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Effects of Biomass Fuels on Engine & System Out Emissions for Short Term Endurance

DEER 2011 Conference

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October 6, 2011

Motivation & Objectives

Motivation:

- To investigate effects of biomass fuels on fuel injection, combustion, emission and the aftertreatment system
- To validate Volvo 2010 Exhaust Aftertreatment System being tolerant of biomass fuels for the Bilateral Project
  - Diesel Particulate Filter model for passive soot regeneration sufficient for biomass soot
  - Selective Catalyst Reduction system avoids degradation throughout testing
- Gain insight into potential obstacles that biomass fuels present

Test Set Up

Single Cylinder

Representative of 13L 475HP US07 Engine

Engine Specifications	
Emissions Year	2007
Displacement (L) - 1 cyl	2.13
HP Max (6 cyl)	475

Data Gathered

- 8 fuels tested
- EGR requirements at constant Nox
- NOx emissions at constant EGR
- Soot Analysis
  - Particle Size
  - Particle Number
  - Particle Mass
  - Oxidation Rate

Chassis Testing

Engine Specifications	
Emissions Year	2010
Displacement (L)	11
HP Max	355

Data Gathered

- 65,000 miles on B20
- B20 - soy methyl ester (SME)
- 3 emissions tests
- Soot Accumulation
- Urea consumption
- EGR Valve Position

Fuel Characteristics
Single Cylinder Engine Study

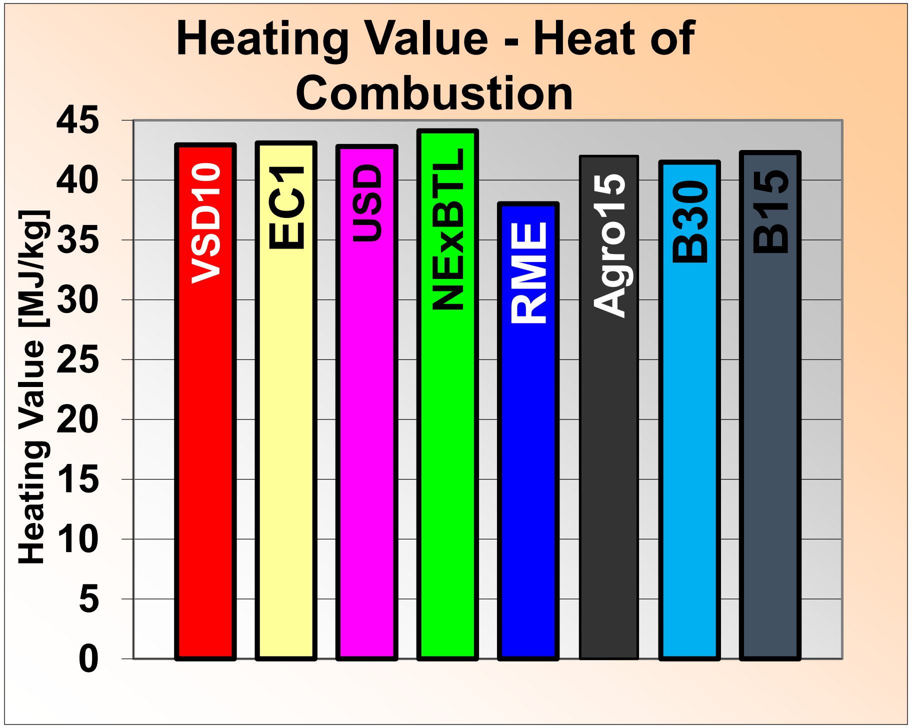
Reference Fuels

- **Volvo Standard Diesel**

  (VSD10 <10ppm S)
- **Environmental Class 1 diesel** (EC1 or MK1)
- **US-Diesel** (ULSD <20ppm S)

Biofuels

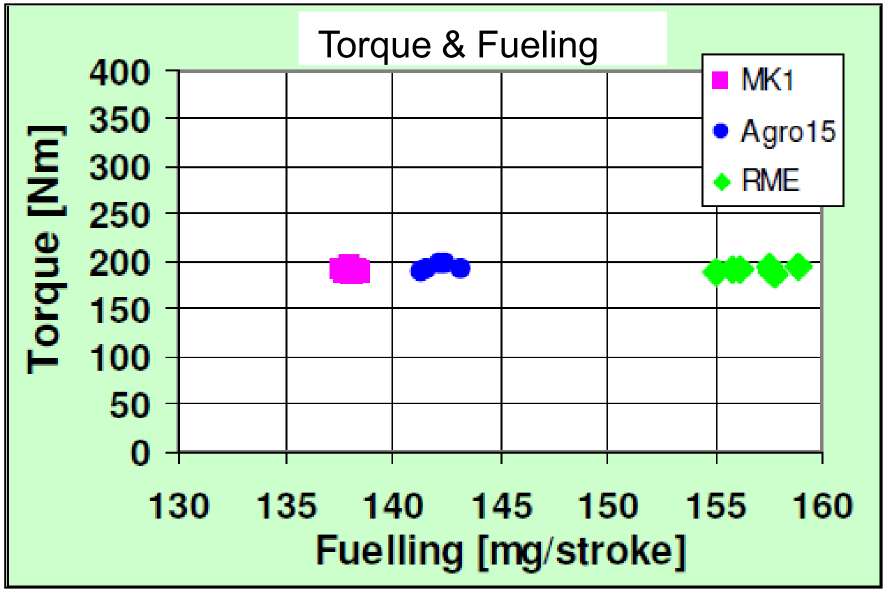
- **NExBTL** (a hydro treated biofuel)
- **RME** (Rapeseed Methyl Ester RME, B100)
- **Agro-diesel 15** (10% heavy bio alcohols 5% RME in 85% EC1)
- **B30** (30% RME in 70% EC1)
- **B15** (15% RME in 85% EC1)

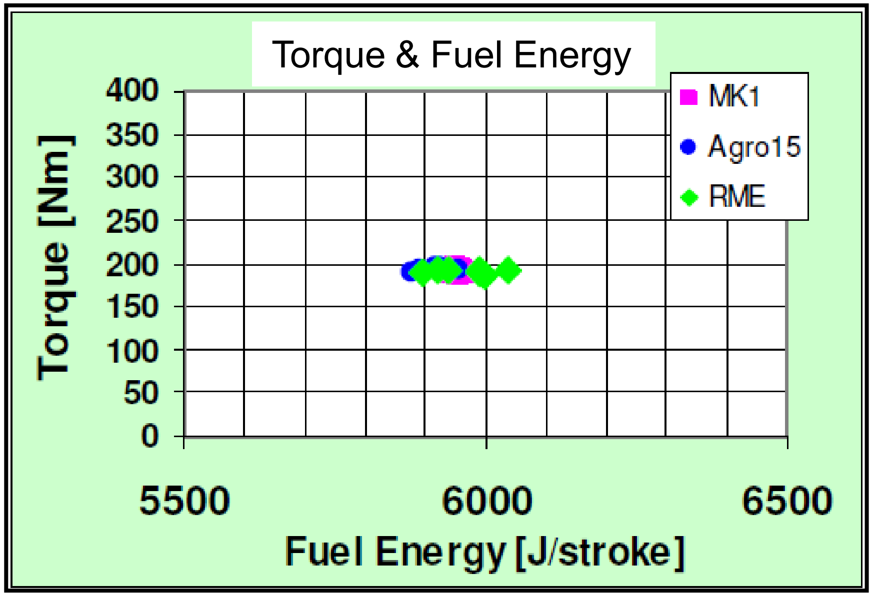


Fuel Energy Kept Constant
Single Cylinder Engine Study

Fuel injection setting was re calibrated for each fuel

Injection duration was compensated for the difference in fuel heating value

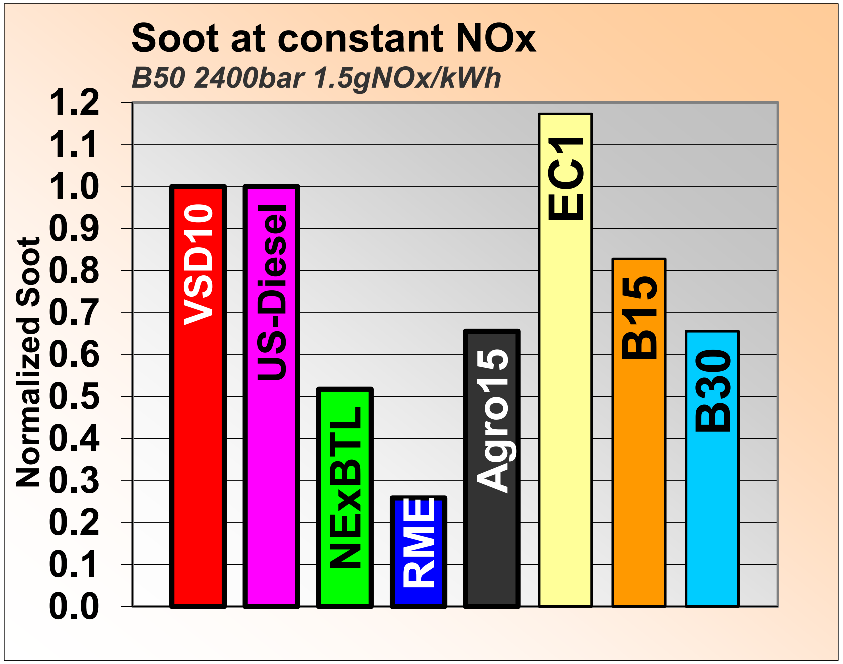




Soot and Fuel Consumption Trends
Single Cylinder Engine Study

RME

- ⬇ Soot emission 60-80% compared to baseline
- ⬆ BSFC 13% than baseline



NExBTL

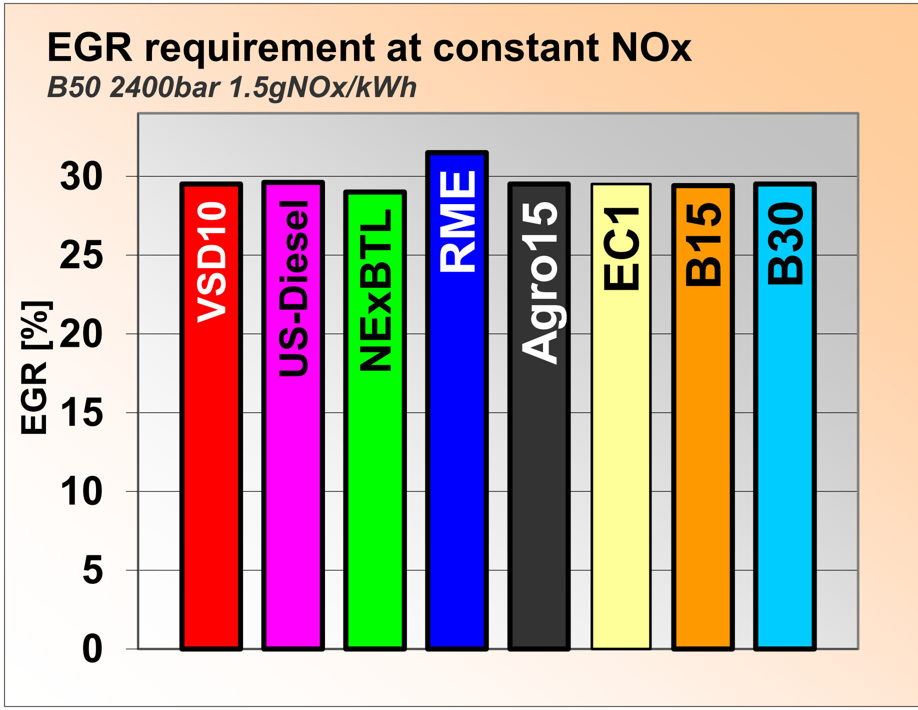
- ⬇ Soot 20-50% compared to baseline
- ⬇ BSFC 2-3 % due to higher heating value

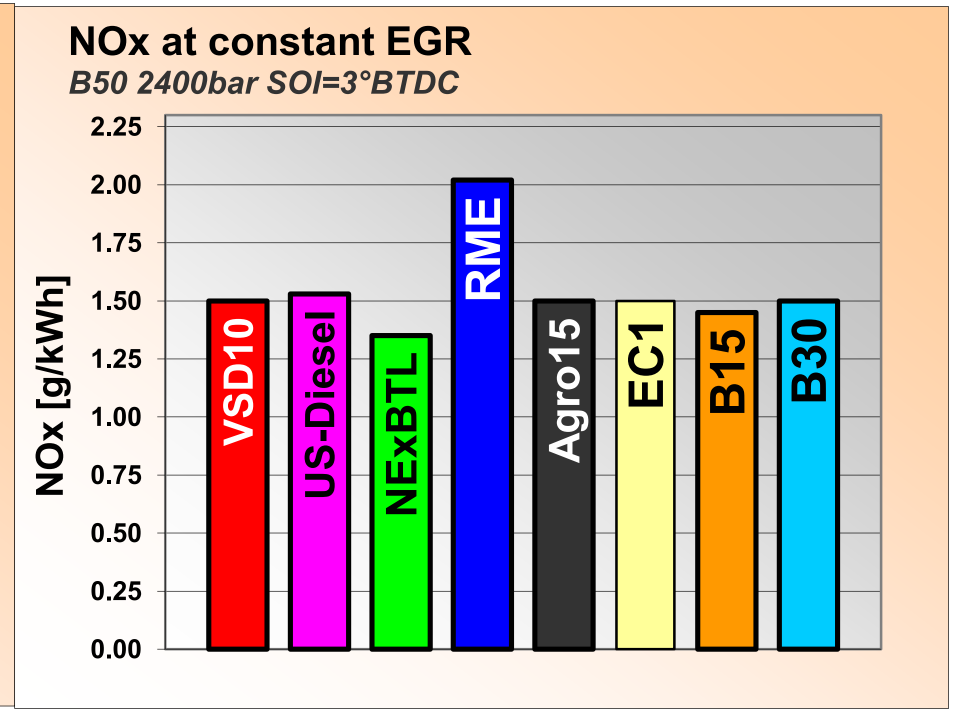
B15 & B30

- ⬇ Increasing the amount of RME lowers soot
- ⬆ BSFC increases as blend increased compared to baseline

Single Cylinder Engine Study Results

1500rpm/1200Nm (6cyl)

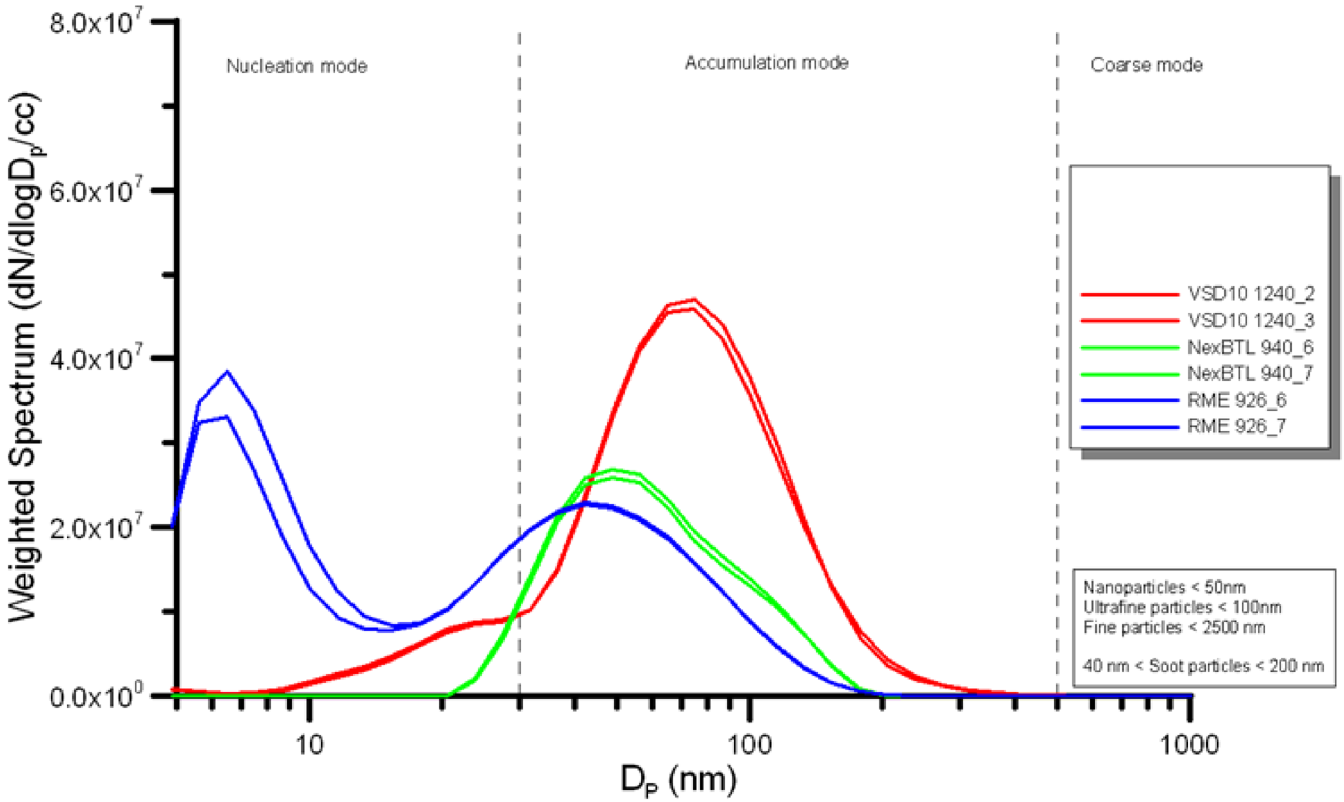




Higher blend biomass fuels have higher EGR requirements to maintain constant NOx emissions

Higher blend biomass fuels have higher NOx emissions at constant EGR

Biomass Soot Particle Size



Particle Number (Y-axis) vs Particle Diameter (x-axis)

<u>Nucleation mode:</u>
Primarily volatile hydrocarbon and hydrated sulphuric acid condensates. small amount of solid material, such as carbon or metallic ash from lube oil additives.

<u>Accumulation Mode:</u>
Mainly solid carbon mixed with condensed heavy hydrocarbons but may also include sulphur compounds, metallic ash, cylinder wear metals

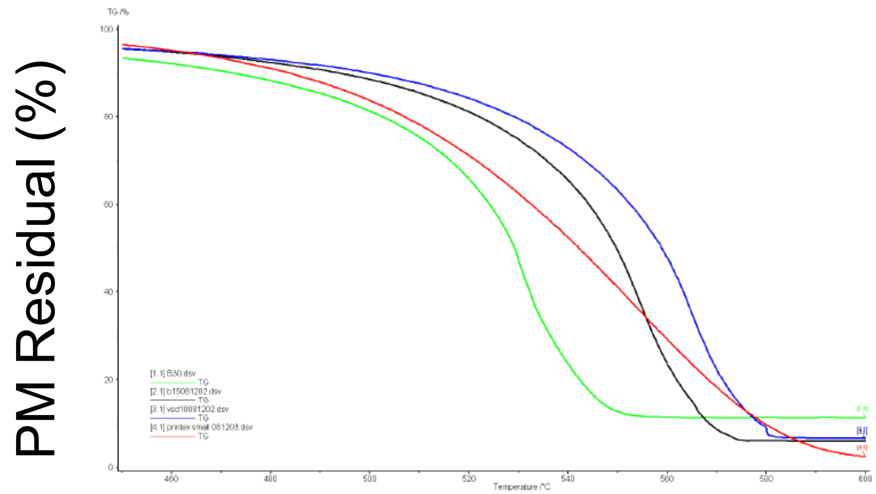
Biomass Soot Oxidation Rates

Synthetic gas bench testing of diesel soot loaded onto Diesel Particulate Filters (DPFs)

Conversion Percent				
	O2-step	O2/NO2 - step	350 O2/NO2	400 O2/NO2
RME	1	1	1	2
B30	3	1	3	3
VSD	2	1	2	1

Soot ranked 1 to 3 based on fastest conversion from solid to gas

Thermogravimetric Analysis

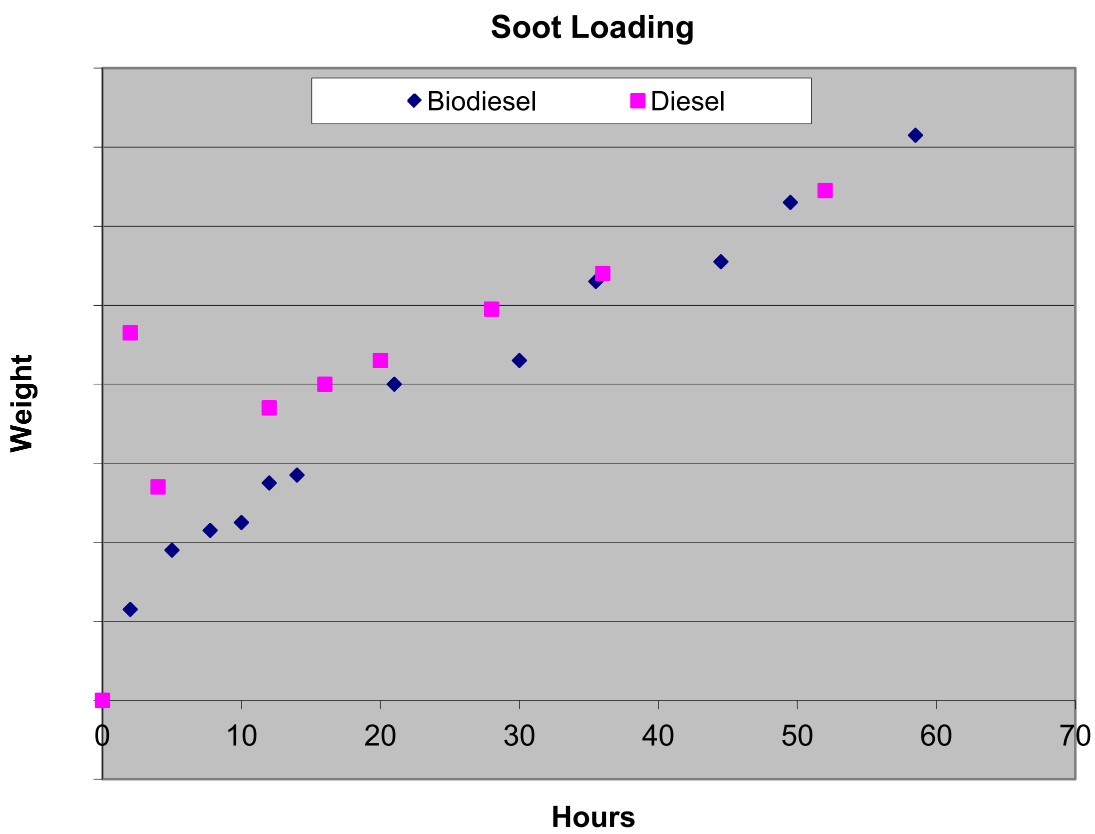


Oxidation Rate Trends

B30>B15>VSD10>Printex

System Out Emissions Chassis Testing

Soot Loading



Soot loading cycle was run for 4 weeks to see if the soot loading calibration holds up while on biodiesel.

Soot loading on biodiesel showed no variation to the soot loading trends demonstrated on diesel.

This demonstrates the calibration for the soot model holds up for biodiesel at early phases.

Emissions Test

An academic preferred partnership between Volvo Group and The Pennsylvania State University allowed for emissions test to be conducted at The Larson Transportation Institute (LTI)

Three Emissions Test Conducted at LTI

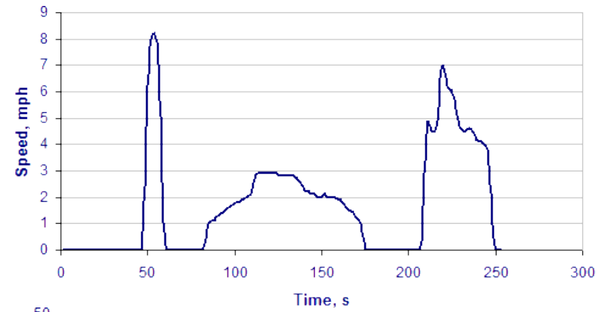
- Baseline Diesel
- Baseline Biodiesel
- Final Biodiesel

Data Recorded by Penn State

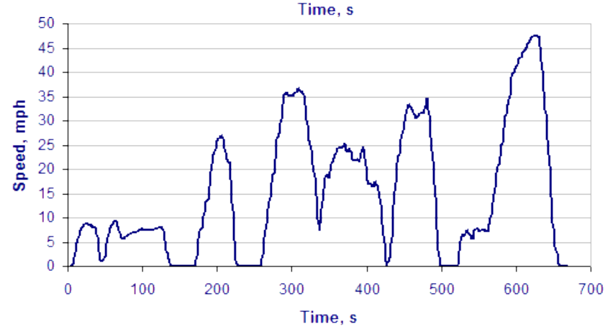
- Fuel consumption
- Gaseous Emissions & Particulate emissions measured using full scale heavy duty dilution tunnel and analyzers

Heavy Heavy-Duty Diesel Truck Cycle

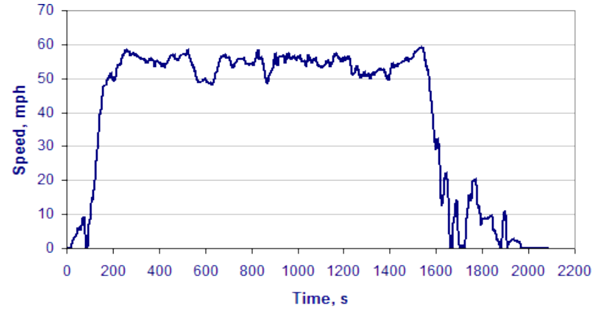
Creep – low speed low load



Transient – high speed high load



Cruise – high speed high load



Parameter	HHDDT Creep	HHDDT Transient	HHDDT Cruise	UDDS
Duration, s	253	668	2083	1063
Distance, mi	0.124	2.85	23.1	5.55
Average Speed, mph	1.77	15.4	39.9	18.8
Stops/Mile	24.17	1.8	0.26	2.52
Max. Speed, mph	8.24	47.5	59.3	58
Max. Acceleration, mph/s	2.3	3	2.3	4.4
Max. Deceleration, mph/s	-2.53	-2.8	-2.5	-4.6
Total KE, mph^2	3.66	207.6	1036	373.4
Percent Idle	42.29	16.3	8	33.4

System Out - Emissions Results Summarized

	Phase	Diesel to Biodiesel	Biodiesel Baseline to Biodiesel Final
Fuel (mpg)	Cruise	slight reduction	no change
CO_2 (g/mi)	Cruise	slight increase	no change
CO (g/mi)	Cruise	no change	no change
THC(g/mi)	Cruise	no change	no change
NO_X (g/mi)	Cruise	Reduced	Reduced
PM (g/mi)	Cruise	no change	no change

System Out Closed Loops for NOx Emissions

Two closed loops used to control system out NOx emissions

- EGR demand
- Urea Consumption

	Engine Out NOx Increase (%)	Urea Consumptin Increase (%)
Biodiesel to Diesel	34.6	35.9

An increase in engine out NOx is compensated by the system by an increase in urea consumption

	NOx Reduction (%)	EGR Valve Position (%)
Diesel	98	84.3
Biodiesel	99	84.9

EGR remains constant, the higher level of urea consumption keeps NOx reduction consistent

*tables based on mean values of the cruise phase

Conclusions

US 2010 EATS that will be equipped on bilateral demonstration truck displayed biomass fuel tolerance

- Soot loading strategy for diesel successfully manages soot generated from biodiesel
- SCR showed no signs of degradation throughout testing from biomass fuels
- System out NOx does not increase operating on biomass fuel despite higher engine out NOx → Urea consumption

As biofuel blend increases

- Fuel economy is reduced by operation on lower calorific value fuels
- Soot accumulation decreases
- Soot oxidation rates increase

Acknowledgments

This material is based upon work supported by

- Department of Energy National Energy Technology Lab under Award Number DE-FC26-07NT43222