Combustion Testing of a Biodiesel Fuel Blend

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in cooperation with

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Introduction

- Prior tests show that Biodiesel lowers emissions of SOx, NOx, and GHG (CO_2)
- Past tests limited to single burner/boilers
- **Purpose**: Test a range of burner-boilers/furnaces to evaluate combustion performance and emissions
- All tests conducted at NEFI training facility with 20% soy-based biodiesel blended with low sulfur (~0.05%) diesel fuel

Topics of Discussion

- Summarize Key Findings
- Describe Methodology and Equipment Tested
- Supply an Overview of Test Results
- Present Conclusions and Recommendations

Executive Summary

- Nitrogen Oxides lowered by ~20%
- Combustion Stability: Very Good
- Sulfur Oxides lowered by 83%
- Greenhouse Gas Lowered by 20%
- Smoke Numbers Lower for same burner air setting
- Fuel Oil and Combustion Odors are improved - less intense and more pleasant smelling

Summary of Tests Completed

NORA / MOC Biodiesel Blend Tests At NEFI

REF	Unit NEFI No.	Unit Type	Fuel Nozzle Gph	Pressure psig	Flow Rate gph	Fuels Tested Biodiesel	Fuel Oil
B-1	**13**	WAF	0.75	100	0.75	20% Bio/LSF	#2 oil
B-2	**13**	WAF	0.65	100	0.65	20% Bio/LSF	#2 oil
B-3	**13**	WAF	0.50	100	0.50	20% Bio/LSF	#2 oil
B-4	**22**	HWB	0.85	100	0.85	20% Bio/LSF	#2 oil
B-5	**22**	HWB	0.65	100	0.65	20% Bio/LSF	#2 oil
B-6	**8**	HWB	0.65	100	0.65	20% Bio/LSF	#2 oil
B-7	**23**	HWB	0.75	100 / 160	0.75 / 0.95	20% Bio/LSF	#2 oil
B-8	**10**	HWB	0.75	100	0.75	20% Bio/LSF	#2 oil
B-9	**10**	HWB	0.75	130	0.85	20% Bio/LSF	#2 oil
B-10	**10**	HWB	0.75	175	0.99	20% Bio/LSF	#2 oil
B-11	**10**	HWB	0.65	100/150/200	0.65	20% Bio/LSF	#2 oil
B-12	**10**	HWB	0.50	130	0.58	20% Bio/LSF	#2 oil
B-13	**10**	HWB	0.50	150	0.62	20% Bio/LSF	#2 oil
B-14	**10**	HWB	0.50	200	0.70	20% Bio/LSF	#2 oil
B-15	**1**	StB	2.50	100	2.50	20% Bio/LSF	#2 oil
B-16	**1**	StB	2.50	150	3.10	20% Bio/LSF	#2 oil
B-17	**1**	StB	2.50	200	3.50	20% Bio/LSF	#2 oil
B-18	**23**	HWB	0.75	100	0.75	**#2 Oil/LSF**	#2 oil
B-19	**22**	HWB	0.75	100	0.75	**#2 Oil/LSF**	#2 oil
B-20	**13**	WAF	0.75	100	0.75	**#2 Oil/LSF**	#2 oil

NOTES: WAF: Warm Air Furnace HWB: Hot Water Boiler
StB: Steam Boiler Bio: Soy-based Biodiesel fuel
LSF: low sulfur (0.05%) Home Heating Oil

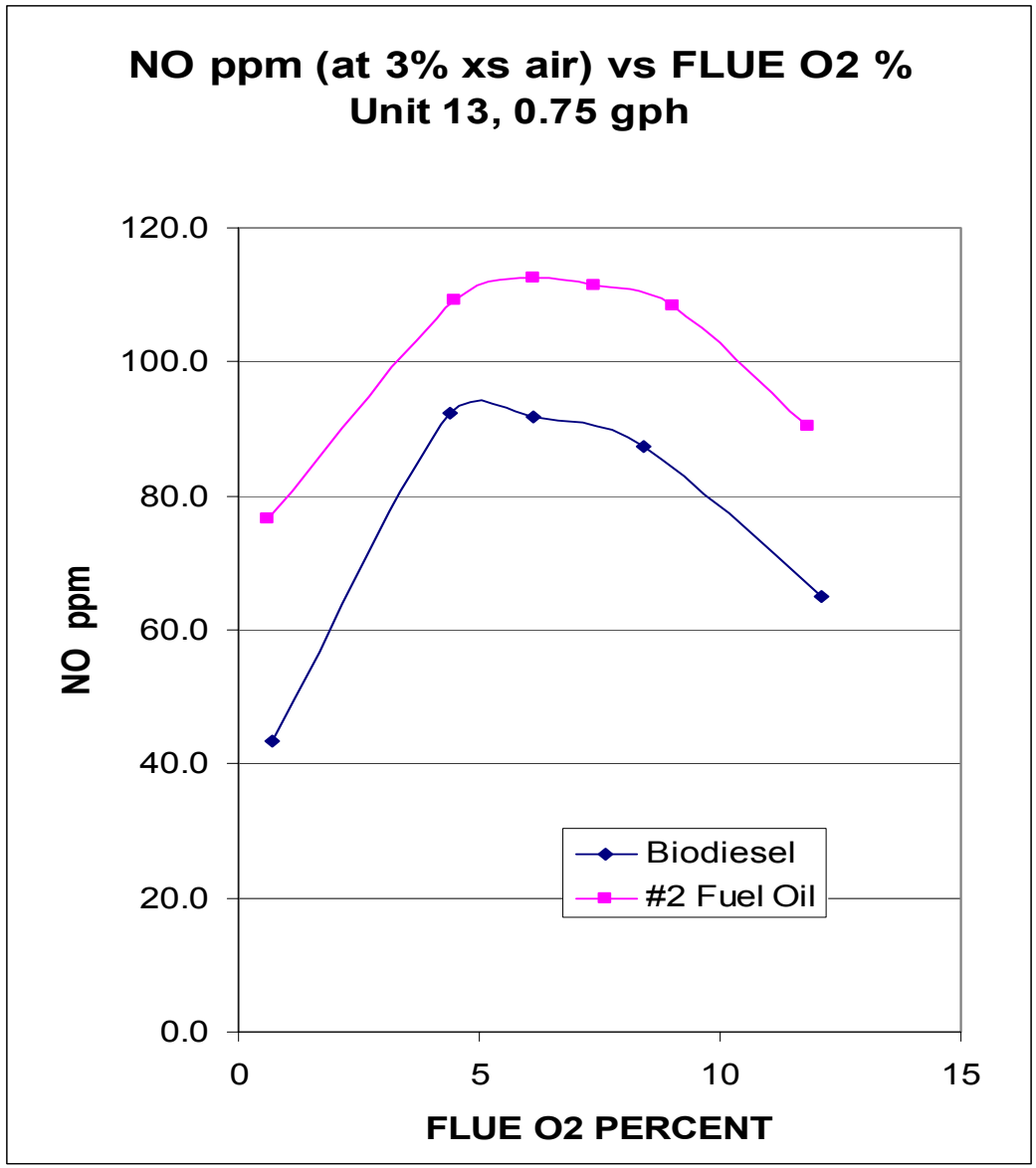
Methodology

- A range of burner-boilers and burner-furnaces were tested
- Flue gas tests included: O_2, Smoke #, Carbon Monoxide, NO, NO_x, SO_2, draft, and temperature
- A range of firing rates were tested for each unit: eg. 0.50, 0.75, and 1.00 gph
- A full range of excess air settings were evaluated for each test unit
- Data were recorded and then the combustion readings were plotted as a function of excess burner air.

Test Results and Analysis

- Reduced Nitrogen Oxide emissions
- Carbon Monoxide emissions - an indicator of combustion stability
- Other Test Observations:
  - Sulfur Oxides
  - Flue Gas Temperatures
  - Smoke Numbers
  - Fuel and Combustion Odor

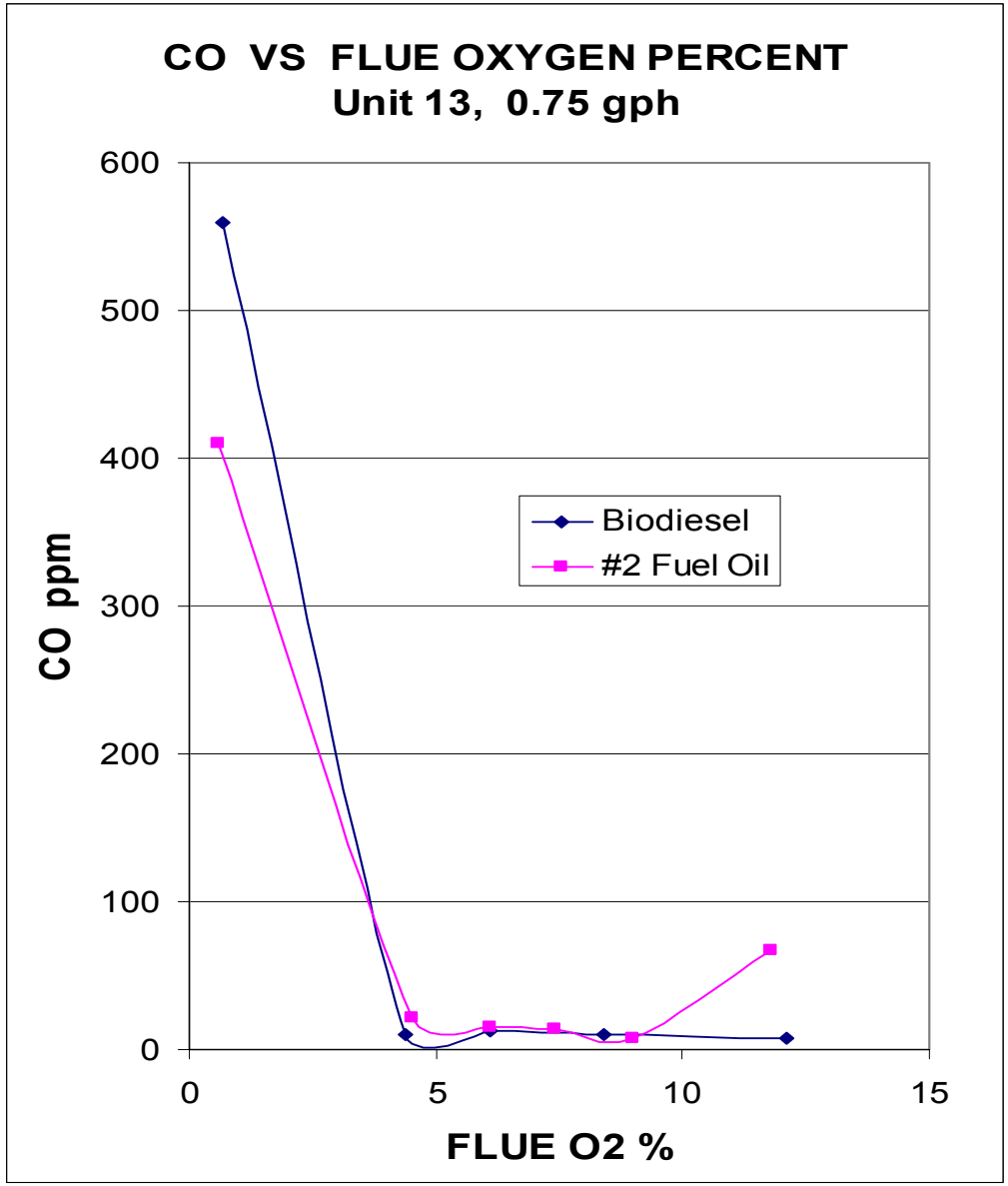
Reduced Nitrogen Oxide Emissions



Key Points - NOx Reductions

- Biodiesel lowers flue gas NO by 20% over the entire range of burner air settings
- Nitric Oxide is maximum at 5% flue gas oxygen levels for this furnace
- Peak NO is 95 ppm for biodiesel and 115 ppm for #2 fuel oil
- Similar reductions observed when furnace fired at 0.65 gph
- Lower NO reductions of 15 ppm were observed for 0.5 gph firing rate.
- 20% reduction was typical for many other boilers and furnaces

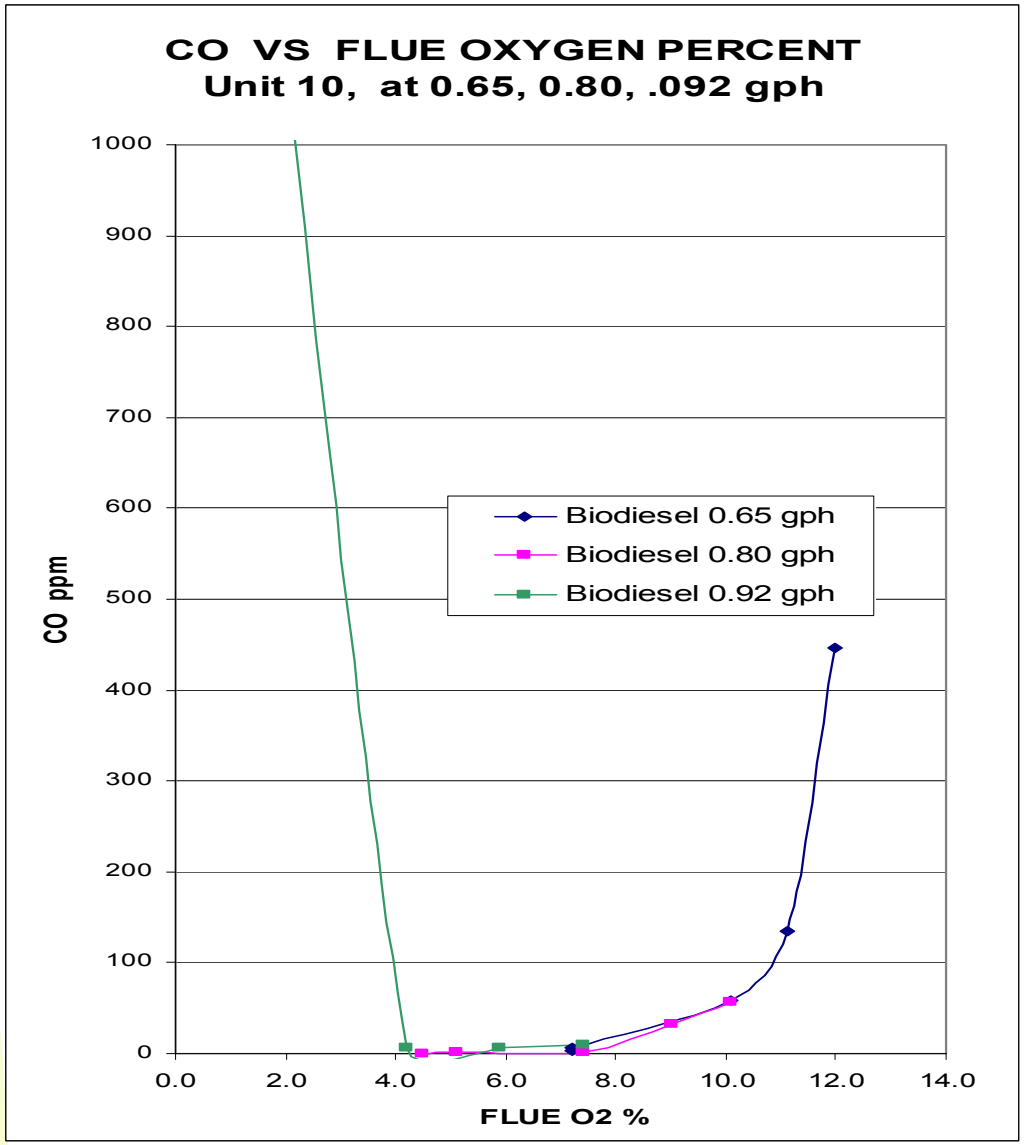
Carbon Monoxide Emissions



Key Points - CO Emissions

- Similar CO emissions were measured for 20% Biodiesel and #2 fuel oil
- CO versus excess air emission profiles are also very similar
- Minimum CO levels are the same
- CO levels begin to rise at similar burner excess air settings
- This suggests <u>similar combustion stability</u> for 20% biodiesel blends and #2 fuel oil.

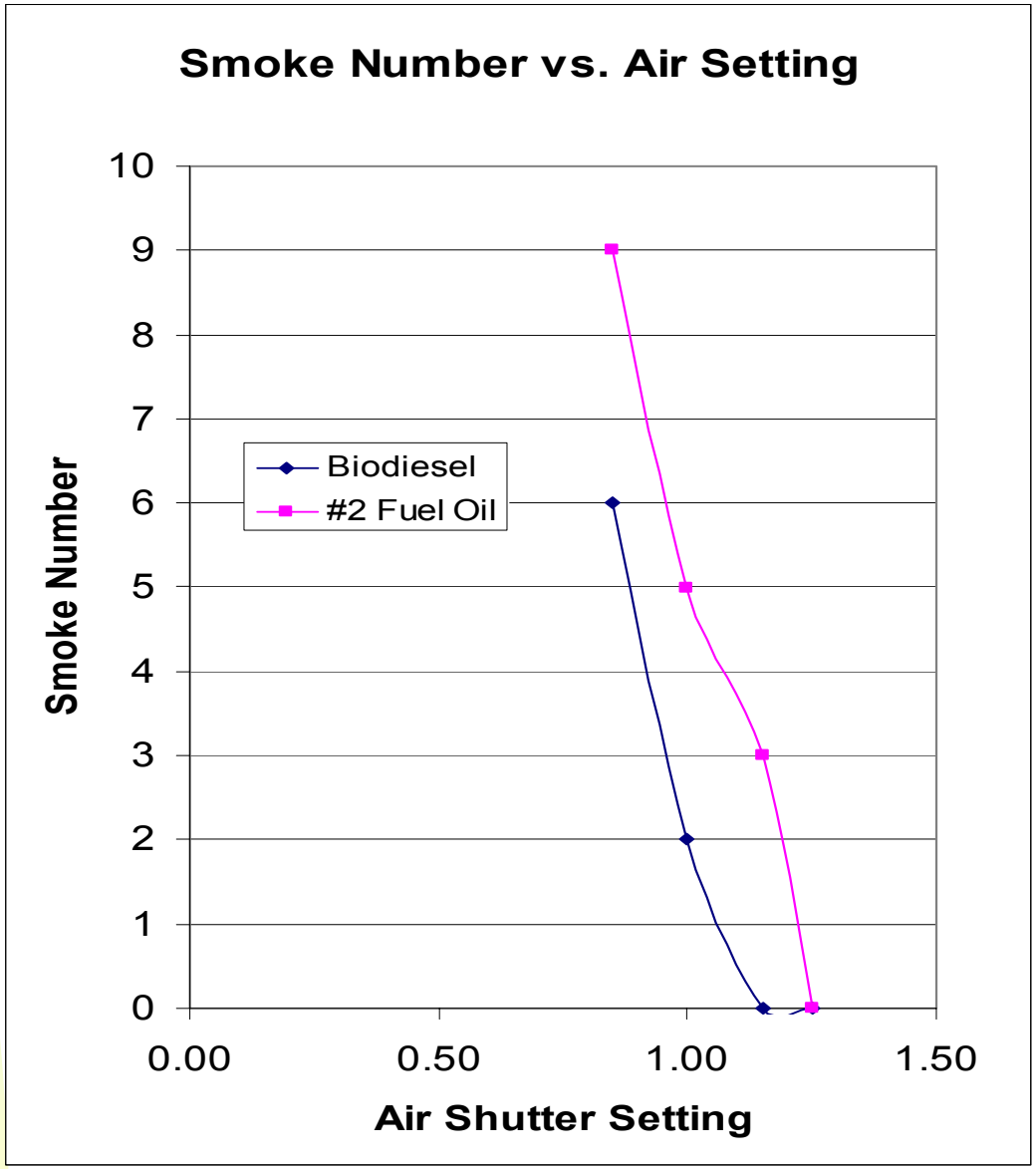
Typical U-Shaped CO Curve w/ Biodiesel

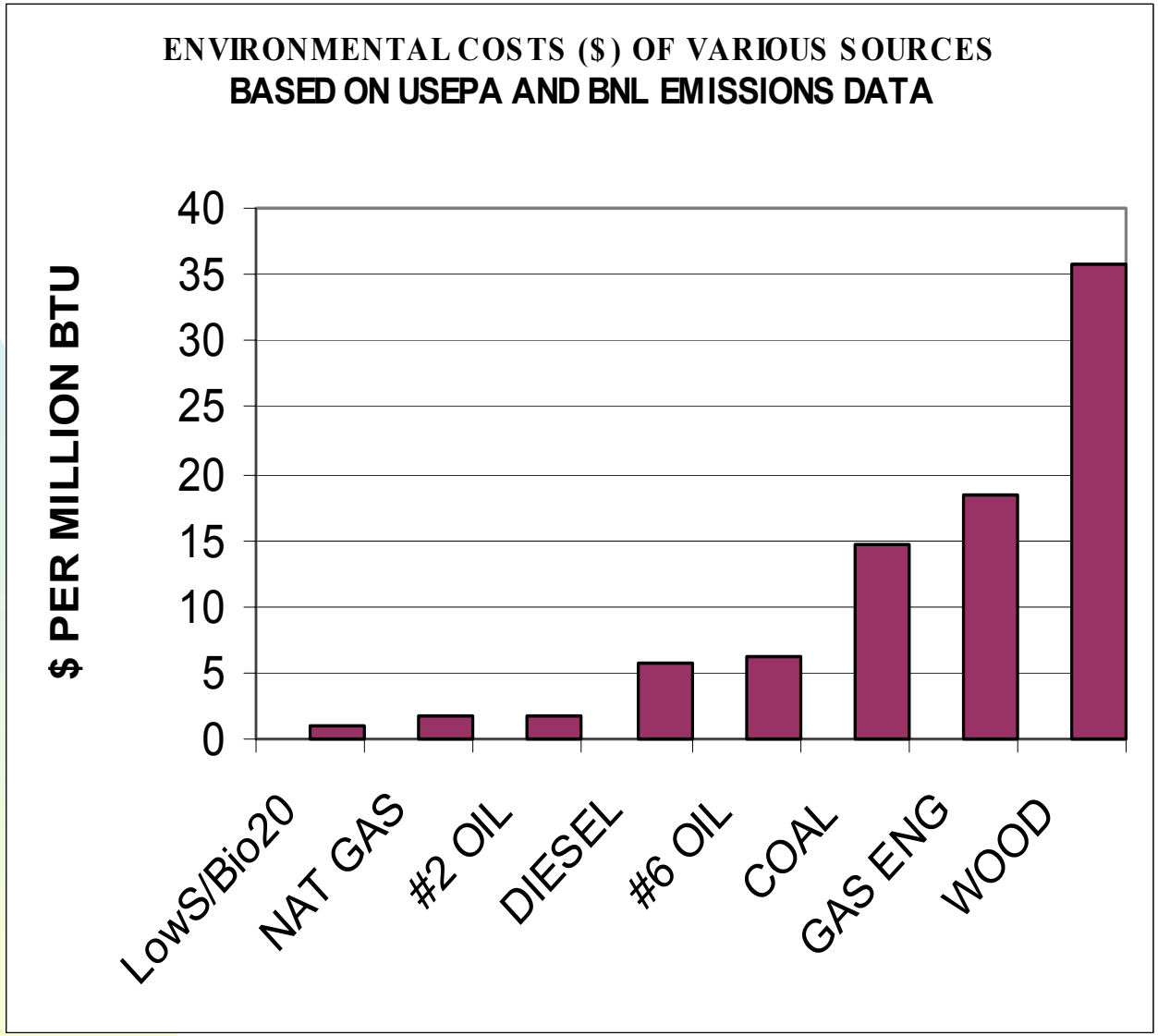


Other Test Observations

- **Sulfur Oxides** were reduced by **83%** f`or the 20% biodiesel /low sulfur diesel blend compared to the **#2 fuel oil**
- **Flue Temperatures** did not change
- **Smoke Numbers** were lower for the biodiesel blend for the same air setting (see Figure)
- **Fuel and Combustion Odors** were improved - less intense odor and more pleasant odor for fuel and combustion gas

Reduced Smoke with 20% Biodiesel Blend




ENVIRONMENTAL COSTS ($) OF VARIOUS SOURCES
BASED ON USEPA AND BNL EMISSIONS DATA
$ PER MILLION BTU
40
35
30
25
20
15
10
5
0
LowS/Bio20
NAT GAS
#2 OIL
DIESEL
#6 OIL
COAL
GAS ENG
WOOD

Conclusions & Recommendations

- Significant reductions in air emissions using the 20% biodiesel / low sulfur diesel blend - SO_x, NO_x, GHG (20%)
- Favorable Combustion Performance: CO profile vs. excess air, and lower smoke numbers
- Improved Odor Characteristics - fuel and combustion products
- Biodiesel is “homegrown” agricultural product and can help to change the perception of foreign dependence for oil.

Next Steps

- Evaluate combustion performance for a range of biodiesel percent blends
- Test cold flow characteristics
- Test interactive effect of biodiesel and ultra-low (0.0015%) fuel oil
- Long-term tests of reduced fouling rates
- Field studies to demonstrate advantage and potential problem areas for biodiesel/fuel oil blends