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Emissions Effects of Using B20 in the Current Transit Bus Fleet

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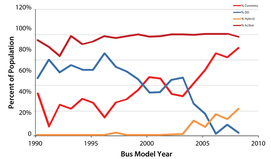
OBJECTIVE

This project focuses on determining the emissions impact of using 20% blends of biodiesel fuel (B20) in regional transit buses representative of current fleets in the United States.

US Diesel Transit Bus Population Breakdown



Transit Bus Population by Emissions Model Year				
Year	% of Active	Cummins	Detroit	Hybrid
'98-'01	39%	19%	19%	0%
'02-'06	44%	24%	15%	3.8%
'07-'08	17%	14%	1%	3.5%

RELEVANCE

- Use of biodiesel is being pursued with the intent of reducing the dependence of the United States on imported oil and to reduce emissions of fossil-fuel-based carbon compounds
- Regional transit operations, which are typically subsidized by federal funding, are concerned about liability for possible increased NOx emissions if they use B20
- The project was intended to provide a comprehensive evaluation of the effects of B20 on NOx emissions in the current fleet of transit buses, which use a wide range of emission control technologies
- This is one of several projects conducted by NREL to support the Clean Cities program goal of reducing petroleum consumption in transportation

ACKNOWLEDGMENTS

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APPROACH

CHASSIS DYNAMOMETER TESTING

Selected buses were tested at NREL's Renewable Fuels and Lubricants (ReFUEL) research laboratory. Testing was performed on a chassis dynamometer over multiple standard drive cycles to evaluate the effects of biodiesel fuel on vehicle exhaust emissions.

The ReFUEL facility is available to members of the research community interested in testing advanced fuels, prototype engines, and hybrid powertrains for next generation vehicle technologies.

ReFUEL Laboratory

Dyno Capabilities

- 8,000 – 80,000 lb (Class 3 – 8)
- Tandem 40" rolls (adjustable wheelbase)
- 380-hp DC motor

Features

- Programmable driver's aid
- Electrical / mechanical inertia simulation
- Augmented braking
- Grade simulation
- Automated warm-up and coast-downs
- Metered, conditioned intake and dilution air
- Altitude simulation (sea level to mile high)
- Flexible full-scale constant-volume-sampler system

Data Acquisition

- Emissions: regulated emissions measurement
- Fuel economy: fuel flow metering, gravimetric and carbon balance
- Analog channels for thermocouples, etc.
- Controller Area Network (CAN) bus integration for engine parameters
- Gravimetric particulate matter (PM) measurement

Photo by NREL PIX 18585

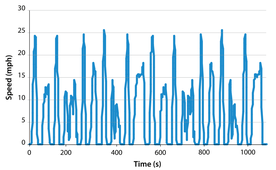
Class 8 Vehicle on Dyno

TEST CYCLES

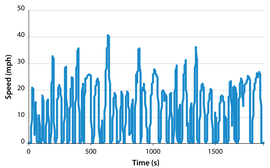
Three test cycles were chosen to bracket real-world range of duty cycles

- Manhattan Bus Cycle (MAN)
- Orange County Transit Authority Cycle (OCTA)
- Urban Dynamometer Driving Schedule (UDDS)

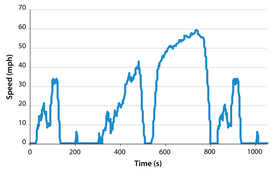
MAN



OCTA



UDDS



VEHICLE SELECTION

APTA 2009 Bus Fleet Survey data used to define target bus configurations for testing

Buses tested:

- 1998 Neoplan w/DDC50 [pre exhaust gas recirculation (EGR)]
- 2005 Gillig w/Cummins ISM [aftermarket diesel particulate filter (DPF)]
- 2008 Gillig w/Cummins ISL (OEM DPF)
- 2008 Gillig Allison hybrid/Cummins ISL (OEM DPF)
- 2010 Gillig Cummins ISL [OEM DPF, selective catalytic reduction (SCR)]
- 2011 Gillig Cummins ISL (OEM DPF, SCR)

Photo by Scott Walters, NREL

1998 Neoplan

Photo by Scott Walters, NREL

2005 Gillig

Photo by Matthew Thornton, NREL

2008 Gillig

Photo by Jon Coapman, NREL

2008 Gillig/Allison (HEV)

Photo by Scott Walters, NREL

2010 Gillig

Photo by Scott Walters, NREL

2011 Gillig

FUELS

Fuels used in the study:

- Ultralow sulfur diesel (ULSD) (cert fuel used for consistency)
- B20 with ULSD base
- Low-aromatic (California Air Resources Board [CARB]) diesel
- B20 with CARB base

Base Fuels Properties	Cert	CARB
Cetane Number	42.5	48.7
Total Aromatics, % vol	29	8.5

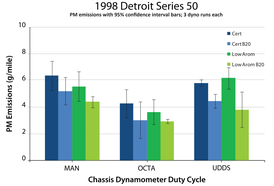
RESULTS

Results to date show that using B20/ULSD has little or no effect on NOx emissions in buses without NOx emissions control, but using B20/CARB in such buses has a significant effect. In buses with NOx emissions control, however, using B20 (or even B100) has no effect on NOx emissions.

1998 DDC S50

- The only technology showing PM sensitivity to fuel (no DPF)
- NOx emissions more sensitive to duty cycle than to fuel
- Lower intensity cycles showed statistically significant increase in NOx emissions of 3%–5% with B20/CARB

1998 Detroit Series 50
PM emissions with 95% confidence interval bars; 3 dyno runs each



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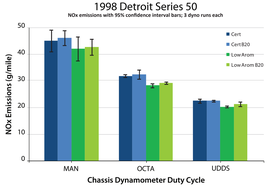
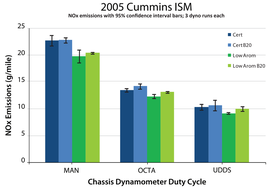


2005 ISM

- DPF-equipped: no PM sensitivity to fuel
- NOx emissions more sensitive to duty cycle than to fuel
- Lower intensity cycles showed statistically significant increase in NOx emissions of 3%–5% with B20/CARB

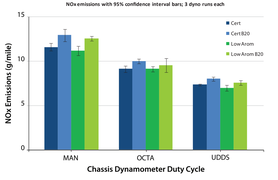
2005 Cummins ISM
NOx emissions with 95% confidence interval bars; 3 dyno runs each



2008 ISL

- DPF equipped: no PM sensitivity to fuel
- NOx emissions more sensitive to duty cycle than to fuel
- B20/ULSD showed statistically significant increase in NOx on all cycles (9%–12%)
- B20/CARB showed statistically significant increase in NOx on UDDS and MAN (9%–12%)

2008 Cummins ISL
NOx emissions with 95% confidence interval bars; 3 dyno runs each



	MAN	OCTA	UDDS
mph	6.8	12.3	18
stops/mile	9.7	4.7	2.5
kinetic intensity	5.7	2.2	0.4

Decreasing work and fuel consumption per mile

2008 ALLISON HYBRID/ISL

- Only tested on Cert and Cert B20 (CARB fuel effect already documented)
- No statistically significant effect from B20 fuel
- PM emissions near zero on both fuels (DPF)
- Drive cycle influence on NOx emissions greater than with non-hybrid drive trains

2010 ISL

- DPF equipped: no PM sensitivity to fuel
- SCR equipped: very low NOx emissions, near detection limits on some cycles
- Feedback NOx control: insensitive to biodiesel (verified with B100)

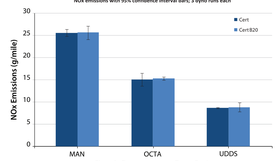
LATE 2011 CUMMINS ISL WITH DPF/SCR

- SCR is highly effective at reducing NOx – emissions near detection on some cycles
- B20 demonstrated a statistically significant REDUCTION in NOx emissions on the Manhattan cycle
- Even B100 NOx emissions increase was eliminated – no statistically significant difference on either cycle
- PM emissions near zero on all fuels (DPF

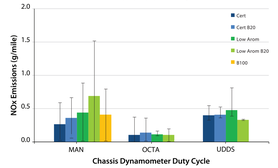
TECHNOLOGY COMPARISONS

- Engine certification level is most dominant effect on bus NOx emissions by far. Roughly 50% reduction obtained with each new cert level
- Duty cycle is second driving factor in bus NOx emissions (20%–25%)
- Fuel choice has least effect on bus NOx emissions (0%–12%)
- B20 effect on NOx emissions statistically significant in fewer than half of comparisons
- Hybrid increase in NOx emissions has been documented before. Likely culprits are engine efficiency management strategies

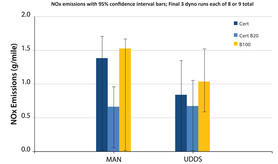
2008 Allison Hybrid Cummins ISL
NOx emissions with 95% confidence interval bars; 3 dyno runs each



2010 Cummins ISL
NOx emissions with 95% confidence interval bars; 3 dyno runs each



2011 Cummins ISL
NOx emissions with 95% confidence interval bars; final 3 dyno runs each of 8 or 9 total



Manhattan Cycle
NOx emissions with 95% confidence interval bars; 3 dyno runs each