

New Technology Diesel Engines: Eliminating NOx Emissions from Higher Biodiesel Blends in Un-modified Diesel Engines

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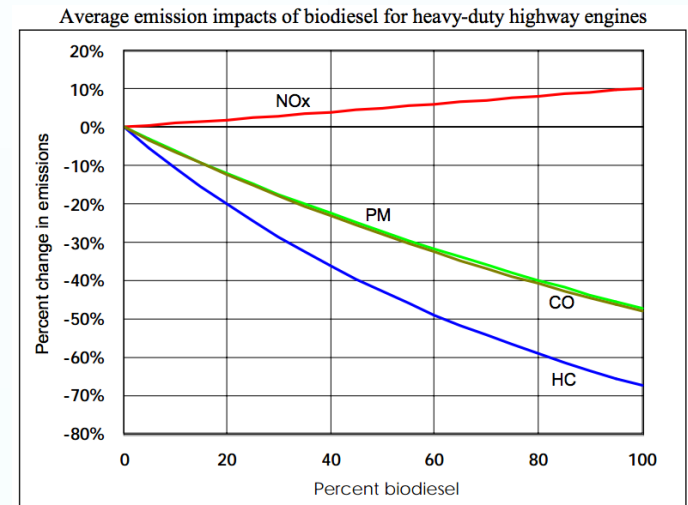
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History of Biodiesel Emissions

- 2002: EPA, A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions-suggested slight NO_x increase with B20 using EPA diesel, heavily weighed on unmodified bus engines
 - Most early testing was on buses, a lead B20 market in the 1990's
 - Substantial decrease in all other emissions
- 2006: NREL, Effects of Biodiesel Blends on Vehicle Emissions: B20 has no statistically significant net impact on NO_x emissions using EPA 49 state petrodiesel
 - Removal of 1992 bus engines which were no longer in service



2002 EPA B20 Evaluation
with EPA 49 state petrodiesel

What is the Real Impact of the Only Emission Biodiesel May not Reduce

- In 2003, the US DOE commissioned Environ to analyze the impact of B20 on ambient air quality in Southern CA
- Used Comprehensive Air Quality Model with Extensions (CAMx) and SoCAB database for Aug 3-7, 1997 Southern California Ozone Study (SCOS) episode
 - Plugged B20 into model for HDDV fleet
 - NO_x +2.4% of 5 gram NO_x engine, CO -13.1%, HC -17.9%)

“The 100% and 50% penetration of a B20 biodiesel fuel is estimated to have very small effects (increases and decreases) in ozone concentrations in the Southern California region. For the most part the changes in ozone due to the biodiesel fuel use are so small that they would not be measurable. Therefore, the main conclusion of the analysis is that the use of a B20 biodiesel in the HDDV fleet would have no significant ozone impact.”

What is the Real Impact of the Only Emission Biodiesel May not Reduce

Maximum increases and decreases in daily maximum 1-hour ozone concentrations (ppb) in the South Coast Air Basin regions in 1997 South Coast Air Basin Domain during ozone incident if B20 were used in 50% and 100% of heavy duty vehicles during 1997 California ozone event:

	<u>Ozone, ppb</u>		<u>Ozone, ppb</u>	
	50% B20		100% B20	
	<u>Penetration</u>		<u>Penetration</u>	
	Max	Max	Max	Max
	<u>Increase</u>	<u>Decrease</u>	<u>Increase</u>	<u>Decrease</u>
August 4, 1997	+0.09	-0.48	+0.17	-0.95
August 5, 1997	+0.10	-0.56	+0.19	-1.1
August 6, 1997	+0.11	-0.60	+0.22	-1.2
August 7, 1997	+0.13	-0.49	+0.26	-0.98

“ The Impact of Biodiesel Fuels on Ozone Concentrations”; R.E. Morris, G.E. Mansell, Y. Jia, and G. Wilson; ENVIRON International Corporation, Novato, California; May 2003; Task 2 Report: NREL/SR-540-33795.

What is the Real Impact of the Only Emission Biodiesel May not Reduce

Maximum increases and decreases in daily maximum 8-hour ozone concentrations (ppb) in the South Coast Air Basin regions in 1997 South Coast Air Basin Domain during ozone incident if B20 were used in 50% and 100% of heavy duty vehicles during 1997 California ozone event:

	<u>Ozone, ppb</u>		<u>Ozone, ppb</u>	
	50% B20		100% B20	
	<u>Penetration</u>		<u>Penetration</u>	
	Max	Max	Max	Max
	<u>Increase</u>	<u>Decrease</u>	<u>Increase</u>	<u>Decrease</u>
August 4, 1997	+0.06	-0.34	+0.12	-0.68
August 5, 1997	+0.07	-0.39	+0.15	-0.77
August 6, 1997	+0.08	-0.48	+0.15	-0.96
August 7, 1997	+0.08	-0.42	+0.15	-0.83

“As the maximum ozone increase (+0.26 ppb) is well below 1 ppb, the use of biodiesel is estimated to have no measurable adverse impact on 1-hour or 8-hour ozone attainment in Southern California.”

“ The Impact of Biodiesel Fuels on Ozone Concentrations”; R.E. Morris, G.E. Mansell, Y. Jia, and G. Wilson; ENVIRON International Corporation, Novato, California; May 2003; Task 2 Report: NREL/SR-540-33795.

New Technology Diesel Engines (NTDE)

- Today's (2010 and newer model year) New Technology Diesel Engines (NTDE) reduce major diesel tailpipe emissions by over 90% compared to 2004 diesel engines (PM, NOx)
 - 95 to 98% reduction over older engines cited in recent studies
- NTDE are ~30% more efficient and provide ~30% better mpg than comparable gasoline or natural gas engines
 - This means new diesel engines can be a major contributor to reducing tailpipe carbon emissions and climate change
- If biodiesel is used in a NTDE, the beneficial carbon effects of biodiesel adds to the carbon advantages of diesel technology
- New Technology Diesel Engines using biodiesel blends can be a preferred clean—and green—technology choice

New Technology Diesel Engines (NTDE)

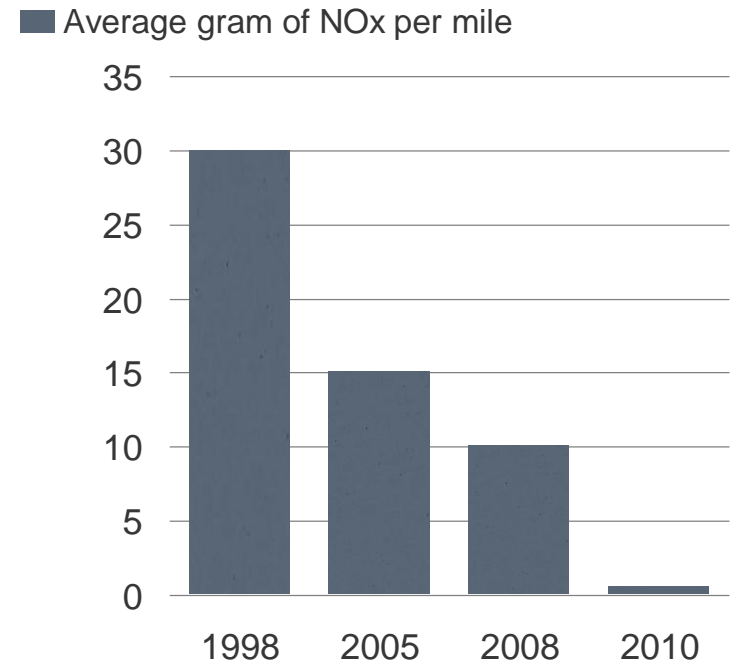
- NTDEs employ a sophisticated combination of diesel engine and fuel system controls, ultra low sulfur diesel fuel, and exhaust after-treatment catalysts to achieve low emissions:
 - Closed loop control systems constantly measure emissions or other parameters on the vehicle and adjusts operation in real time regardless of fuel
 - 15 ppm sulfur or lower fuel (i.e. on-road petrodiesel, biodiesel)
 - Oxidation catalysts and particulate traps reduce PM, HC, CO
 - Selective catalytic reduction (SCR) reduces NO_x through addition of DEF (diesel exhaust fluid)

B20 Works in New Technology Diesel Engines (NTDE)

- The National Biodiesel Board (NBB), the Truck and Engine Manufacturers Association (EMA), and the National Renewable Energy Laboratory (NREL) have studied how biodiesel works in NTDEs
 - Testing completed by respected independent third party laboratories (NREL, SwRI) or by EMA members themselves
 - Over \$15 million hard cash in testing since 2004
 - This does not include internal EMA member testing
 - Both engine dynamometer and full vehicle chassis dynamometer
- B20 impacts on NTDE:
 - Lubricity of biodiesel eliminates lubricity concerns with ULSD
 - Oxygen in biodiesel provide less particulates in trap, those collected burn easier and at lower temperatures
 - Closed loop NOx controls reduce NOx to same engine out level as with pure petrodiesel
 - Engine optimizes for fuel economy, power and takes advantage of after-treatment to reduce NOx to ultra-low levels with B20 or petrodiesel

Average NOx Emissions: Various Cycles

This chart is a rough summary of NOx emissions levels over various emissions cycles completed by NREL on buses using a chassis dynamometer from SAE paper 2012-01-1984. It shows the dramatically lower overall NOx levels as engine technology improves.



SAE 2012-01-1984

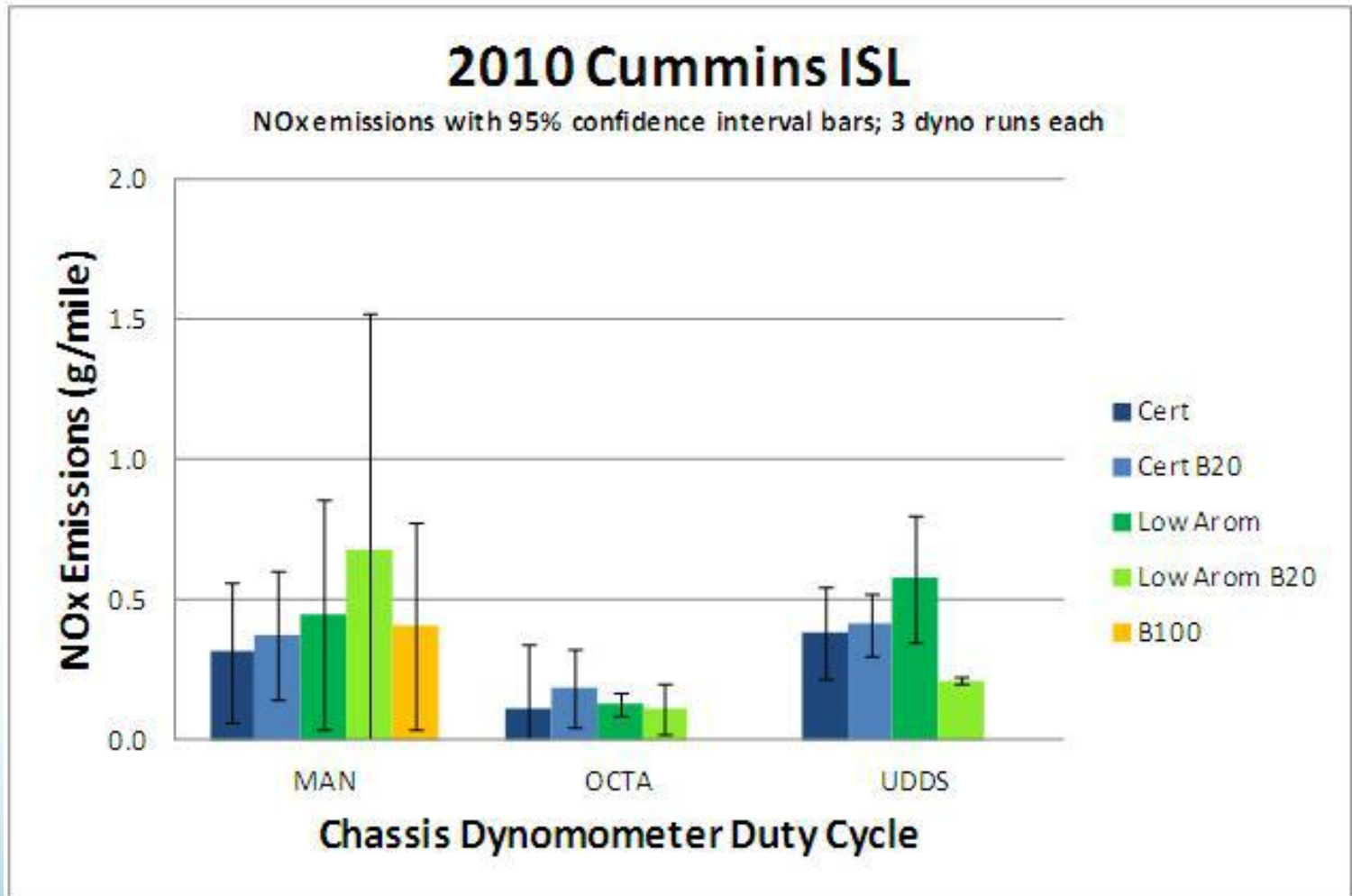


Figure 10 - NOx emissions from a 2010 transit bus..

SAE 2012-01-1984

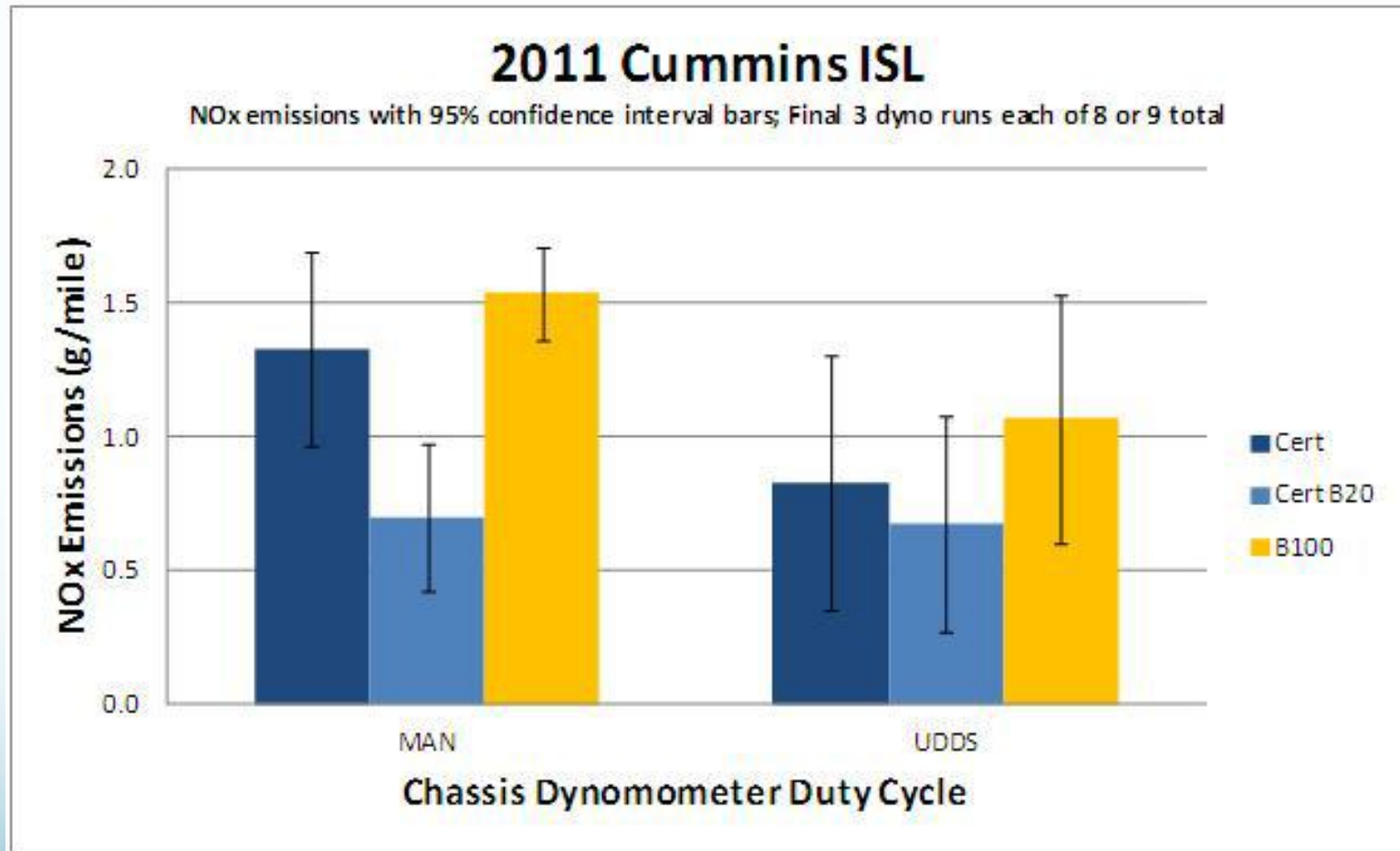


Figure 11 - NOx emissions from a 2011 transit bus.

New Technology Diesel Engines and Biodiesel Blends

- NTDEs are changing the way we talk about and think about biodiesel regulated emissions
- NTDEs emissions are so low due to after-treatment technology, it is difficult—if not impossible—to discern any difference between fuels whether that be EPA diesel, CARB diesel, or biodiesel blends
- NTDEs use closed loop controls for NO_x control: constantly measuring parameters and adjusting the engine operation or DEF use so emissions limits are always met
 - No two runs will provide the same results, even with same fuel
 - Allows engine companies to optimize operation for fuel economy, torque, and horse power and let after-treatment handle emissions
- The question is not whether one fuel is different than another, it is whether the engine will simply meet ultra low vehicle/engine emissions specifications with fuel being used

New Technology Diesel Engines and Biodiesel Blends--Summary

- Short term emissions tests show that today's NTDE with B20 meet or exceed the significantly lower (~90% lower) engine/vehicle emissions standards for NOx and PM from NTDE
 - Potentially even B100, although very few data points with B100
- Additional work is on-going to confirm that the biodiesel specifications are set to insure:
 - Long term durability of the after treatment systems on NTDEs
 - Catalyst long term effectiveness is the same as petrodiesel
- Today's NTDEs resolve potential NOx concerns with B20 blends, even when using CARB like diesel fuel
 - And the biodiesel industry is working with OEMs on future engines
- New emissions after-treatment technology—or use of blend level sensors and modifying timing slightly—provides a path forward for low NOx from new or existing engines