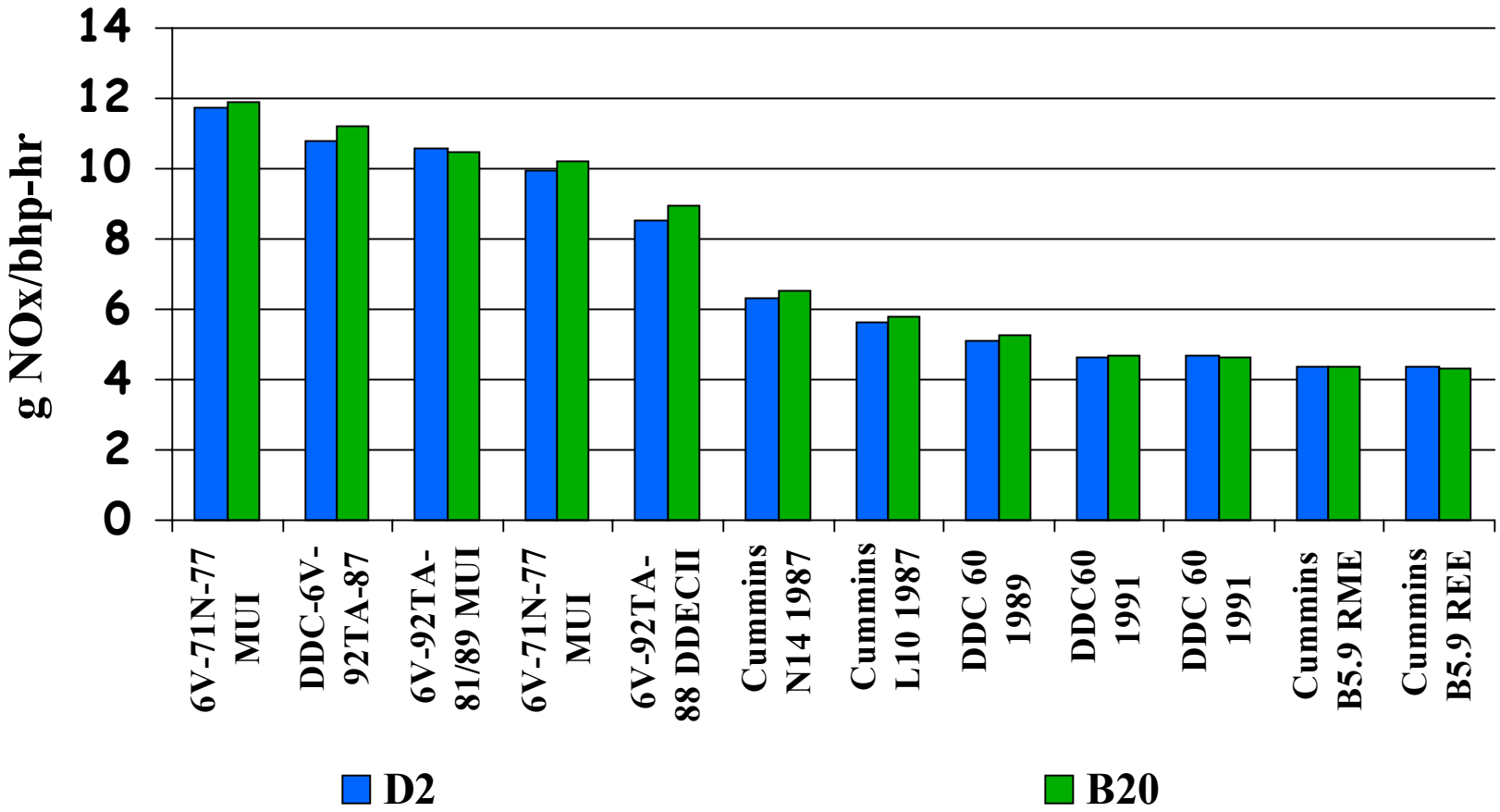
- **BTU Content (121,000 BTU/gal)**
  - Diesel No. 2 averages 131,000
  - Diesel No. 1 averages 126,000
- **High Lubricity (Over 6000 g SLBOCLE)**
  - 1% or less can improve a poor lubricity diesel fuel by 40%
- **Biodegradable**
  - Used as a clean up technology with oil spills
- **Non Toxic in small quantities**
  - Fatty acid methyl esters listed as a food additive with FDA
  - DO NOT DRINK!
- **Safer to use than diesel**
  - Very high flash point

EPA Emission Analysis

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

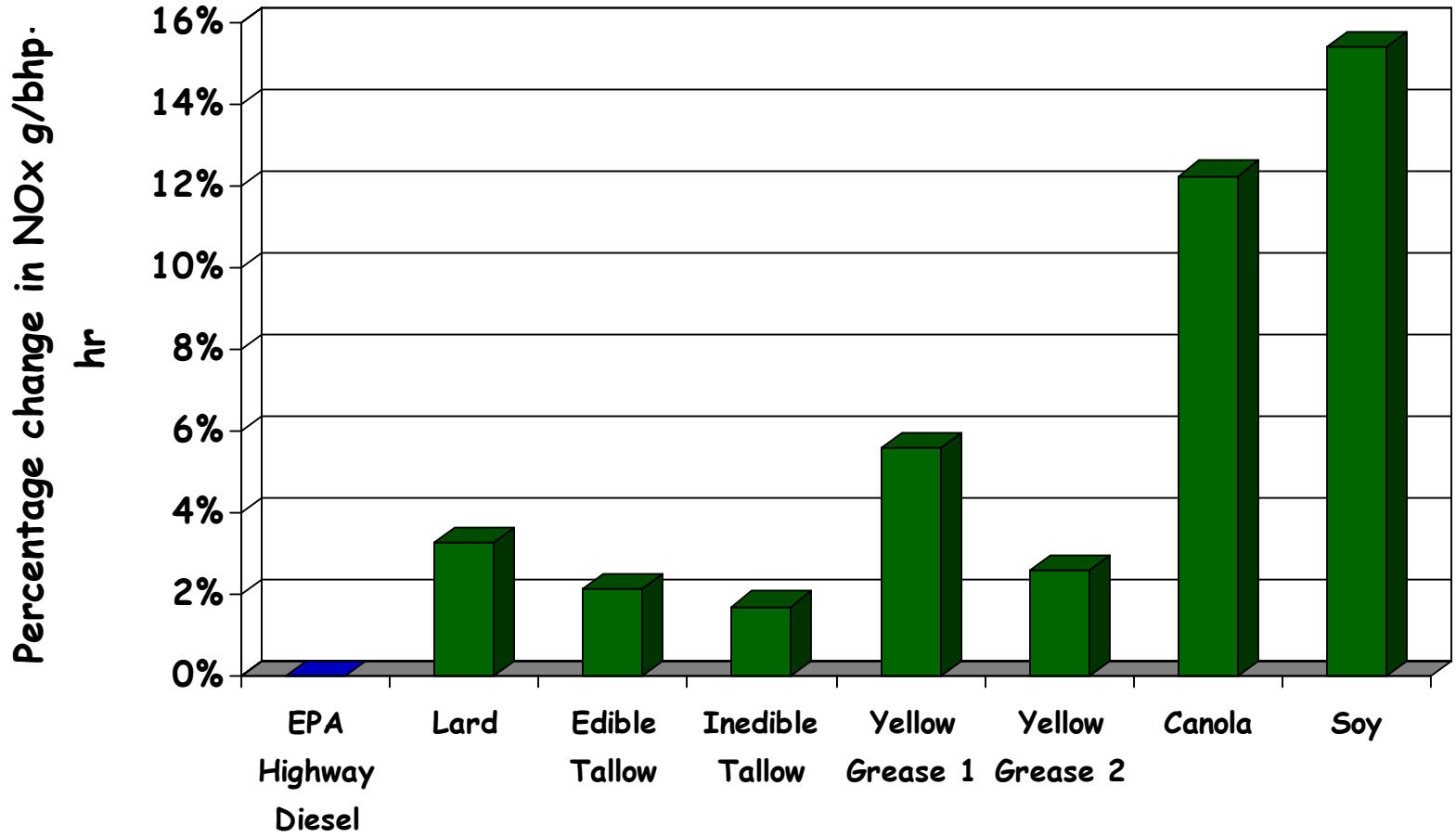


B20 NOx Emissions are Within Legal Limits
D2 and B20 Emissions Improving over Time
Increase is Consistent Across Time & Engine Types



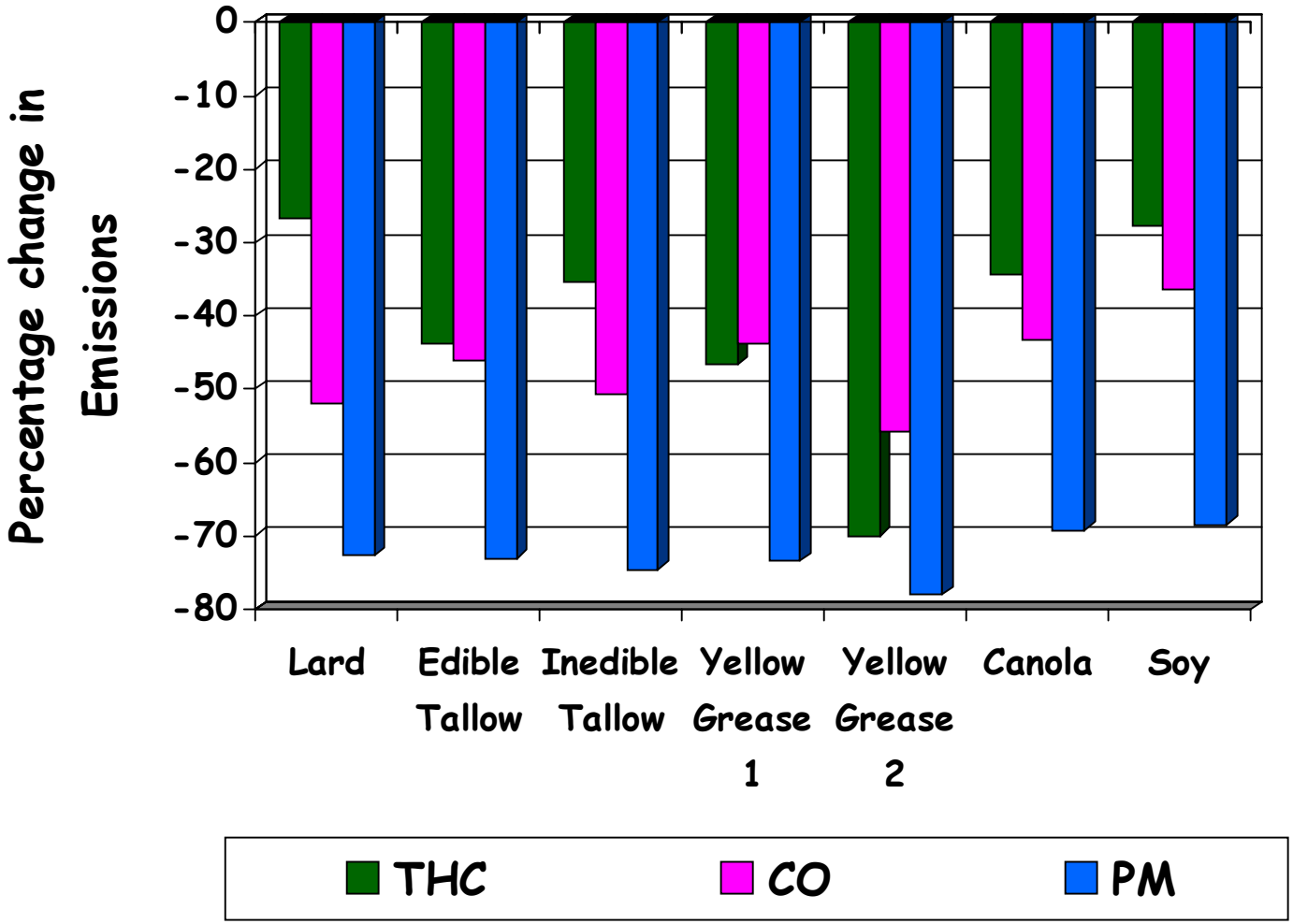
All Data EPA HD FTP Composite & Replicated Hot Starts

Biodiesel (B100) NOx Emissions

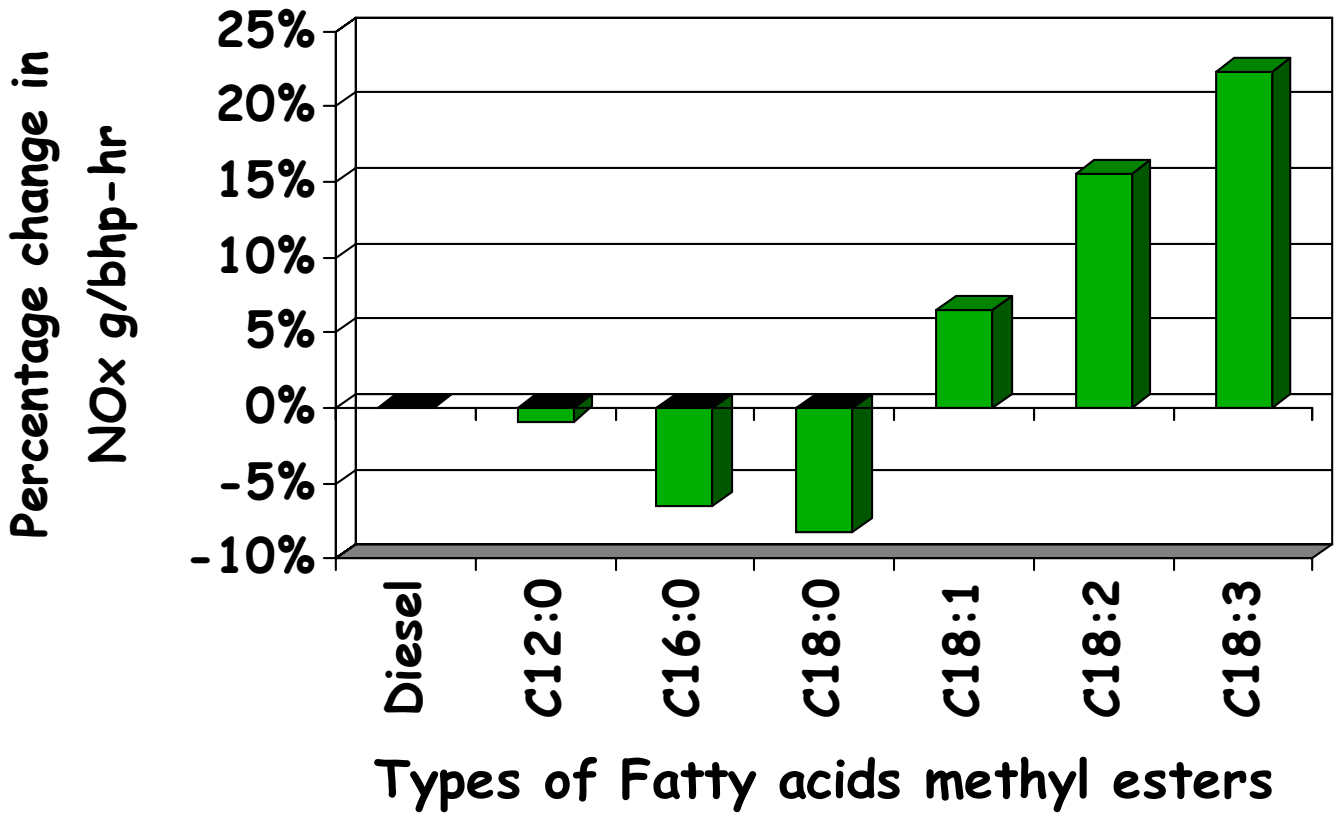


O_2 content =	0%	11.82%	11.74%	11.08%	11.10%	11.28%	11.04%	11.16%

B100 - CO, HC, PM Emissions



NOx Emissions of Biodiesel Components



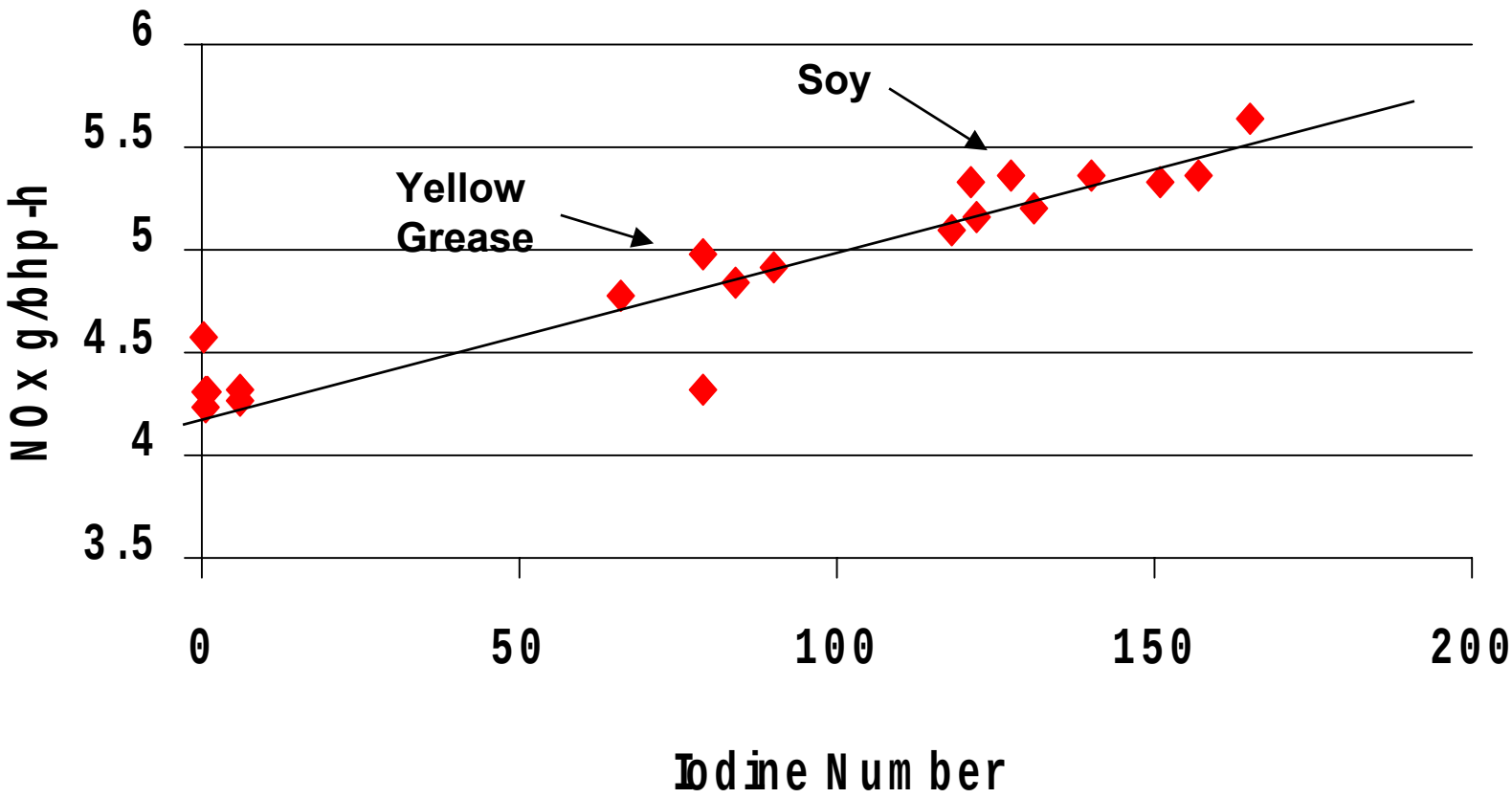
Feedstock Composition

Fatty Acids: C# carbons: # C=C bonds

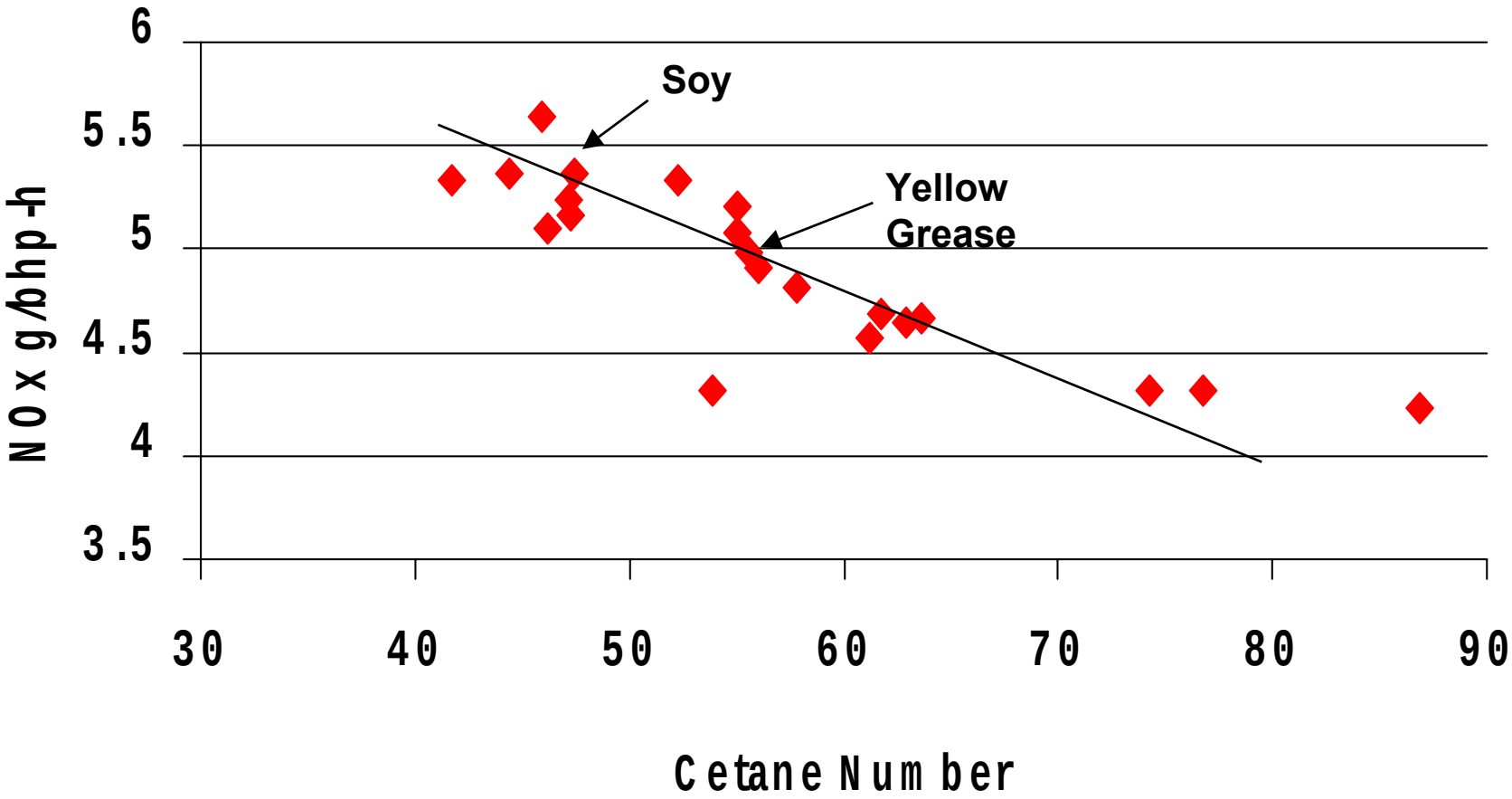
	≤C12	C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	≥C20
Soy	0	0	12	0	4	23	55	7	1
Corn	0	1	9	1	3	40	45	0	1
Yel Grease	0	1	23	1	10	50	15	0	0
Rape	0	0	4	0	1	10	15	10	60
Mustard	0	0	3	0	2	39	15	9	30
Sunflower	0	0	6	0	4	19	69	0	2
Lard	0	1	25	2	14	46	10	0	3
Tallow	0	2	27	2	25	40	2	0	2

saturated monounsaturated polyunsaturated Saturated & monounsaturated

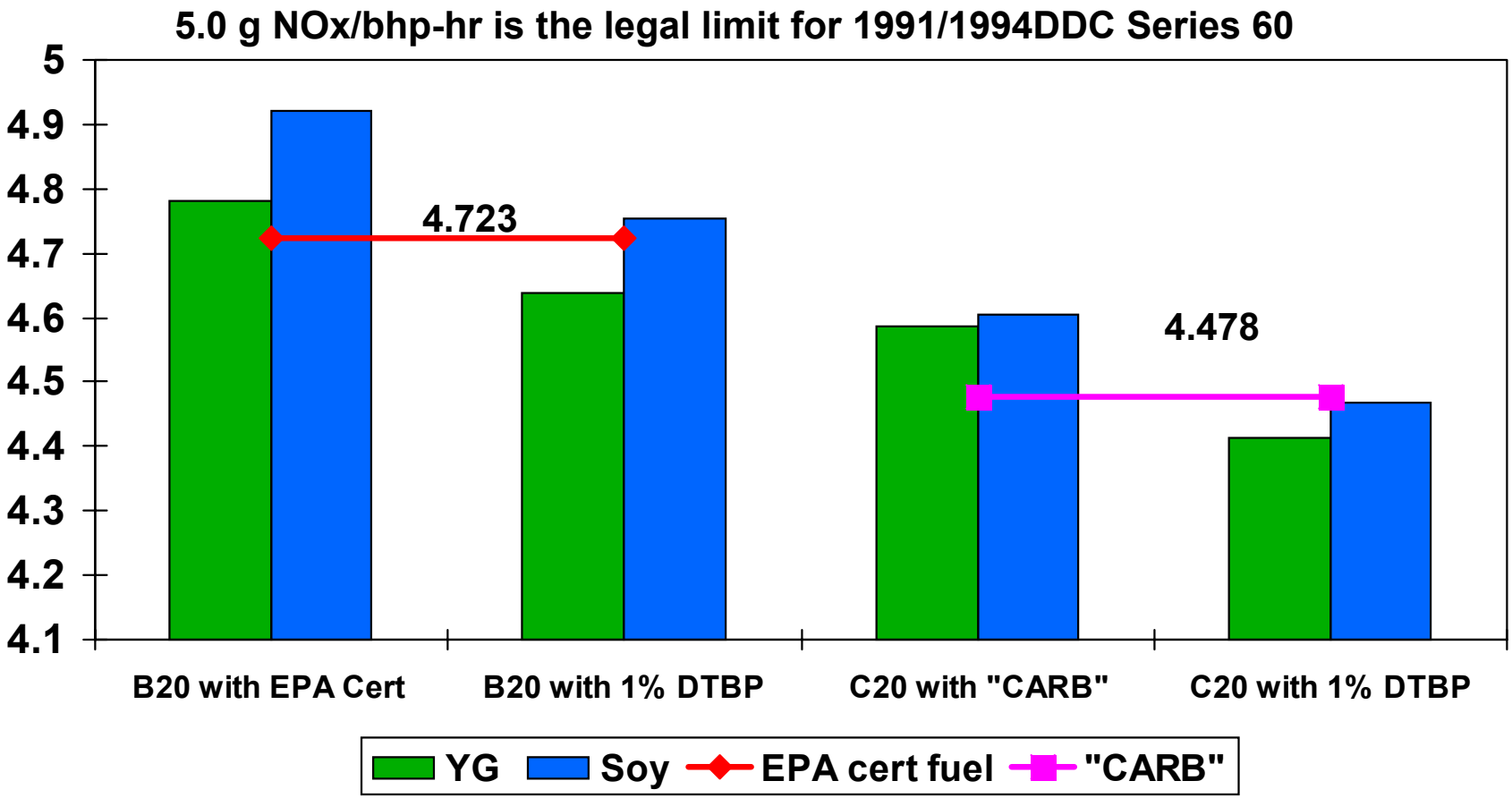
Fuel Iodine No. and NOx



Fuel Cetane and NOx

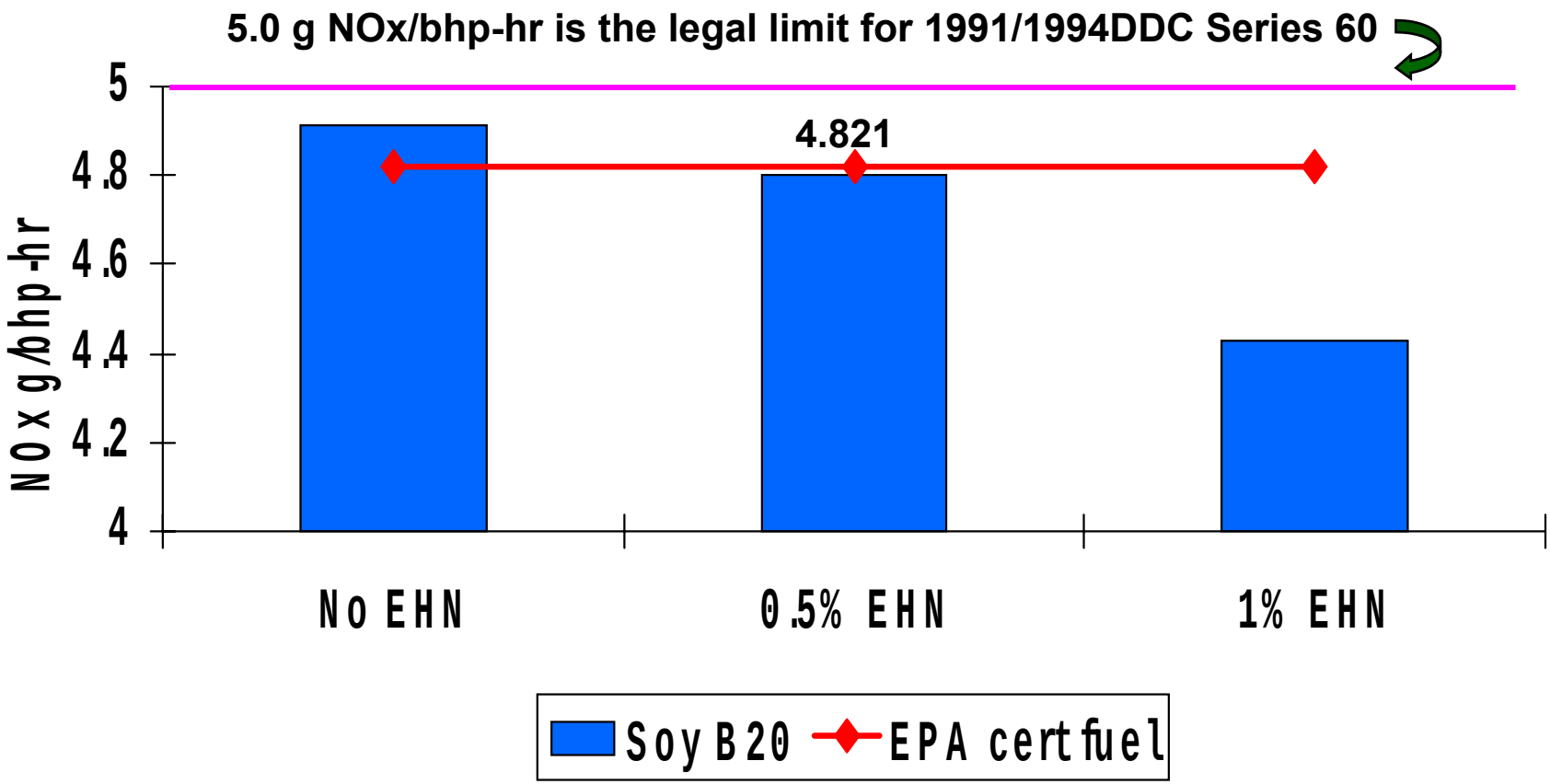


NOx Solutions for B20

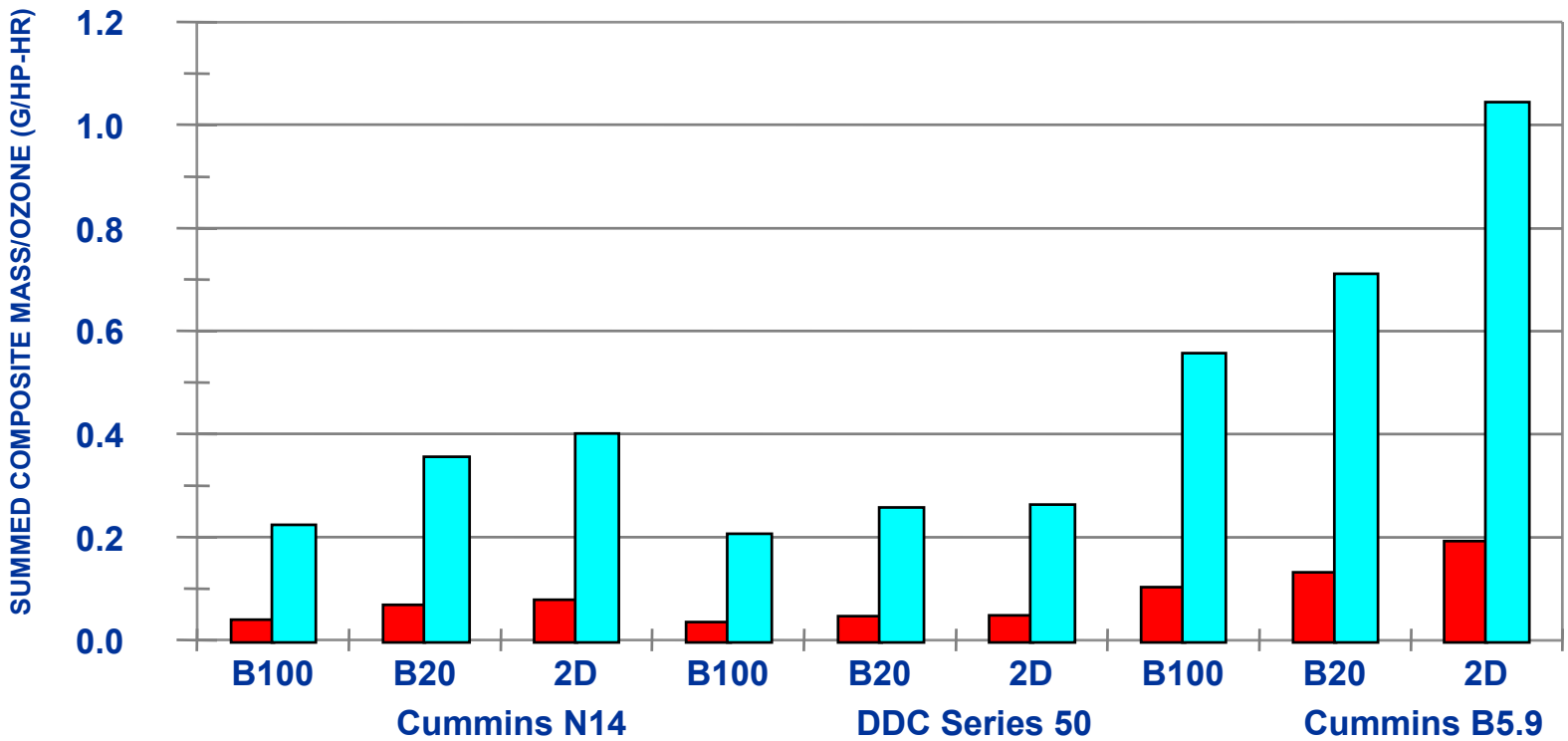


"CARB" is a fuel with 10% aromatics purchased to represent a typical low aromatic CARB test fuel.

NOx Solutions for B20

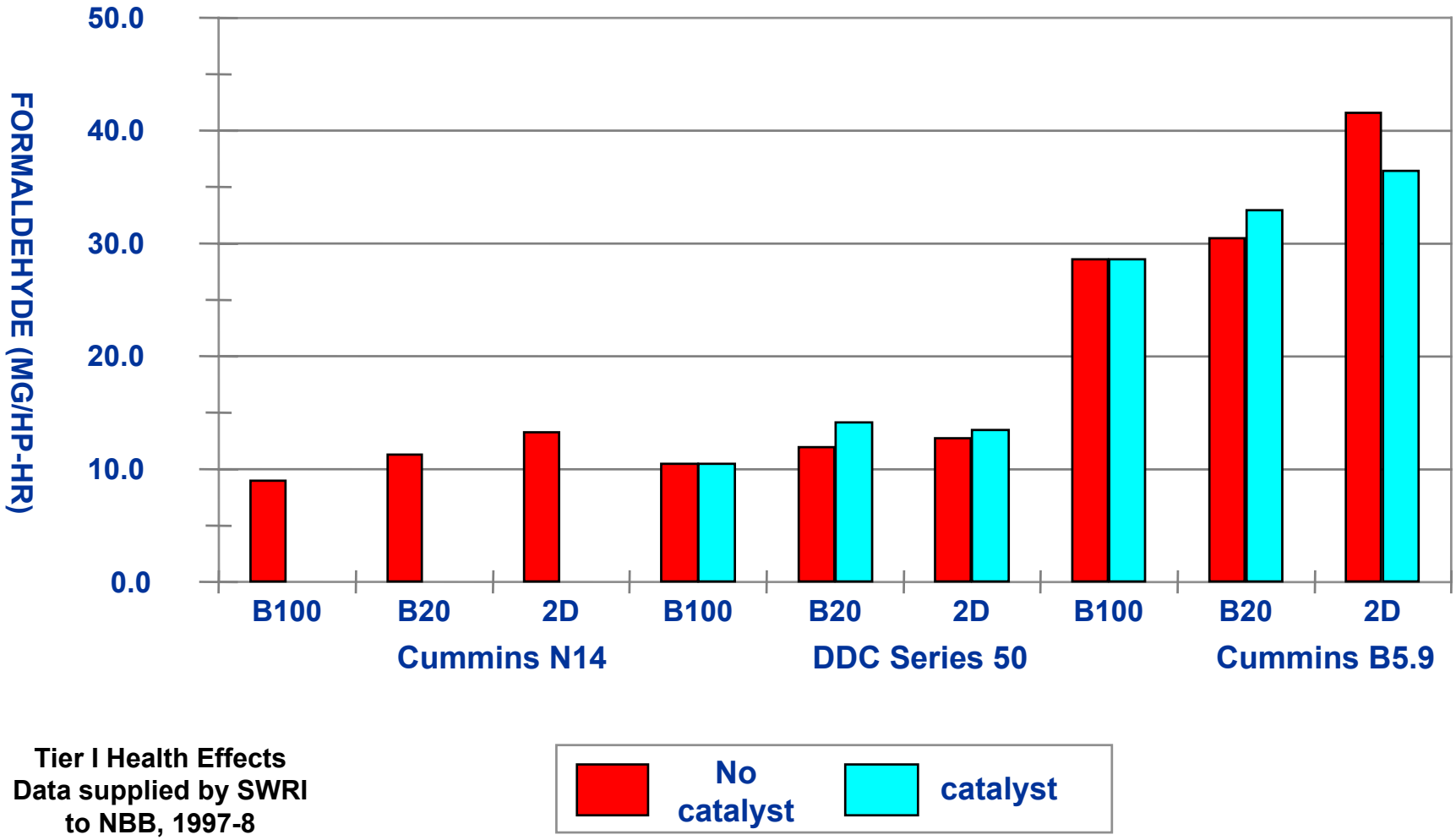


C_1 TO C_{12} SPECIATION
TOTAL MASS AND OZONE POTENTIAL



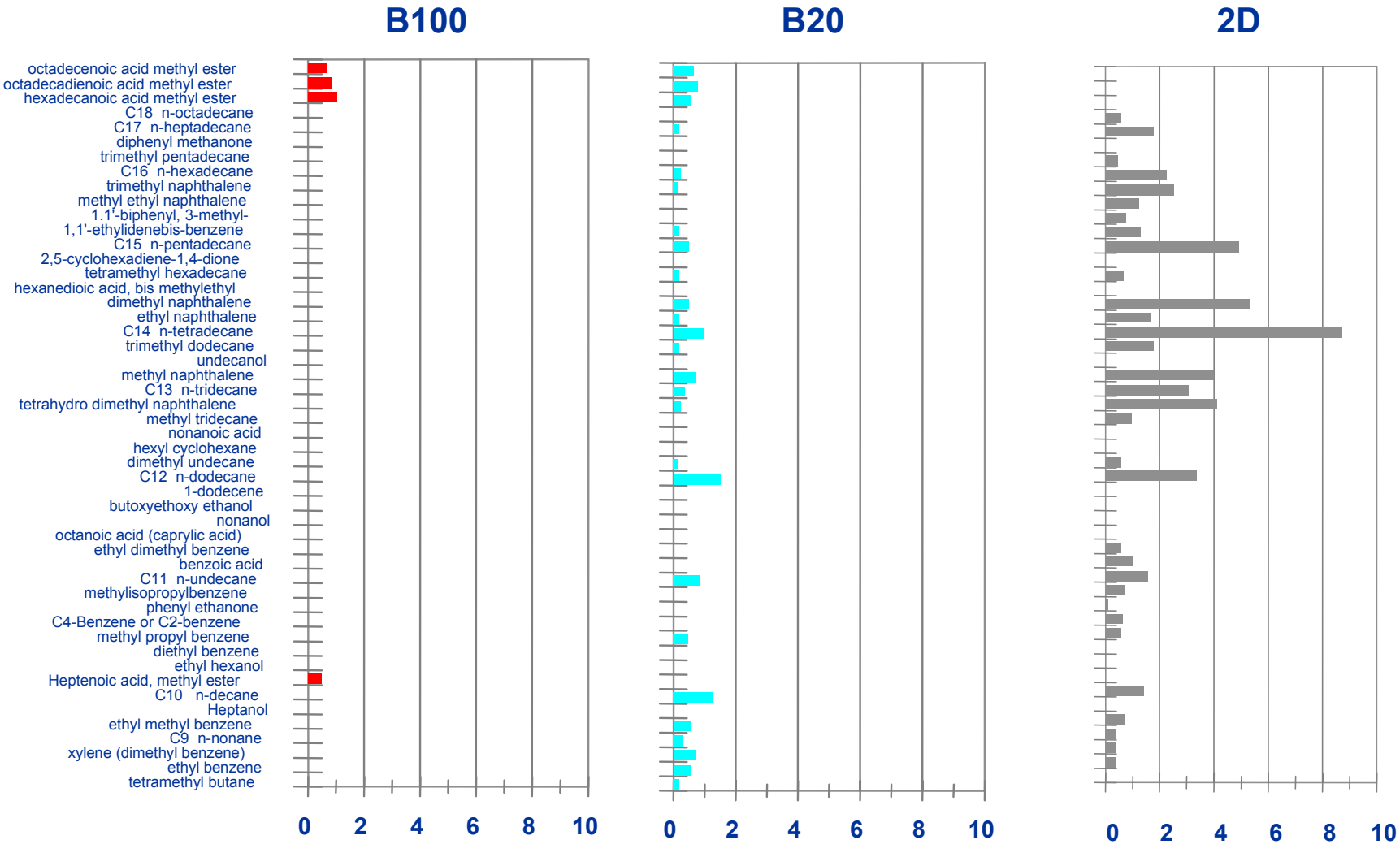
Tier I Health Effects
Data supplied by SWRI
to NBB, 1997-8

FORMALDEHYDE EMISSIONS



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

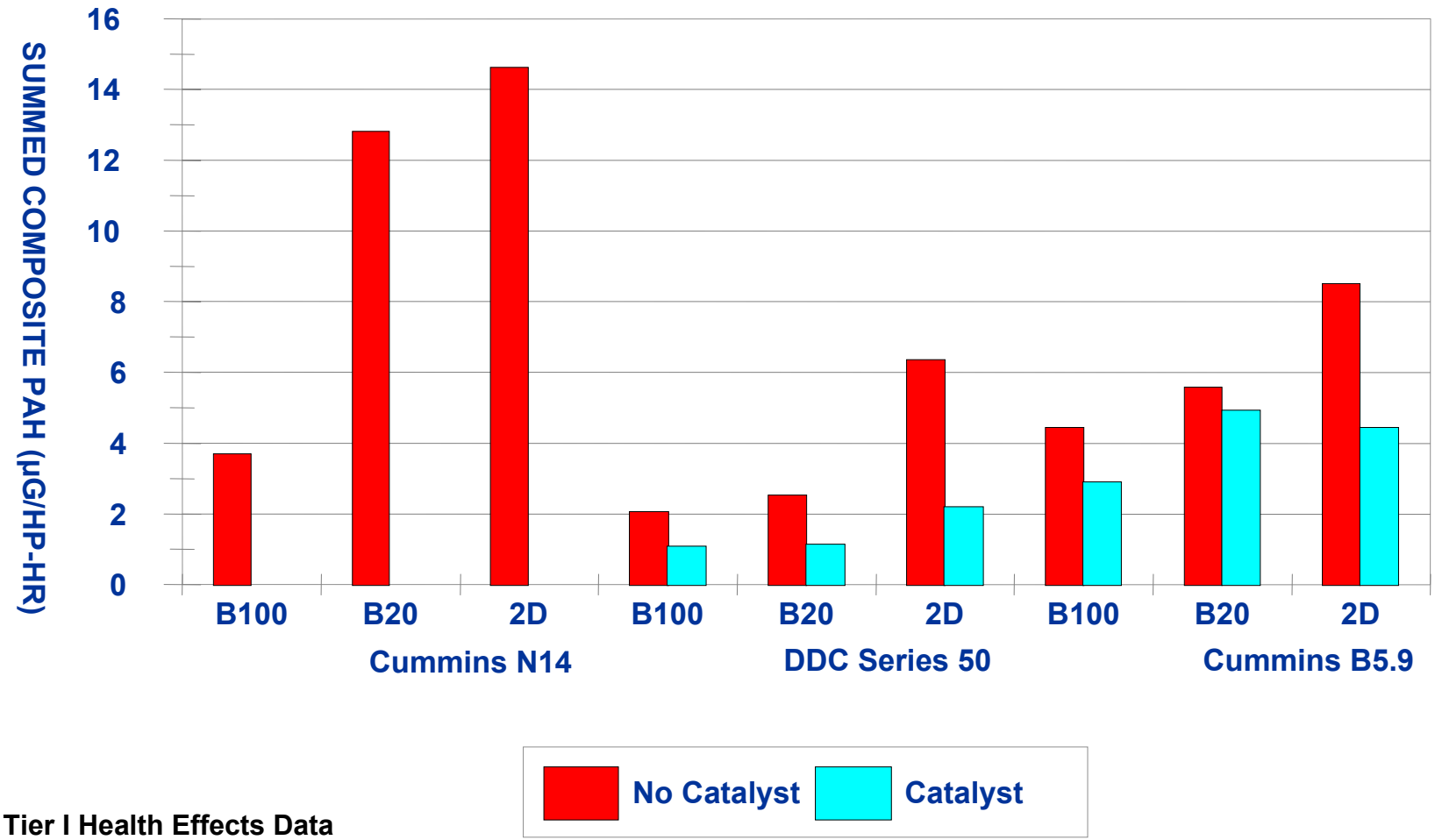
HEAVY HC SPECIATION - CUMMINS N14 ENGINE



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

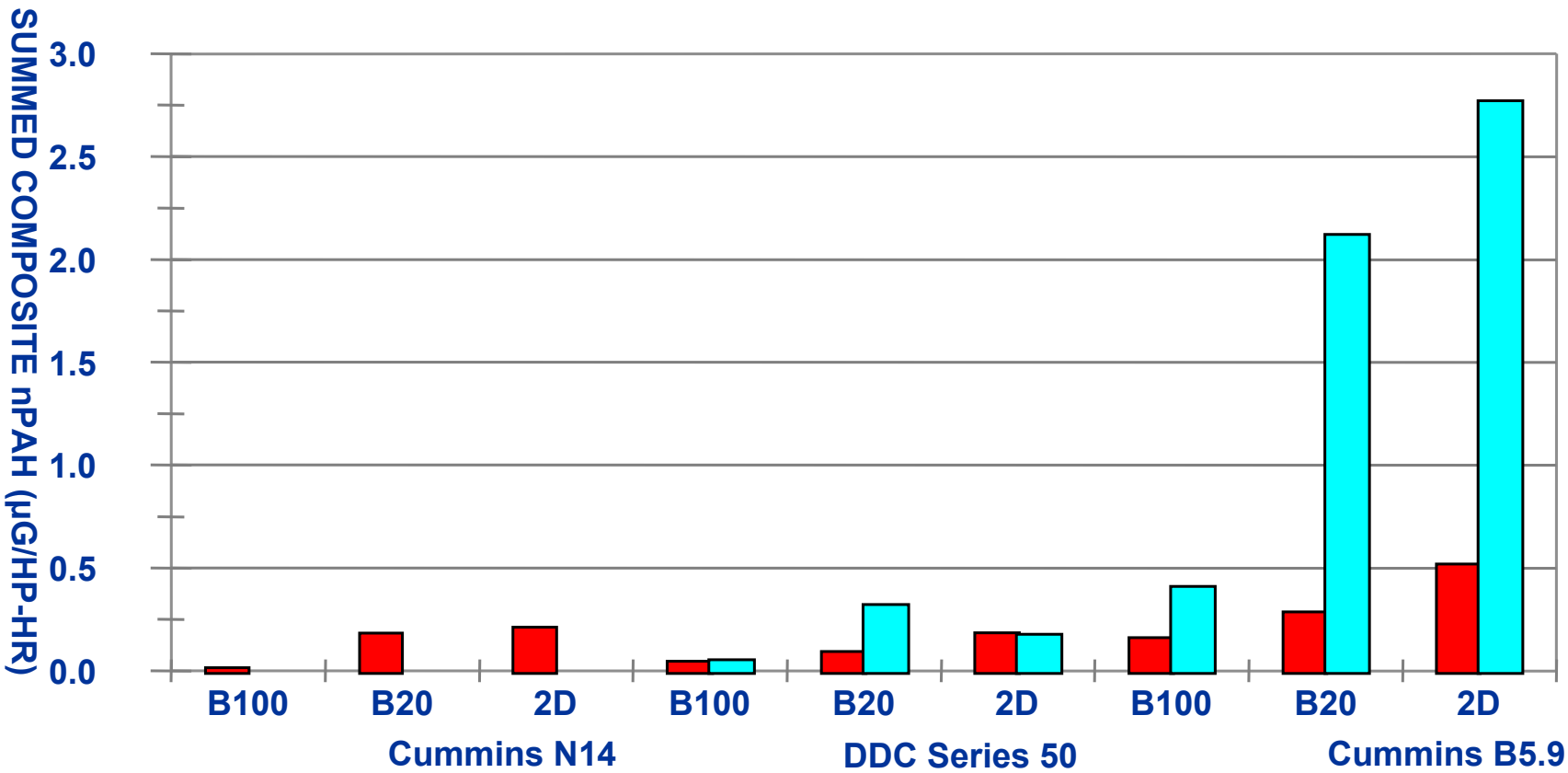
RELATIVE EMISSION RATE (MG/HP-HR)

PAH EMISSIONS SUMMARY
ALL ENGINES



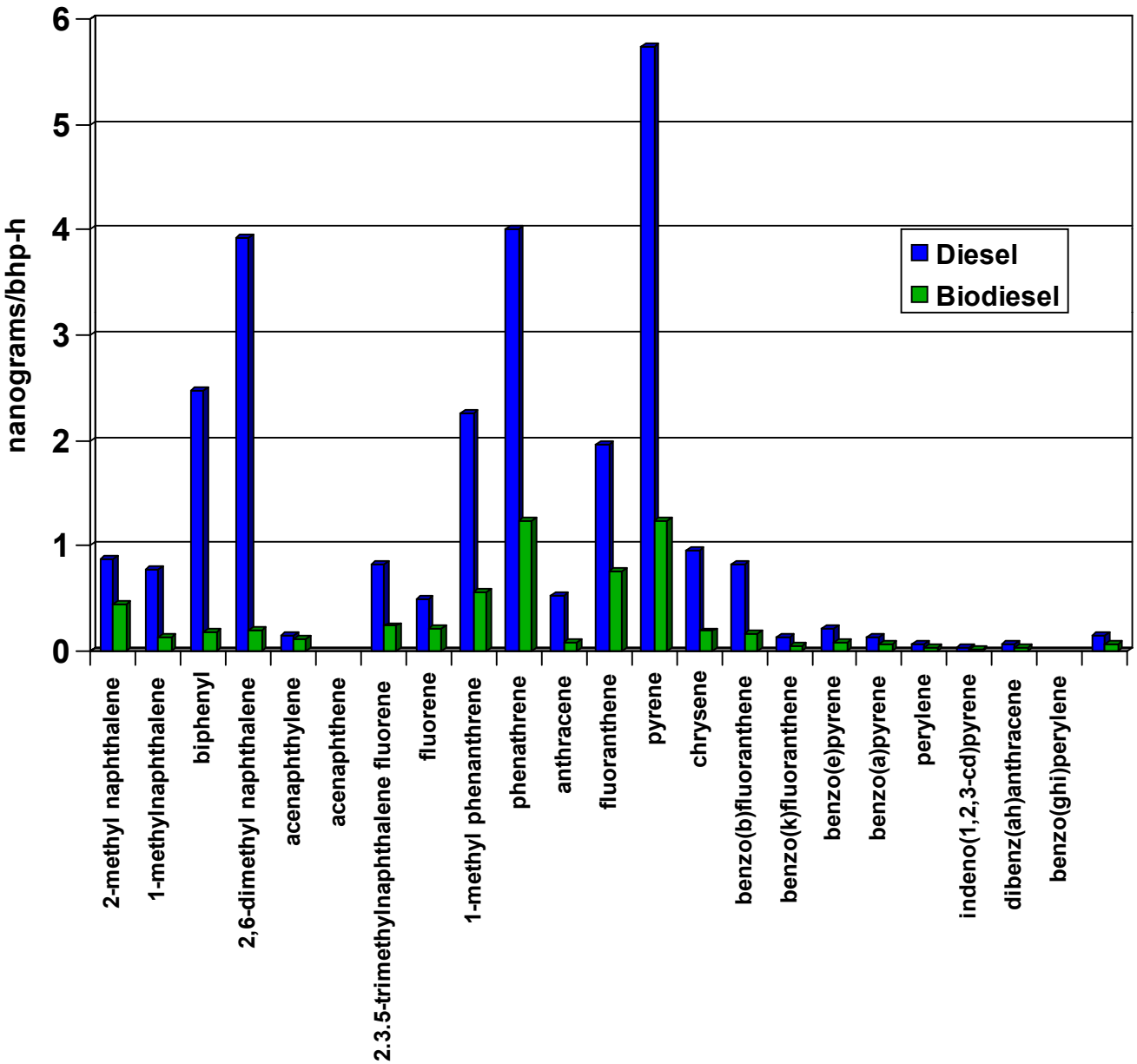
Tier I Health Effects Data
supplied by SWRI, 1997-8

NPAH EMISSIONS SUMMARY
ALL ENGINES

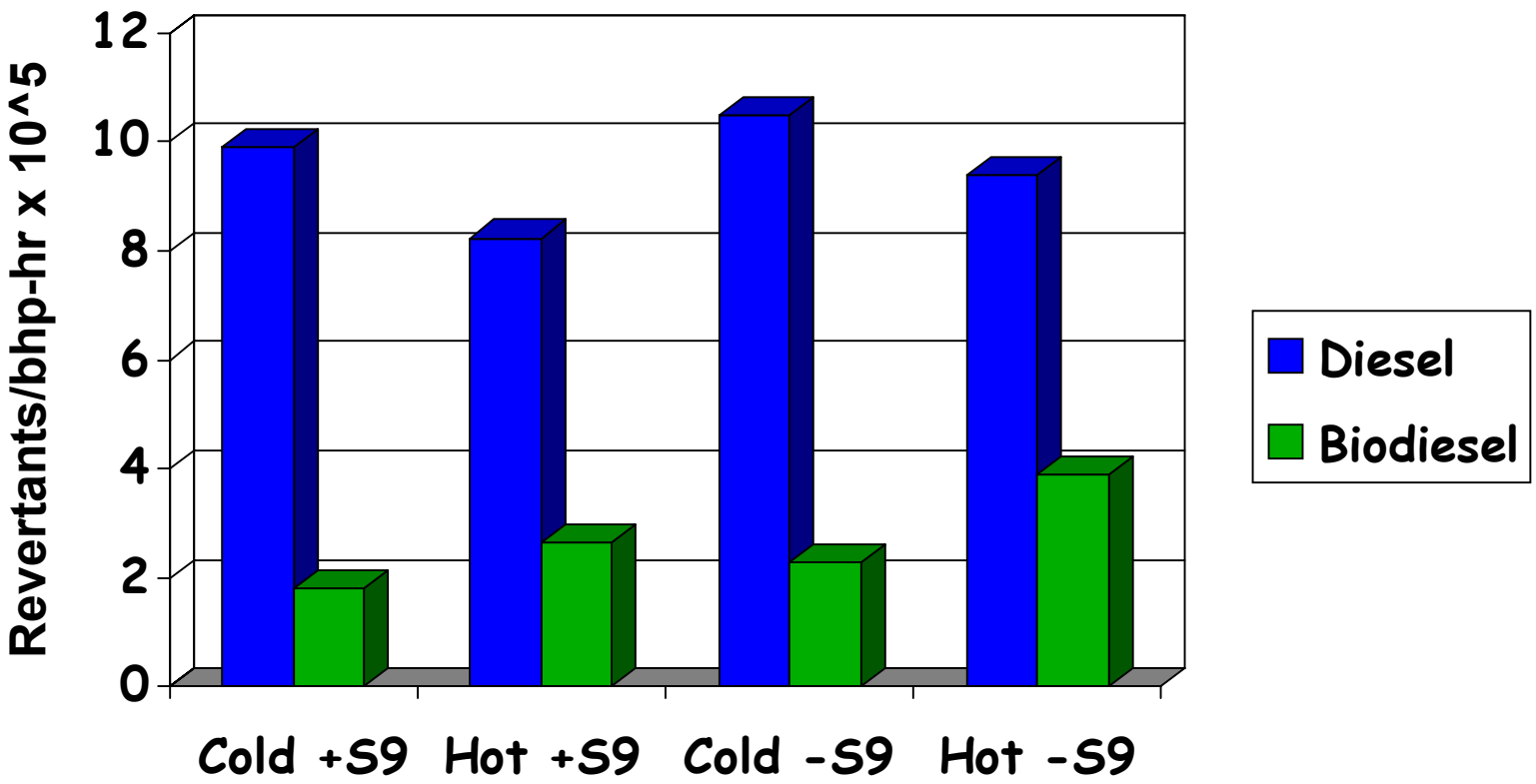


Tier I Health Effects Data
supplied by SWRI, 1997-8

PAH Air Toxics on Semi Volatiles



Mutagenicity Testing



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**

Conclusions

- **B20 is a drop in technology**
- **B100 can be used in existing infrastructure with some cautions**
- **B20 increases NOx by 0-4%**
- **B100 by 1.5% to 16% depending on fuel composition**
  - NOx solutions are evolving and likely to make an impact in the near future
- **B100 reduce CO, PM, NMHC an average of 43%, 55%, and 56% respectively**
- **B20 reduction of CO, PM, NMHC linear with blend level**
- **Biodiesel offers significant reductions in Air Toxics**

For More Info

- **National Biodiesel Board**
  - www.biodiesel.org
  - 1-800-841-5849
- **K. Shaine Tyson and Robert McCormick**
  - www.ott.doe.gov/biofuels
  - 303-384-6284 Tyson - Feedstocks & Processing
  - 202-275-4432 McCormick - End Use R&D