

# Changes in Emissions from Use of Biodistillate Fuels in the U.S.

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# CRC AVFL-17 Project

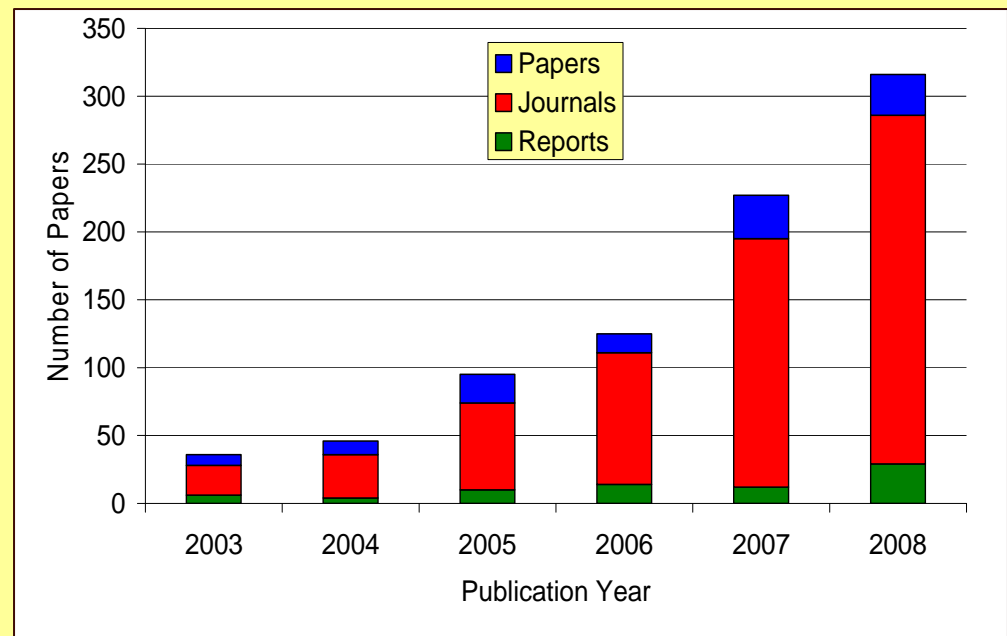
- Objective: Assess state-of-knowledge regarding bio-derived mid-distillate fuels
- Topics covered:
  - Policy drivers
  - Biofuel feedstocks
  - Fuel production technologies
  - Fuel properties and specifications
  - In-use handling and performance
  - **Exhaust emissions**
  - **Life-cycle impacts**
- Final report will be available from CRC website:  
[www.crcao.org](http://www.crcao.org)

# Biodistillate Terminology

- Biodiesel Fuel (BD):
  - ASTM D 6751: “... mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats.”
  - Transesterified triglycerides
  - Fatty acid methyl esters (FAME)
  - B100
- Renewable Diesel (RD)
  - Hydro-processed triglycerides
  - Green Diesel
  - NExBTL
- “Biodistillate” includes both BD and RD
  - Neat biodistillates vs. biodistillate blends
  - 1<sup>st</sup> Generation vs. 2<sup>nd</sup> Generation fuels

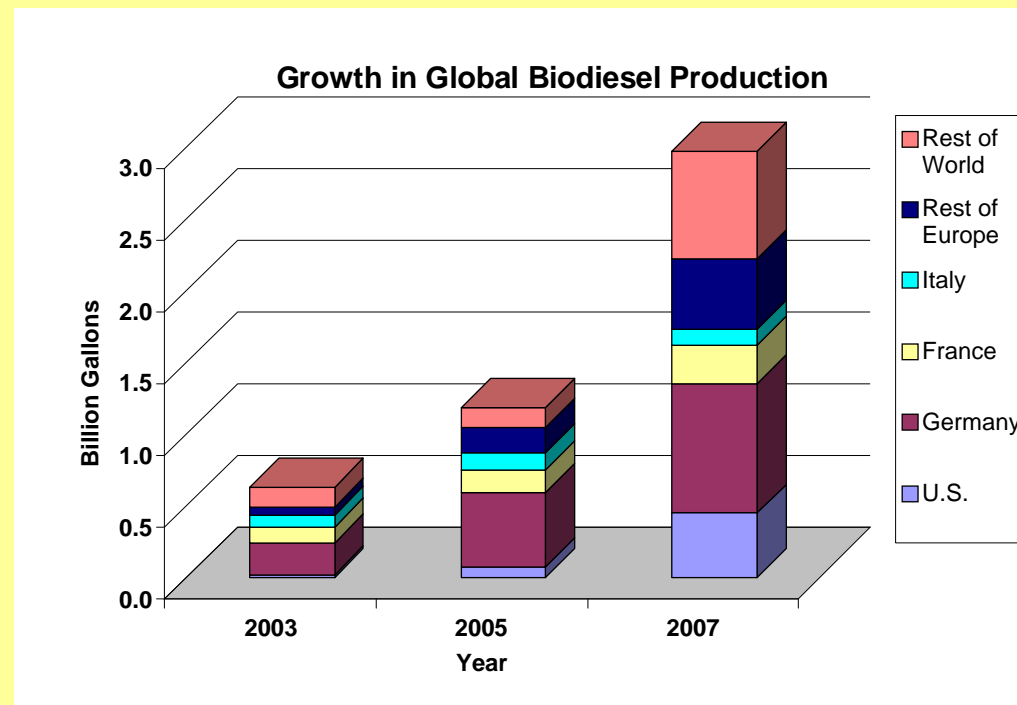
# Topic of Biodistillates is Very Active in the Literature

- Detailed literature review was conducted
  - Focused on years 2000 to present
  - Over 1000 items of interest identified
- Most relevant papers and reports are very recent



# Rapid Growth in Biodistillate Industry

- Current U.S. growth is driven by 2007 EISA
  - Requires 0.5 bg/y by 2009
  - Increases to 1.0 bg/y in 2012
- Future growth is limited by availability and cost of feedstocks
  - Soybean oil in U.S.
  - Rapeseed oil in Europe
- Great interest in non-conventional feedstocks



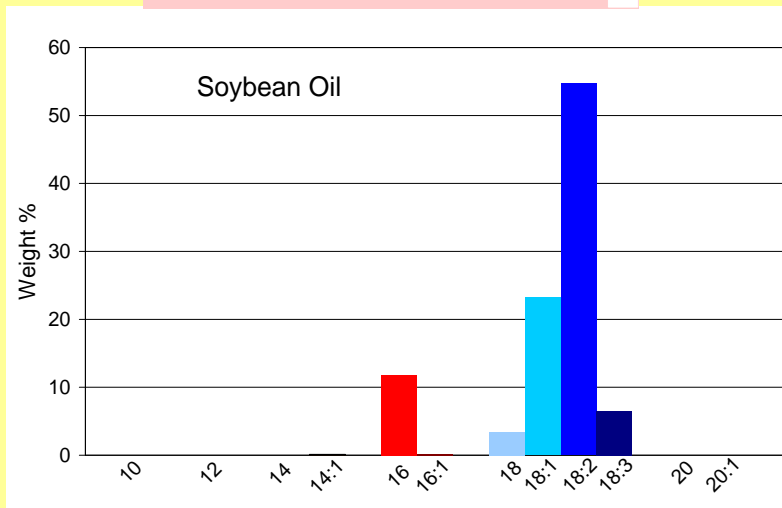
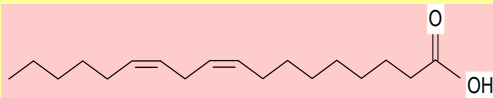
# Typical Properties of ULSD, FAME, and Renewable Diesel

Property	No. 2 Petroleum ULSD	Biodiesel (FAME)	Renewable Diesel
Carbon, wt%	86.8	76.2	84.9
Hydrogen, wt%	13.2	12.6	15.1
Oxygen, wt%	0.0	11.2	0.0
Specific Gravity	0.85	0.88	0.78
Cetane No.	40-45	45-55	70-90
T <sub>90</sub> , °C	300-330	330-360	290-300
Viscosity, mm <sup>2</sup> /sec. @ 40°C	2-3	4-5	3-4
Energy Content (LHV)			
Mass basis, MJ/kg	43	39	44
Mass basis, BTU/lb.	18,500	16,600	18,900
Vol. basis, 1000 BTU/gal	130	121	122

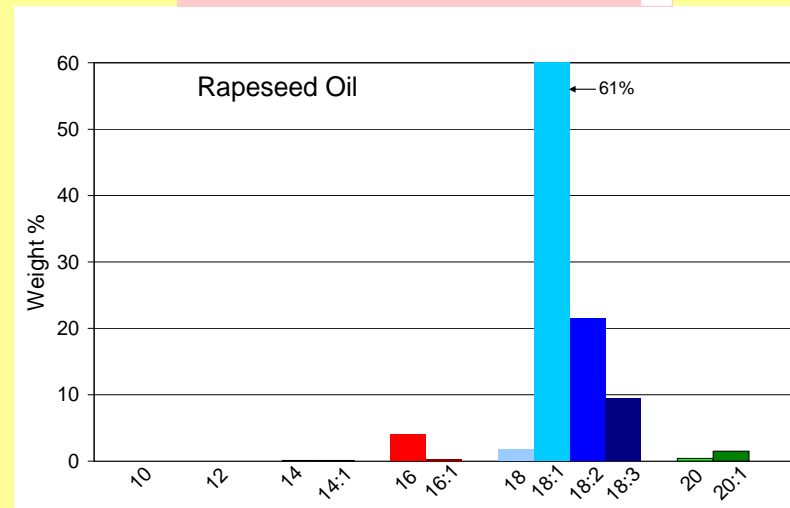
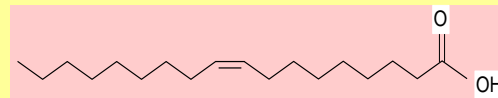
# Biodiesel Composition

- Two critical factors define physical properties and performance attributes of biodiesel
  - Carbon chain length of fatty acids ( $C_{16}$  and  $C_{18}$  predominate)
  - Degree of unsaturation in fatty acid

## Linoleic Acid (C18:2)

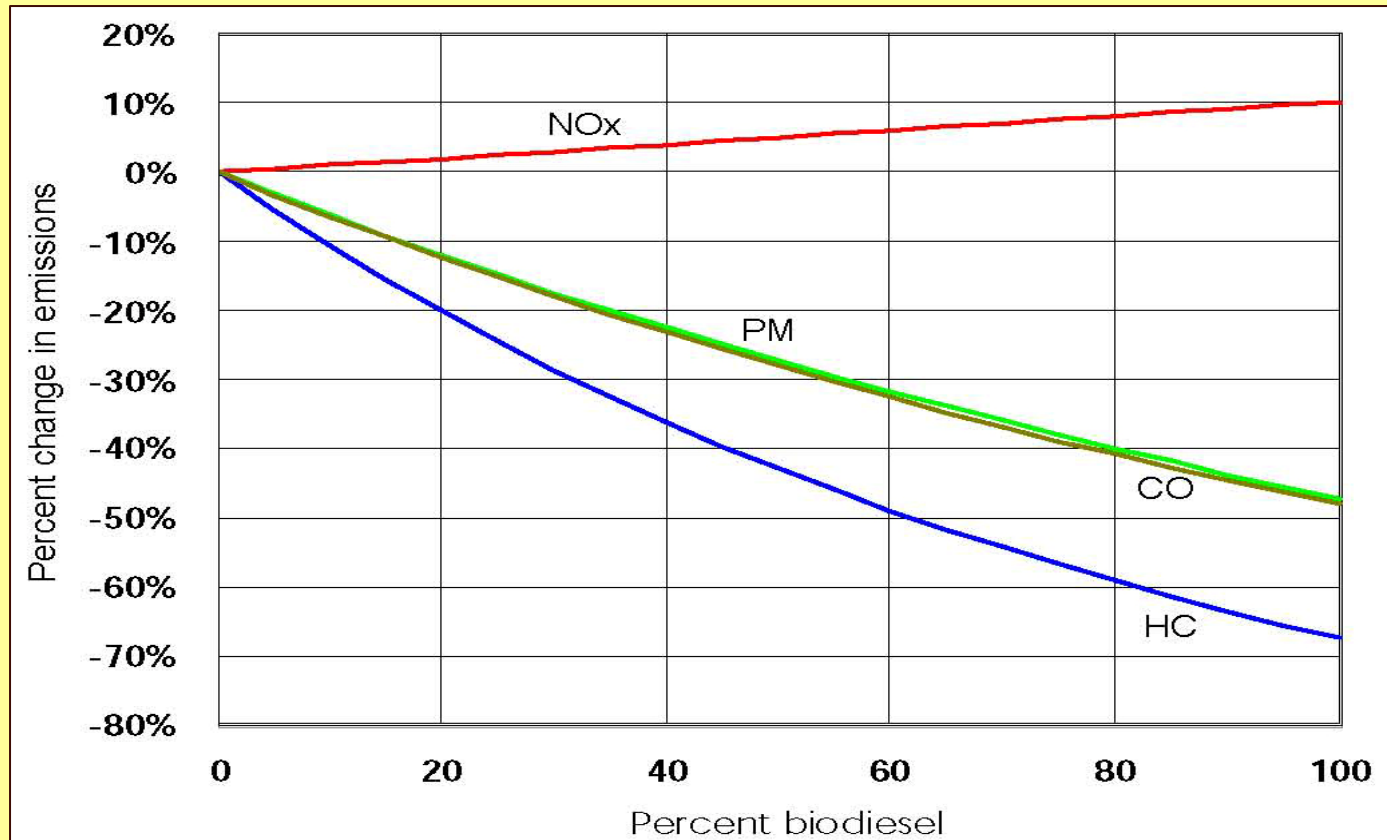


## Oleic Acid (C18:1)



Carbon Number and Unsaturation

# Exhaust Emissions Impacts: Previous Studies



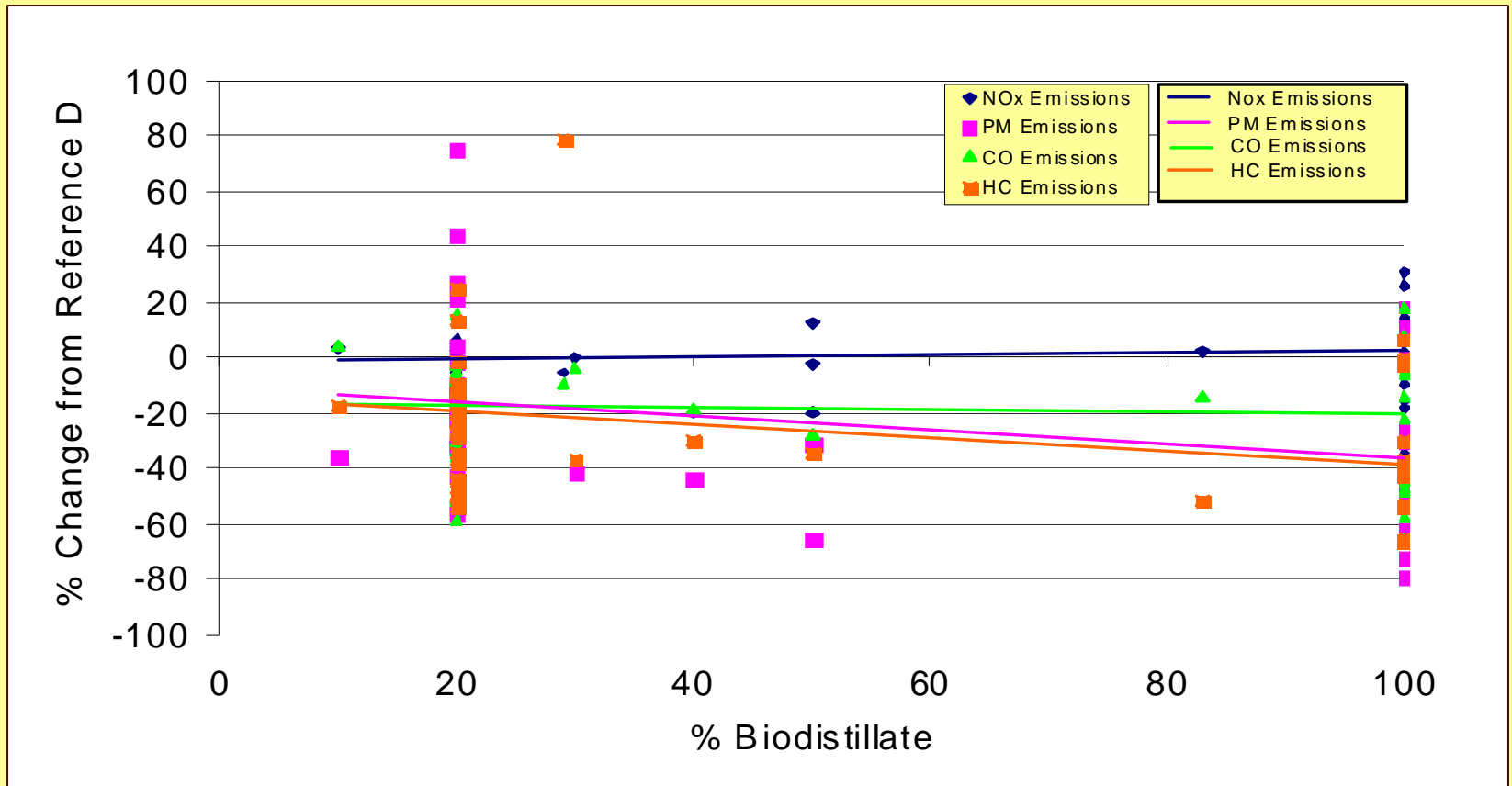
**EPA report of biodiesel emissions impacts in HD engines (2002)**

# Assessment of Exhaust Emissions Impacts – This Study

- 94 literature references were reviewed
  - 346 distinct emissions test results
  - Both biodiesel and renewable diesel cases
  - Many engine types, operating conditions, fuel types, blend levels, emissions control systems, etc.
- Biodistillate emissions results expressed as % difference from base fuel results
- Results analyzed separately for:
  - 4 emissions species: HC, CO, PM, and NO<sub>x</sub>
  - 3 engine types: HD, LD, single cylinder test engine (TE)

# Emissions Impacts from HD Engines

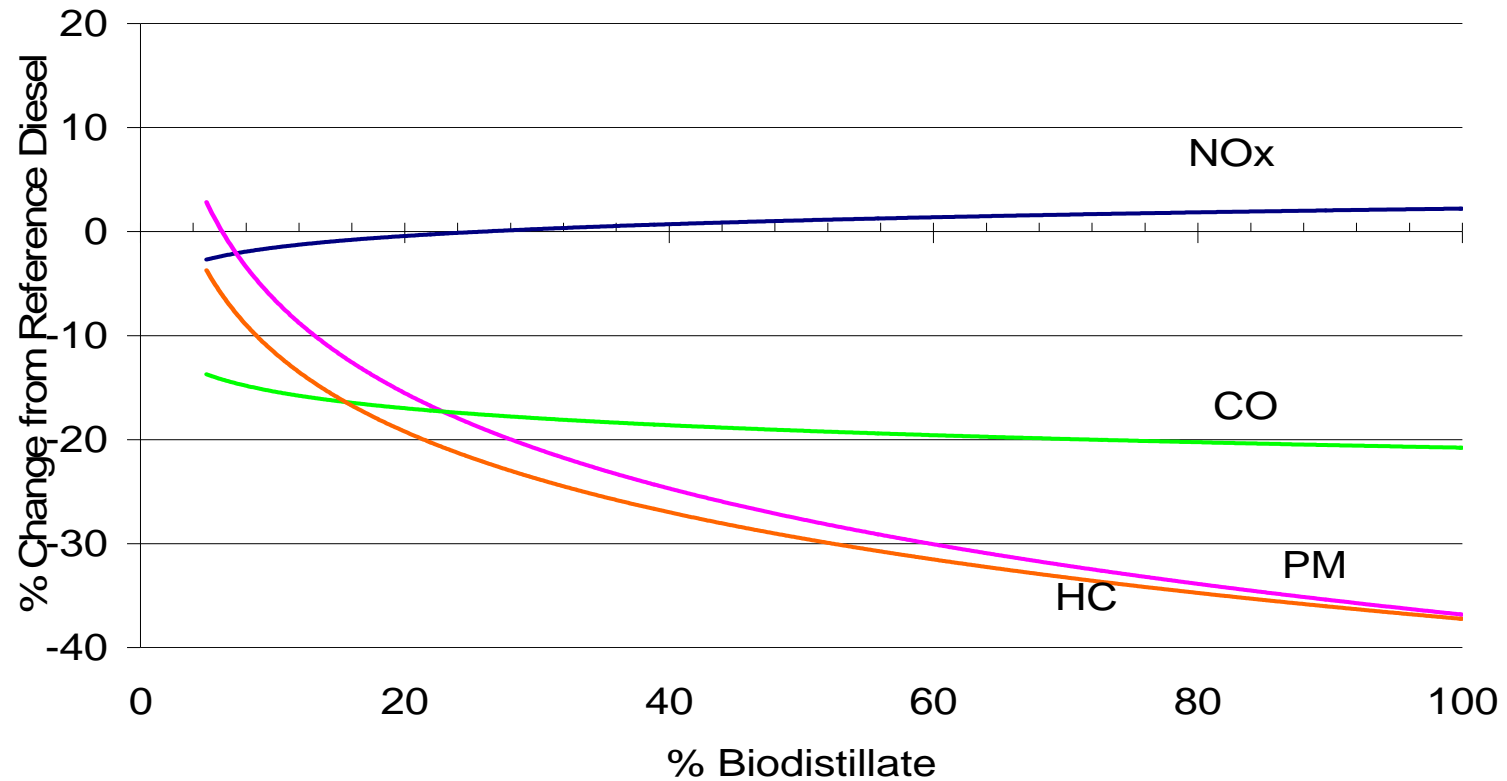
## Average Results from Individual Studies



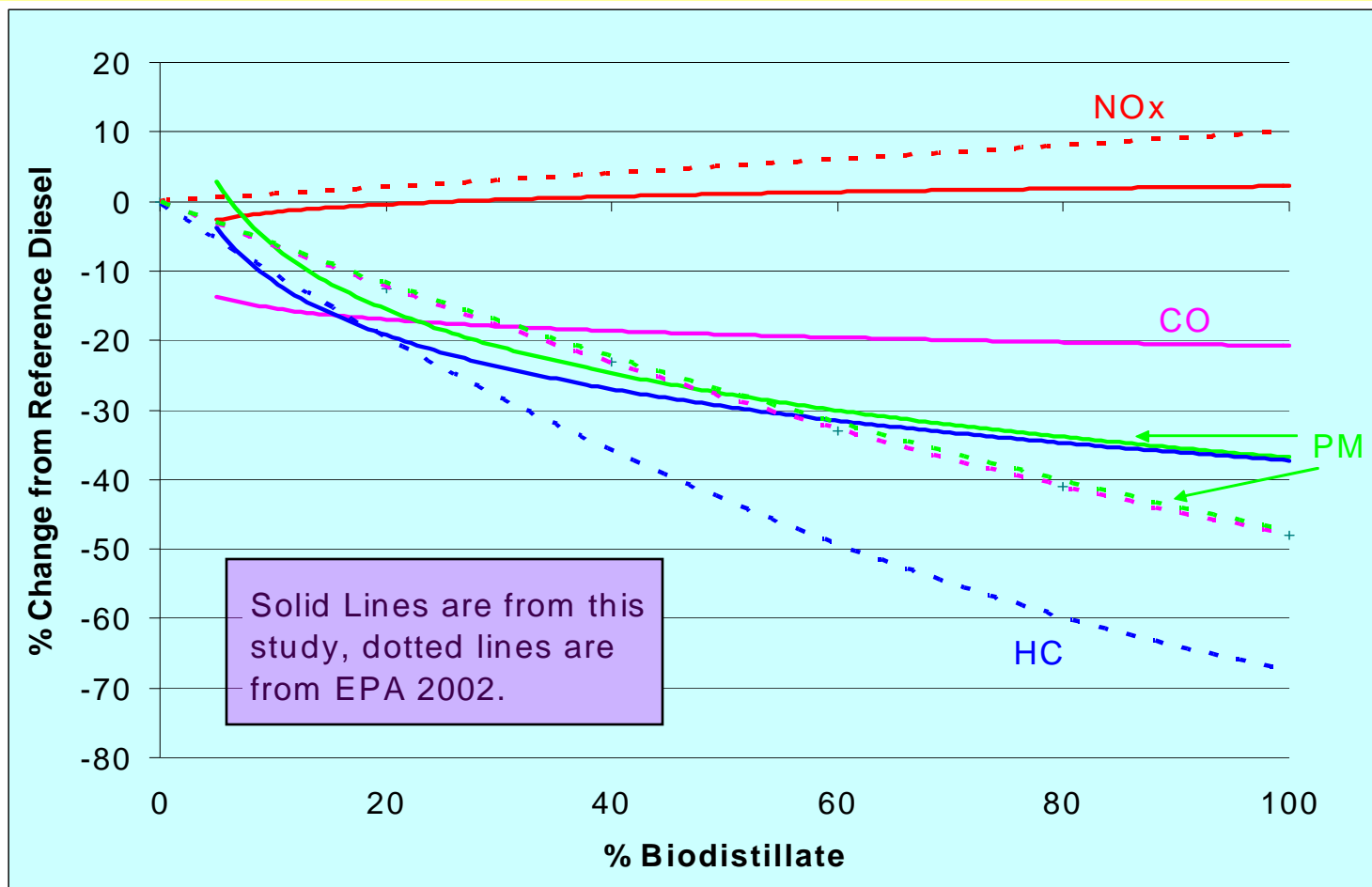
- Most tests conducted with B20 and B100
- High degree of variability from test-to-test

# Emissions Impacts from HD Engines

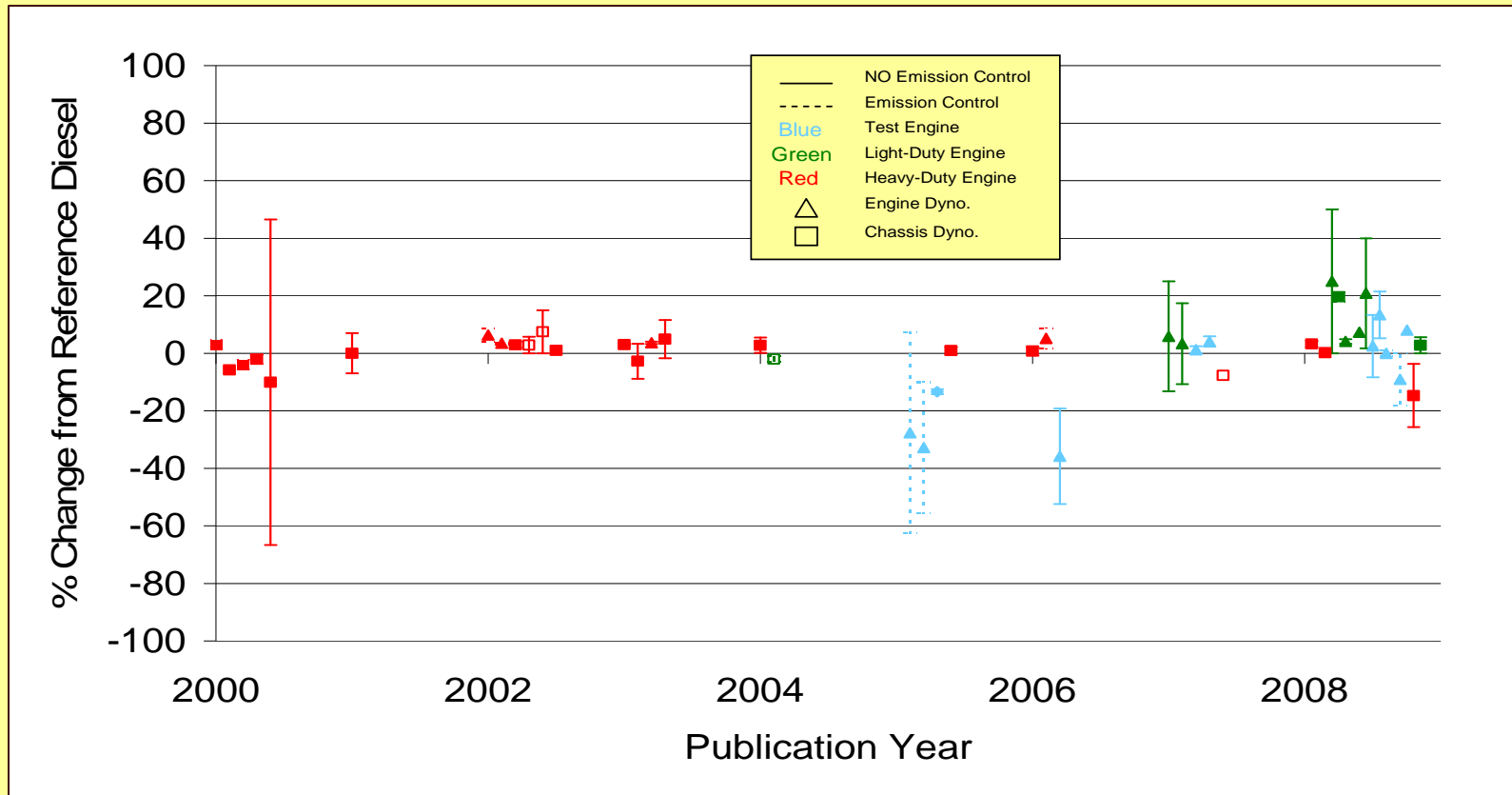
Best Fit from Log. Regression of Avg. Results



# HD Exhaust Emissions Impacts – Comparison with Previous Studies



# NOx Emissions Impacts of Biodistillates (20% Blends)



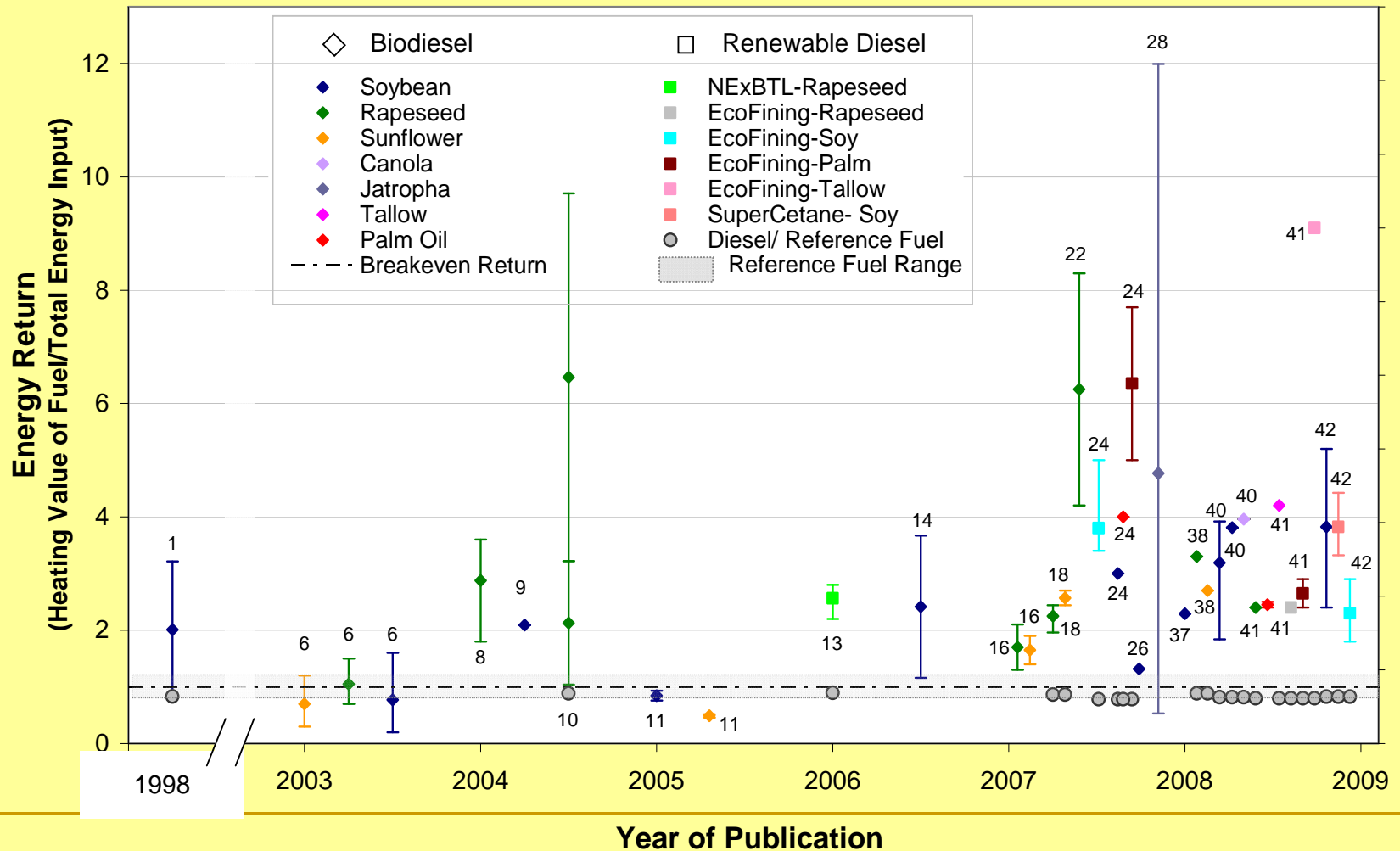
- No dramatic effect of engine type or model year
- Biodiesel and renewable diesel give similar results

# Life-Cycle Assessments (LCA) of Biodistillates

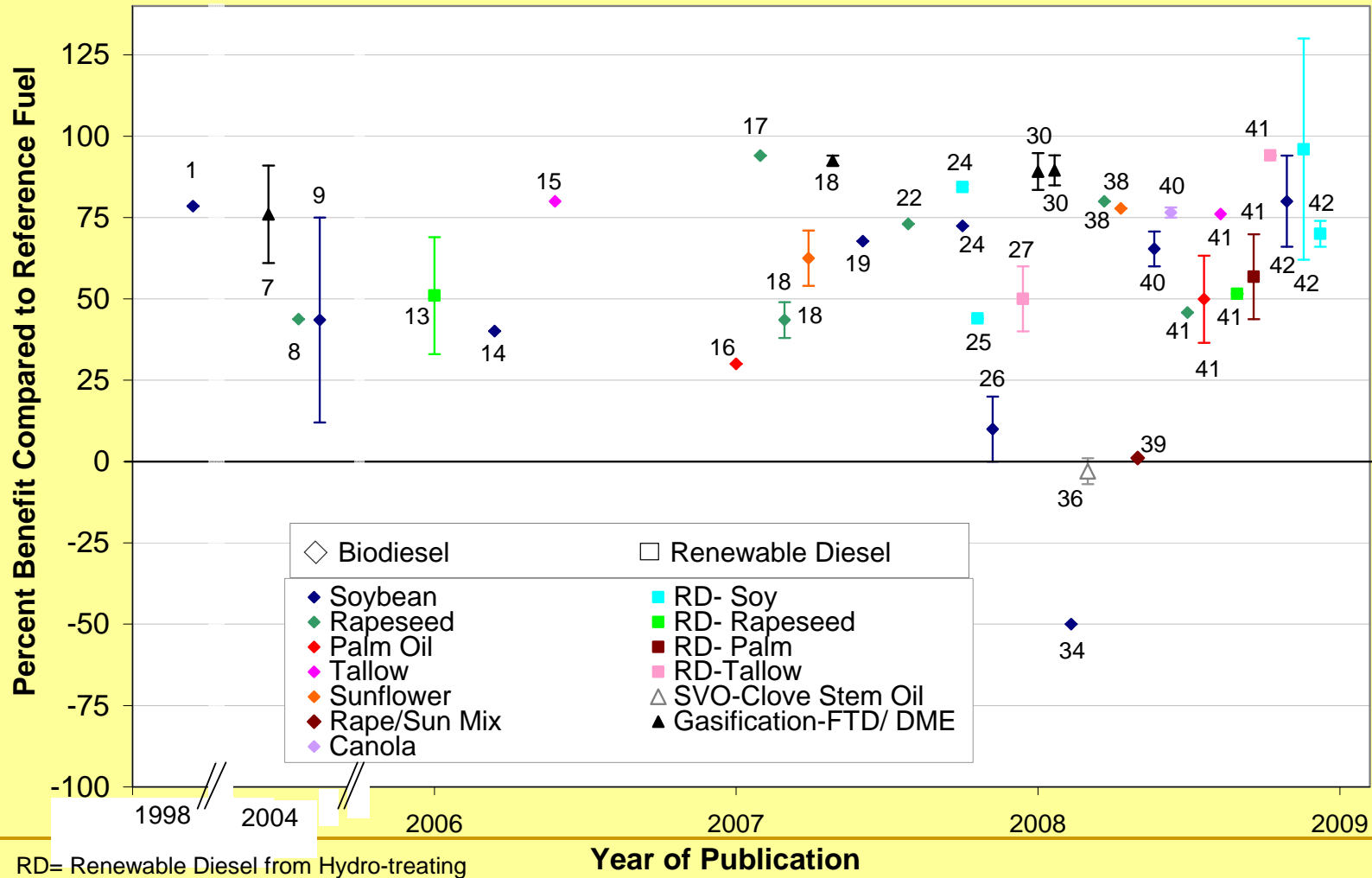
- Life-cycle (well-to-wheels) impacts of biodistillates compared to reference diesel fuel with respect to:
  - Energy return (ER)
  - Global warming potential (GWP)
- Over 40 published LCA studies for biodistillates
- Controversial topic with highly variable results, depending upon:
  - Type of model used
  - Input assumptions with respect to:
    - Land use change (LUC) – direct and indirect
    - Co-product allocation method
    - Many other factors

# LCA Energy Return (ER) for Biodistillates

## Results from 19 Published Studies – Many Scenarios



# LCA GWP Benefits for Biodistillates vs. Reference Fuel Results from 24 Published Studies – Many Scenarios



# Summary and Conclusions (1 of 2)

- Biodistillate production and use are increasing rapidly in the U.S. and elsewhere. U.S. production levels of:
  - 450 mg/y in 2007
  - 1 bg/y by 2012 required by EISA 2007
- Biodiesel from transesterified soybean oil is dominant fuel production pathway in the U.S.
  - Increasing interest in non-edible feedstocks
  - Increasing interest in hydroprocessed RD
- Biodistillates provide emissions benefits for HC, CO, and PM
  - 10-20% reductions for 20% blends
  - Similar results for B20 and R20

# Summary and Conclusions (2 of 2)

- NOx impacts are much smaller and hard to discern
  - Probably small NOx increase (2-3%) from B100 in HD engines
  - NREL (2009): “At this time, the data are insufficient for users to conclude anything about the average effect of B20 on NOx, other than it is likely very close to zero.”
- Life-cycle impacts of biodistillates are highly variable, depending upon assumptions used
  - Both for energy return and global warming potential
  - Most studies show significant benefits of biodistillates compared to conventional diesel fuel
    - 10-90% reduction in GWP
    - Similar results for BD and RD

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# Acknowledgements

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