Biodiesel and Renewable Diesel Advisory Meeting

Biodiesel and Renewable Diesel Emissions Study and Biodiesel Multimedia Evaluation

March 12, 2008

California Environmental Protection Agency

Air Resources Board

Agenda

I. Introductions
II. Updates
- A. Heavy-Duty Diesel Engine Testing
  - Dr. Tom Durbin
    - a. NOx Impact
    - b. NOx Mitigation
- B. Heavy-Duty Chassis Testing
  - a. Vehicle one
- C. TRU update

III. Lunch
IV. Biodiesel Multimedia Evaluation
- A. Tier one
  - Dr. Thomas McKone
- B. Tier Two Test Protocol
  - Dr. Tim Ginn

V. Open Discussion

Introductions

- Executive Order S-1-07 Low Carbon Fuel Standard (LCFS)
  - Reduce at least 10 percent of the carbon intensity of California's transportation fuels by 2020.
  - Early action item with a regulation to be adopted and implemented by 2010.
- Executive Order S-06-06, establishing targets for the use and production of biofuels and biopower
  - Includes biodiesel and ethanol.
  - California shall produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050.

Biofuels

- Biodiesel
  - specification by 2009
- Renewable diesel fuel

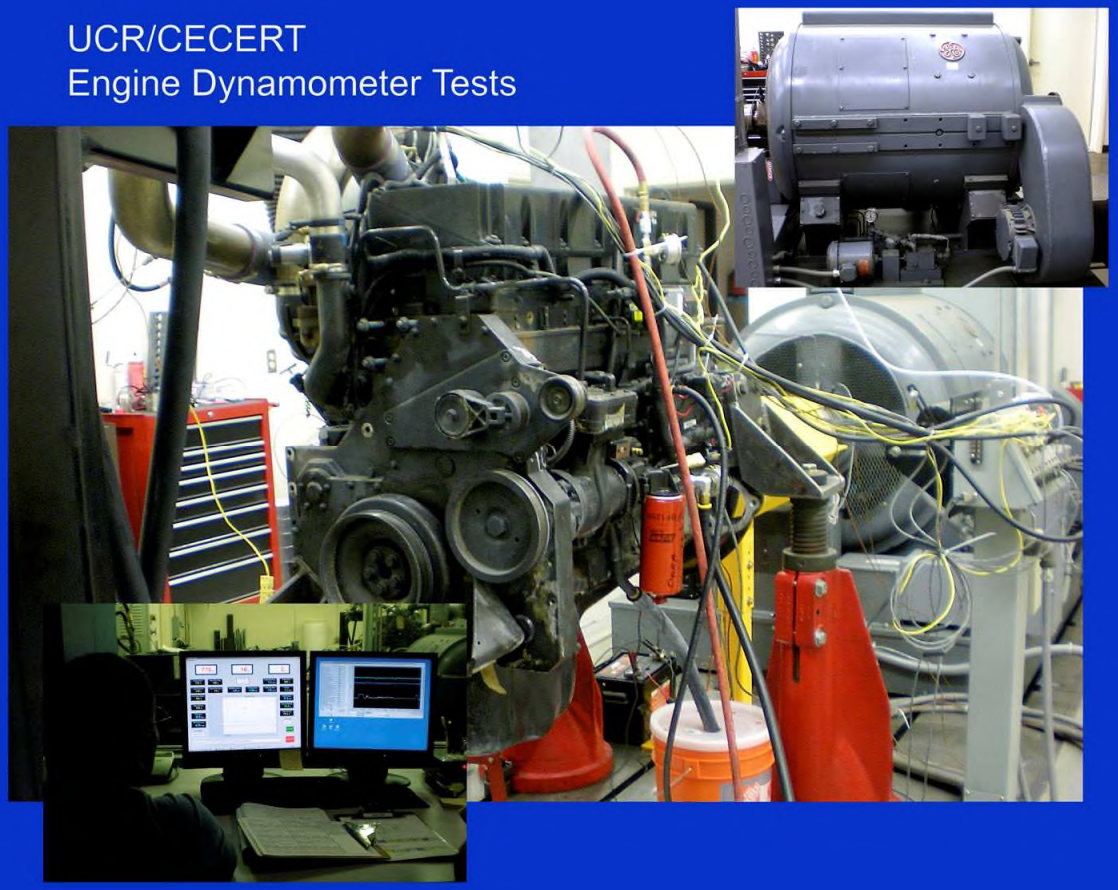
Biodiesel and Renewable Diesel Study

- Heavy-Duty Diesel Engine Emissions Tests
  - Dr. Tom Durbin
- Heavy-Duty Diesel Chassis Emissions Tests
- Transportation Refrigeration Units (TRUs)

Updates

Heavy-Duty Diesel Engine Emissions Tests

UCR/CECERT
Engine Dynamometer Tests



Chassis Dynamometer Tests

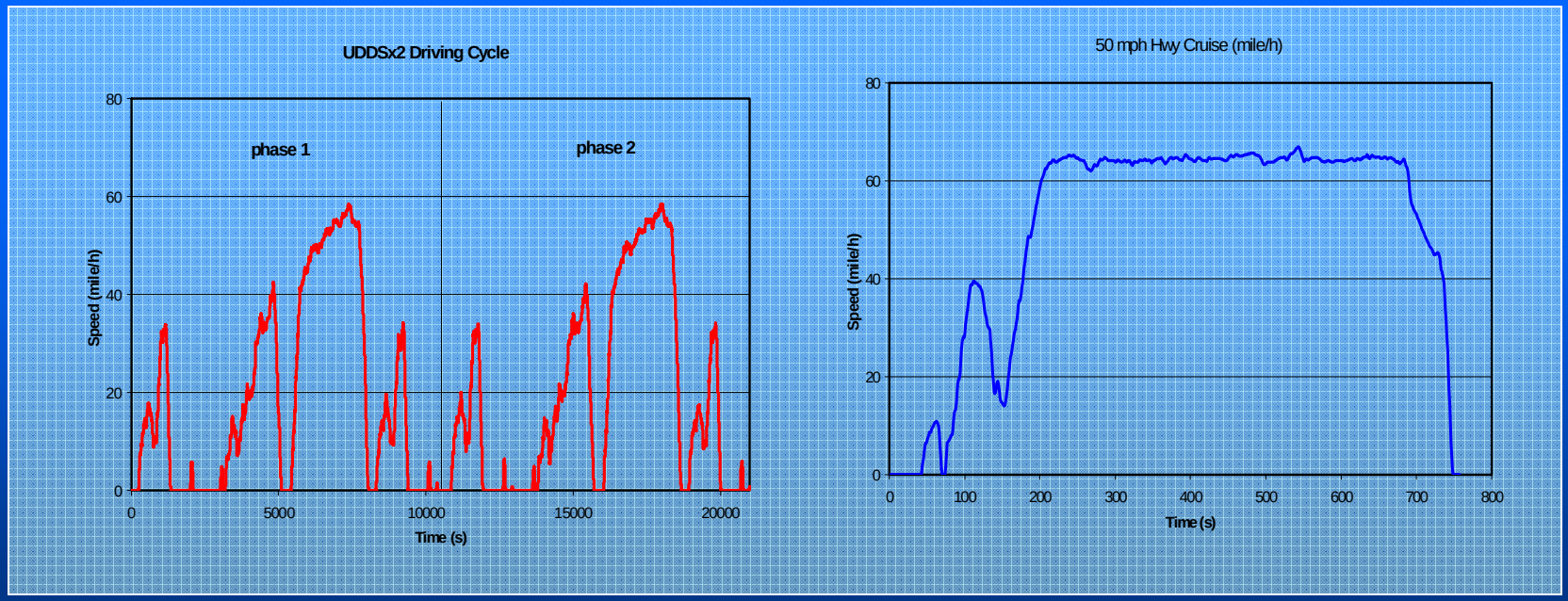
- Conducted at ARB's Heavy-Duty Emissions Test Facility in Los Angeles
- Unregulated Emissions and Health Effects Tests analyzed by Monitoring Laboratory Division (South), University California at Davis, Arizona State University, Wisconsin State laboratory of Hygiene, US EPA

Biodiesel Characterization Vehicle One Chassis Test

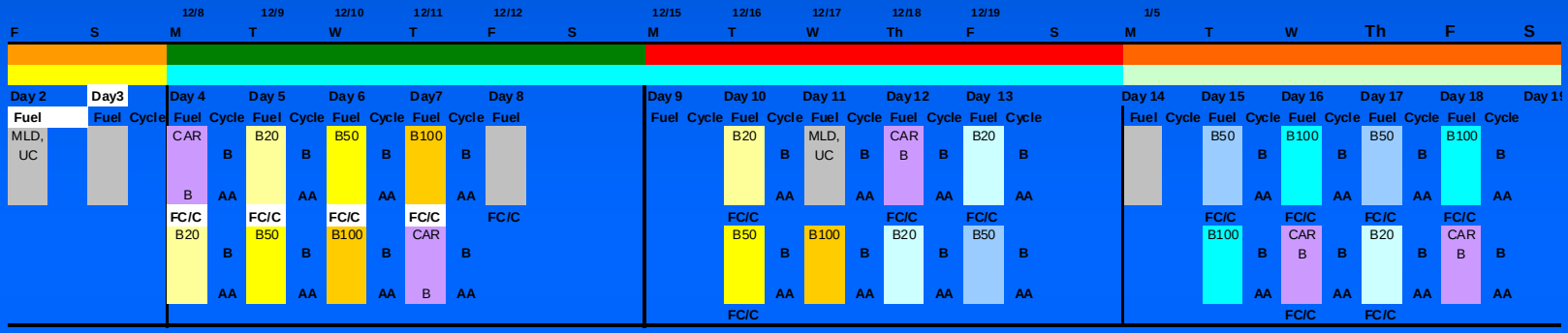
- Freightliner truck equipped with a 2001 C15 Caterpillar engine

Test Cycles

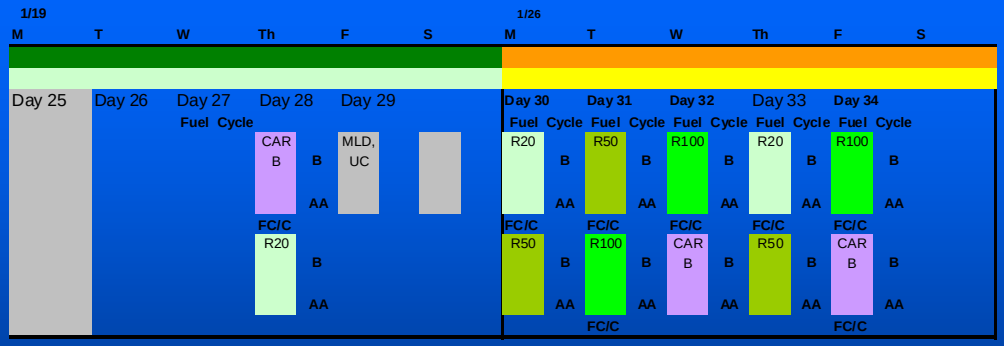
- UDDS: Mid load cycle (vehicle weight 43,000 lbs)
- 50 mph Highway Cruise: High load cycle (vehicle weight 58,000 lbs)



Test Matrix for Vehicle One Freightliner



Holiday Break



Example of Daily Test Schedule

Test Cycle	UDDSx2
Fuel	Animal B20
Test Cycle	ARB hwy cruise
Test Cycle	UDDSx2

FC/C

Sample Collection Schedule

Time	Schedule	PAH med vol	Bio Med vol	HiVol	Mist Sam	Mist Amb	Ele	EC/ OC	Ion	N2O Samp	N2O amb	VOC samp	VOC amb	DNPH S1	DNPH S2	DNPH amb	DMS	EPPS	CPC	PAS	EAD
5:30	Start																				
	Tunnel conditioning																				
	Emissions lab prep																				
7:00	Sampling team start																				
	Morning briefing																				
	Animal B50																				
	Samp prep																				
8:00	Vehicle prep-ARB hwy cruise																				
8:30	ARB hwy cruise-mor run # 22				1	1						1	1	1	1	1	1		1	1	1
9:00	Change samples VOC+Car																				
9:30	UDDSx2-1 mor run #23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
10:30	Collect samples																				
	Change Fuel to CARB																				
	Contact MLD to pickup sam																				
	Transfer VOCs to MLD																				
	Animal B20																				
	Vehicle prep																				
	Setup samples																				
12:00	Vehicle prep-ARB hwy cruise																				
12:30	ARB hwy cruise-afn run # 23											1	1	1	1	1	1		1	1	1
1:00	Change samples VOC+Car																				
1:30	UDDSx2-2 afn run #24	1	1	1			1	1	1	1	1	1	1	1	1	1	1		1	1	1
2:30	Collect samples																				
	Fuel Change to A100																				
	Contact Chris for delivery																				
	Login data																				
	Post sample prep																				
	QA/QC																				
4:00	End of test day																				

PRELIMINARY DRAFT DATA

- Regulated emissions
  - Soy and animal biodiesel feedstocks
  - Renewable Diesel
- Soy feedstock
  - Volatile Organic Emissions
  - Ions
  - Elemental/Organic Carbon
- Other emissions data will be released as it becomes available

PRELIMINARY DRAFT DATA (Cont)

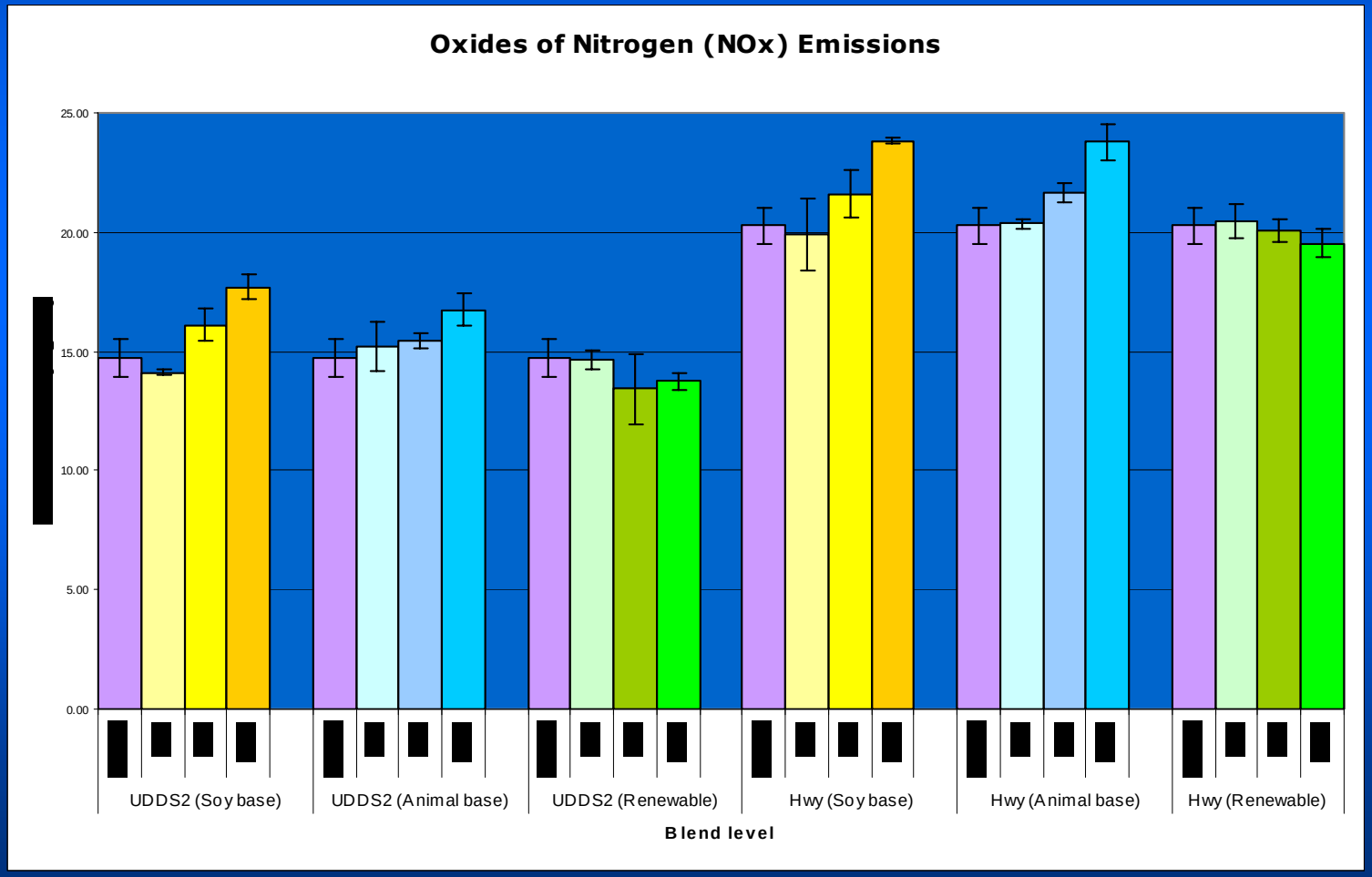
- Completed initial laboratory QA/QC
- Program review initiated
- No in-depth statistical analysis performed

Emissions

- Regulated Emissions
  - Oxides of Nitrogen (NOx), Particulate Matter (PM), Total Hydrocarbons (THC), Carbon Monoxide (CO)
- Carbon Dioxide (CO2)
- CARB diesel, biodiesel, renewable diesel
  - Soy and soy blends (S100, S50, and S20)
  - Animal and animal blends (A100, A50, and A20)
  - Renewable diesel and blends (R100, R50, and R20)
- UDDS and 50 mph Highway Cruise (50-Cruise)

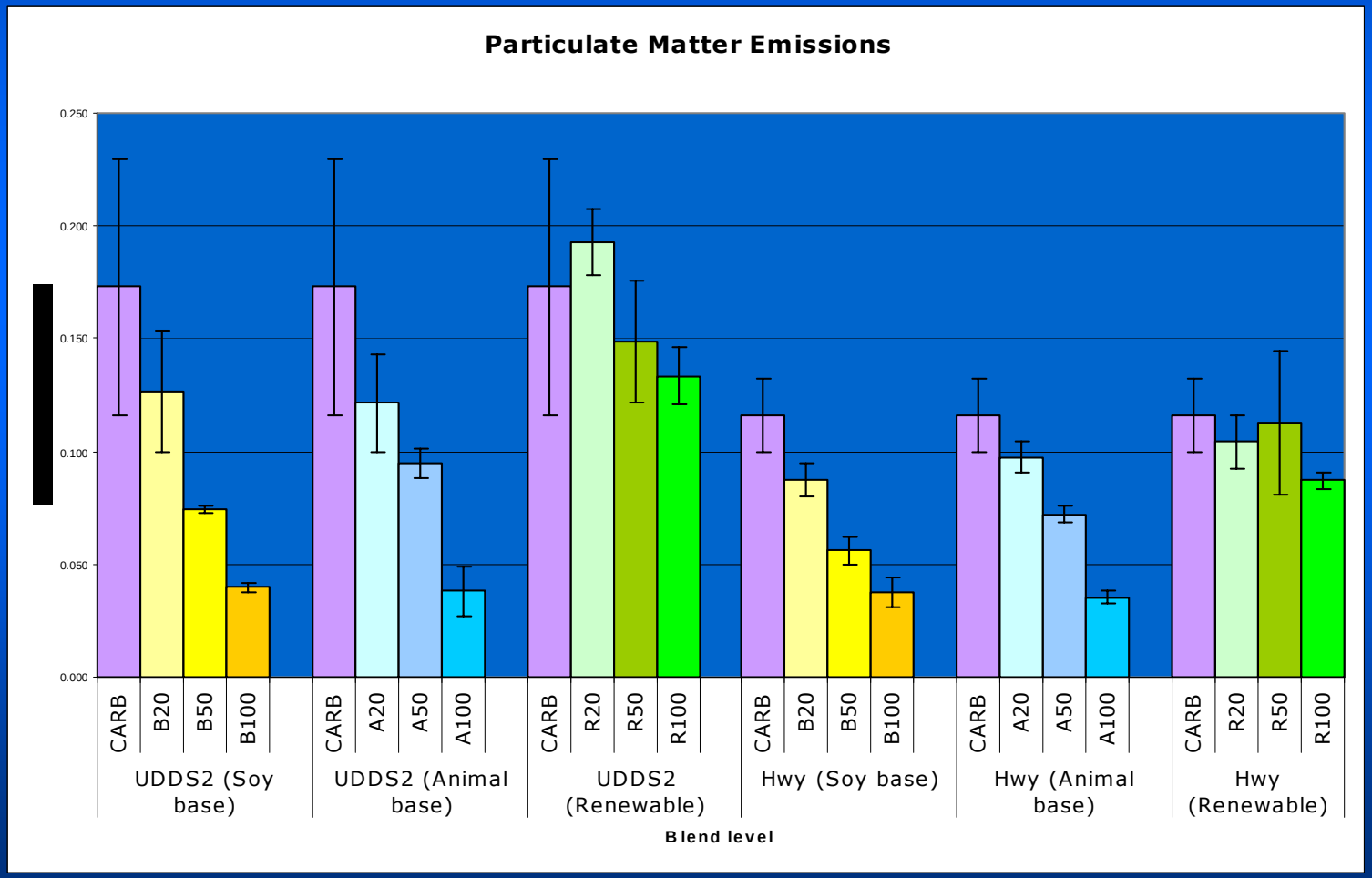
Preliminary Draft Data

Vehicle One: Oxides of Nitrogen



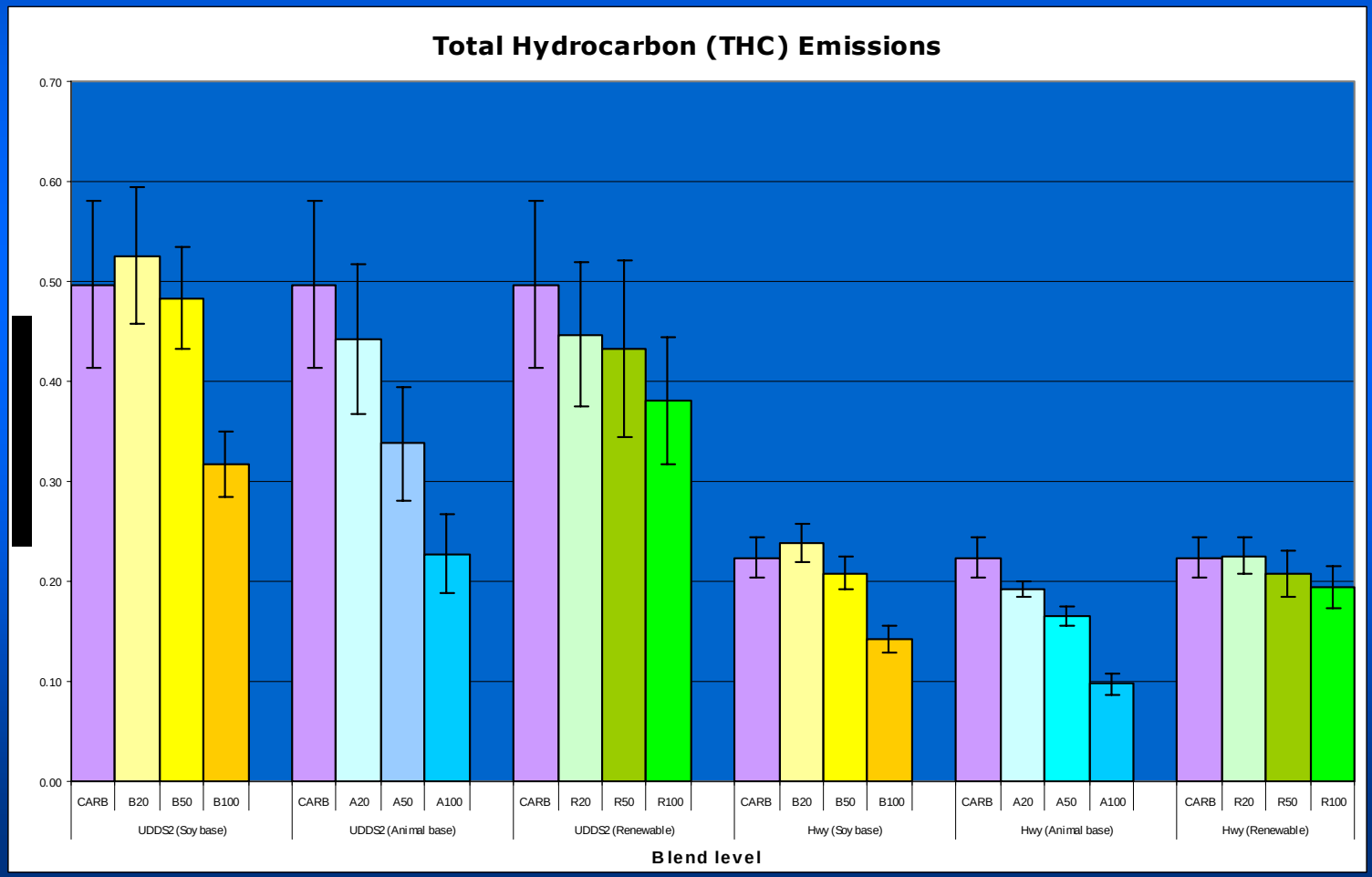
Preliminary Draft Data

Vehicle One: Particulate Matter Emissions



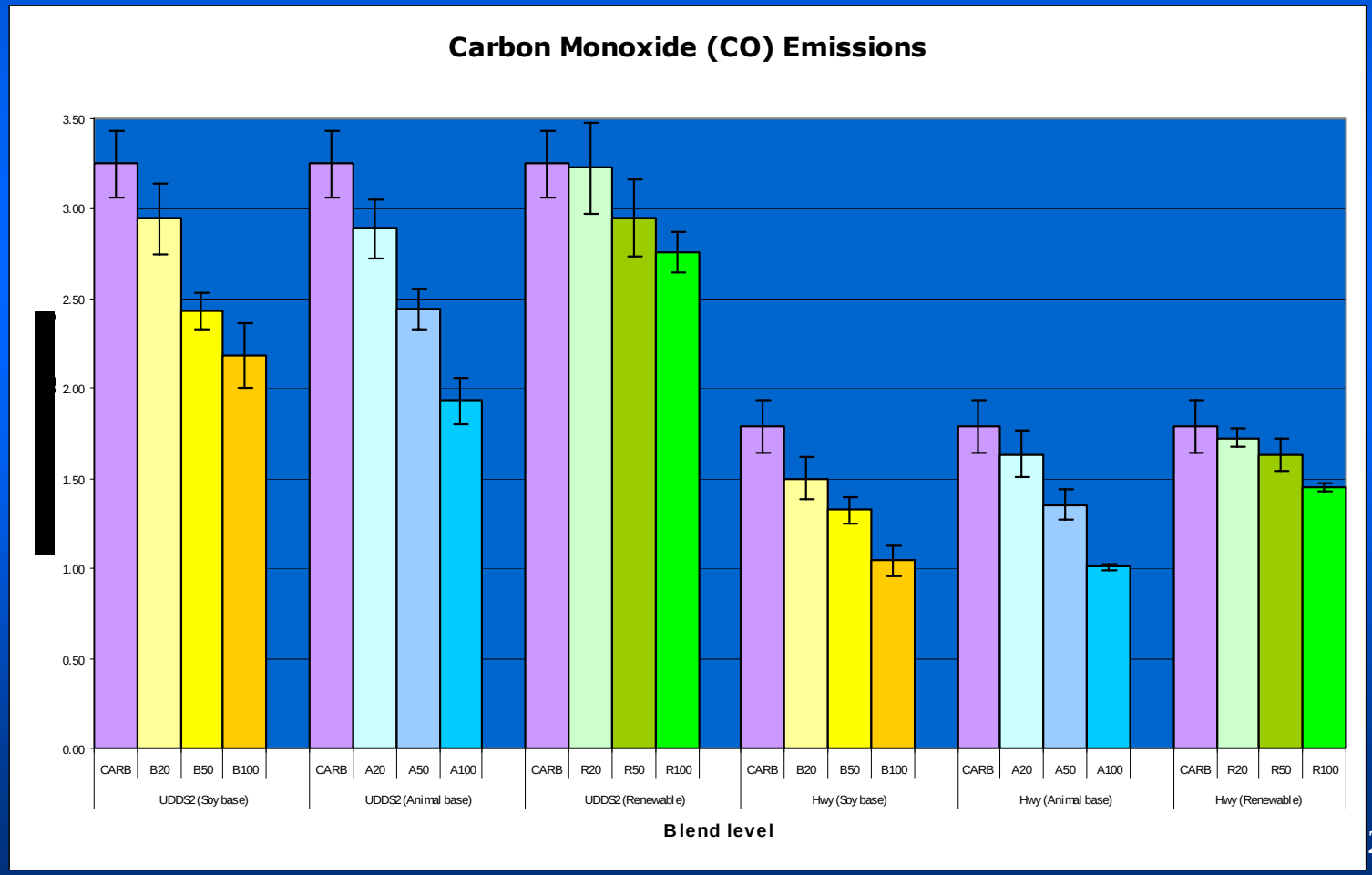
Preliminary Draft Data

Vehicle One: Total Hydrocarbon Emissions



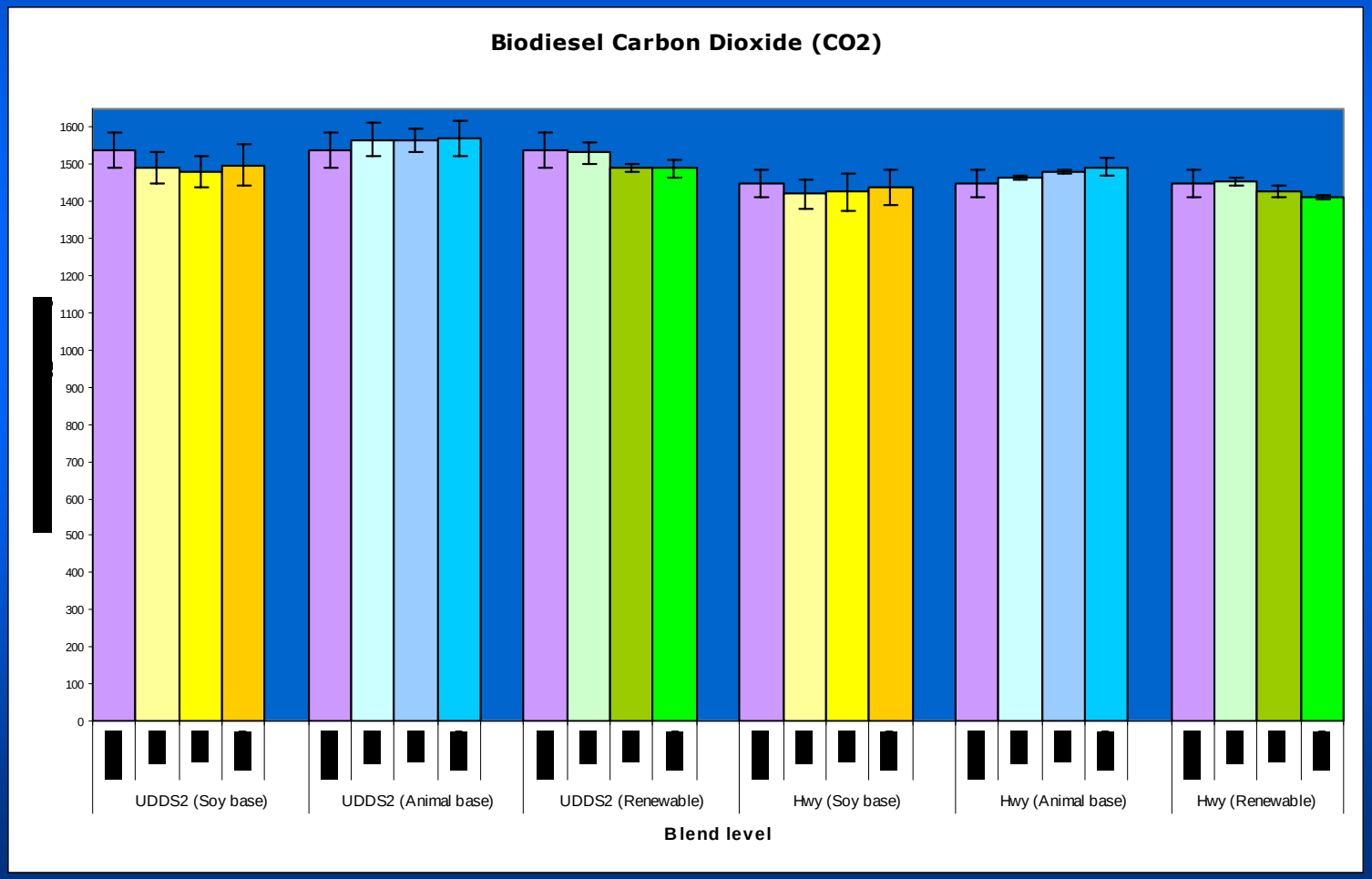
Preliminary Draft Data

Vehicle One: Carbon Monoxide Emissions



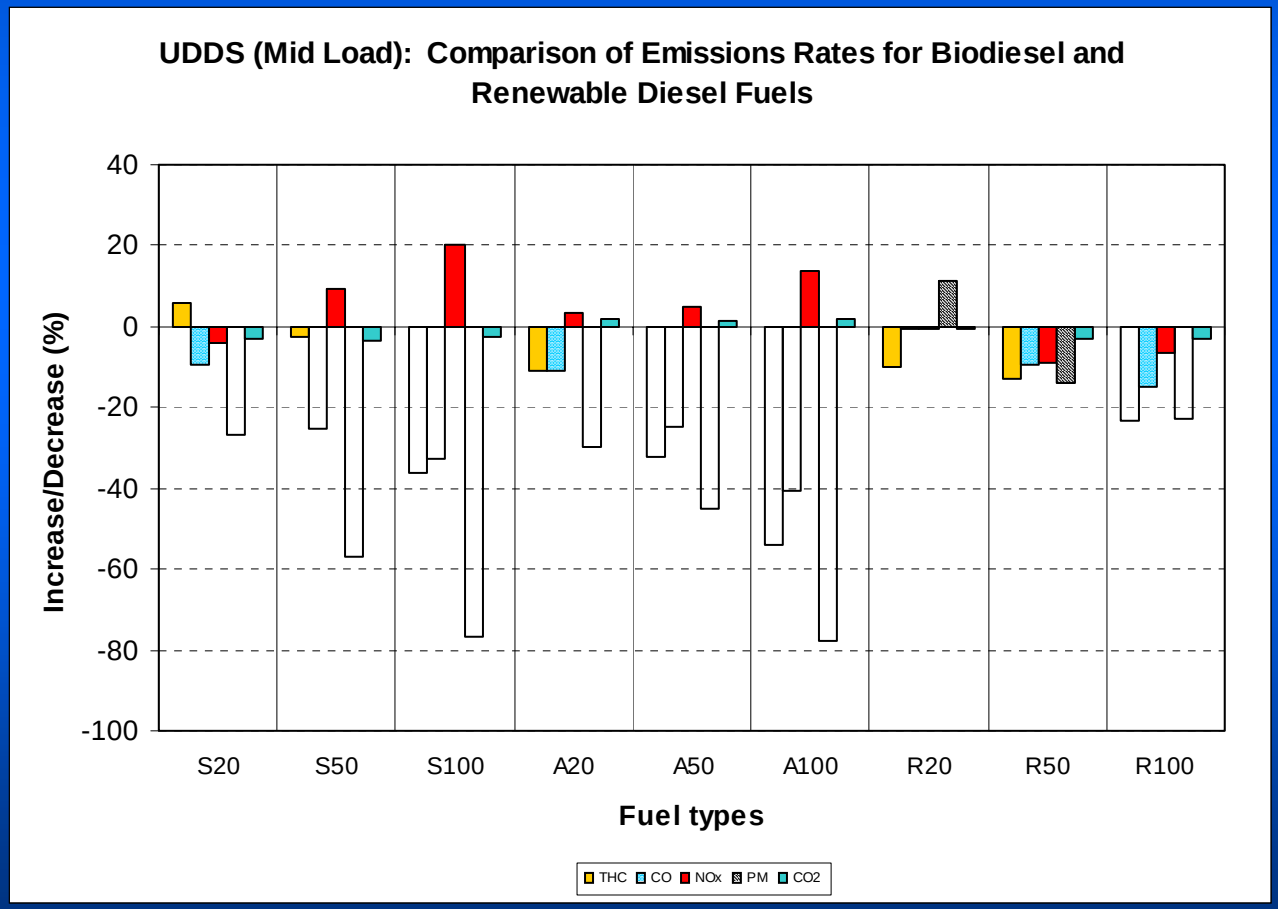
Preliminary Draft Data

Vehicle One: Carbon Dioxide Emissions

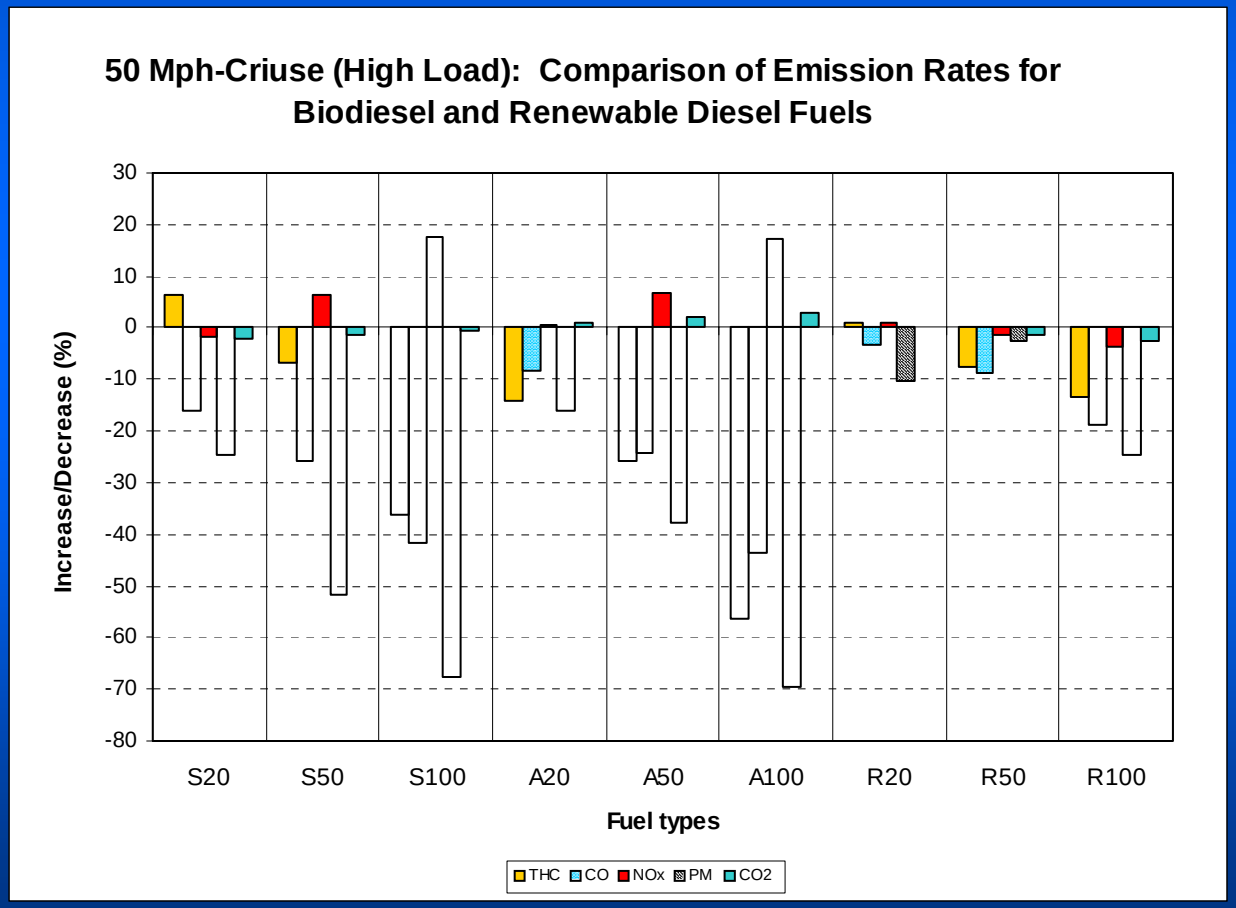


Preliminary Draft Data

Vehicle One: UDDS (mid load) Average Emissions Differences



Preliminary Draft Data:
Vehicle One: 50 Mph Cruise Average Emission Differences



Preliminary Results

- Compared to CARB Diesel
  - Average PM, THC, CO emission rates decreased with increasing blend level for Biodiesel
  - NOx increased with increasing biodiesel blend level
  - Biodiesel showed good PM emission reductions
  - Renewable diesel showed similar or lower emissions for all regulated emissions
  - Trend wise chassis tests were similar to the engine tests

Preliminary Results (Cont)

- The standard deviation of the measurements is to large to resolve emissions differences between CARB diesel and B20 and between CARB diesel and R20
- Additional replicates would be a possible way to resolve the differences between the 20 percent blends and CARB

Discussion

Unregulated Emissions

- Soy Feedstock
- Three replicates
- B20, B50, B100
- Volatile Organic Compounds (VOC): UDDS and 50 mph Highway Cruise
- Ions, Elemental/Organic Carbon (EC/OC): UDDS

Preliminary Draft Data

UDDS: Volatile Organic Compounds

UDDS	CARB mg/mile	B20 mg/mile	B50 mg/mile	B100 mg/mile	CARB Stdev	B20 Stdev	B50 Stdev	B100 Stdev
1,3-Butadiene	2.0	2.0	1.7	1.4	0.9	0.4	0.6	0.2
Benzene	3.5	4.1	4.0	4.1	0.4	0.2	1.1	1.5
Toluene	2.3	2.3	2.2	1.7	0.1	0.1	0.5	0.4
Ethylbenzene	0.6	0.8	0.5	ND	0.1	0.1	0.1	NC
m-/p-Xylene	1.5	1.9	1.2	1.0	0.2	0.1	0.2	0.6
Styrene	ND	ND	0.2	ND	NC	NC	0.3	NC
o-Xylene	1.0	1.4	0.7	0.3	0.5	0.4	0.2	0.5

Cruise-50	CARB mg/mile	B20 mg/mile	B50 mg/mile	B100 mg/mile	CARB Stdev	B20 Stdev	B50 Stdev	B100 Stdev
1,3-Butadiene	ND	0.3	0.6	0.3	NC	0.2	1.0	0.5
Benzene	2.0	2.3	2.8	1.8	0.1	0.3	1.0	0.4
Toluene	1.2	1.2	1.5	0.7	0.2	0.1	0.8	0.1
Ethylbenzene	0.3	0.3	0.4	ND	0.1	0.0	0.3	NC
m-/p-Xylene	0.8	0.8	1.2	0.4	0.2	0.2	0.8	0.1
Styrene	ND	ND	0.1	0.1	NC	NC	0.2	0.2
o-Xylene	0.3	0.4	0.6	0.1	0.1	0.2	0.5	0.2

Preliminary Draft Data

UDDS: Ions

	CARB mg/mile	B20 mg/mile	B50 mg/mile	B100 mg/mile		CARB Stdev	B20 Stdev	B50 Stdev	B100 Stdev
Chloride	ND	ND	0.15	ND		NA	NA	0.25	NA
Nitrate	0.29	4.59	0.17	0.20		0.05	6.75	0.16	0.18
Sulfate	0.07	0.17	0.16	ND		0.09	0.04	0.06	NA
Sodium	ND	0.05	0.25	0.09		NA	0.08	0.17	0.08
Ammonium	0.19	0.21	0.15	0.04		0.03	0.03	0.01	0.07
Potassium	ND	ND	0.11	ND		NA	NA	0.11	NA
Magnesium	ND	ND	ND	ND		NA	NA	NA	NA
Calcium	0.18	0.29	0.30	0.29		0.02	0.08	0.03	0.08

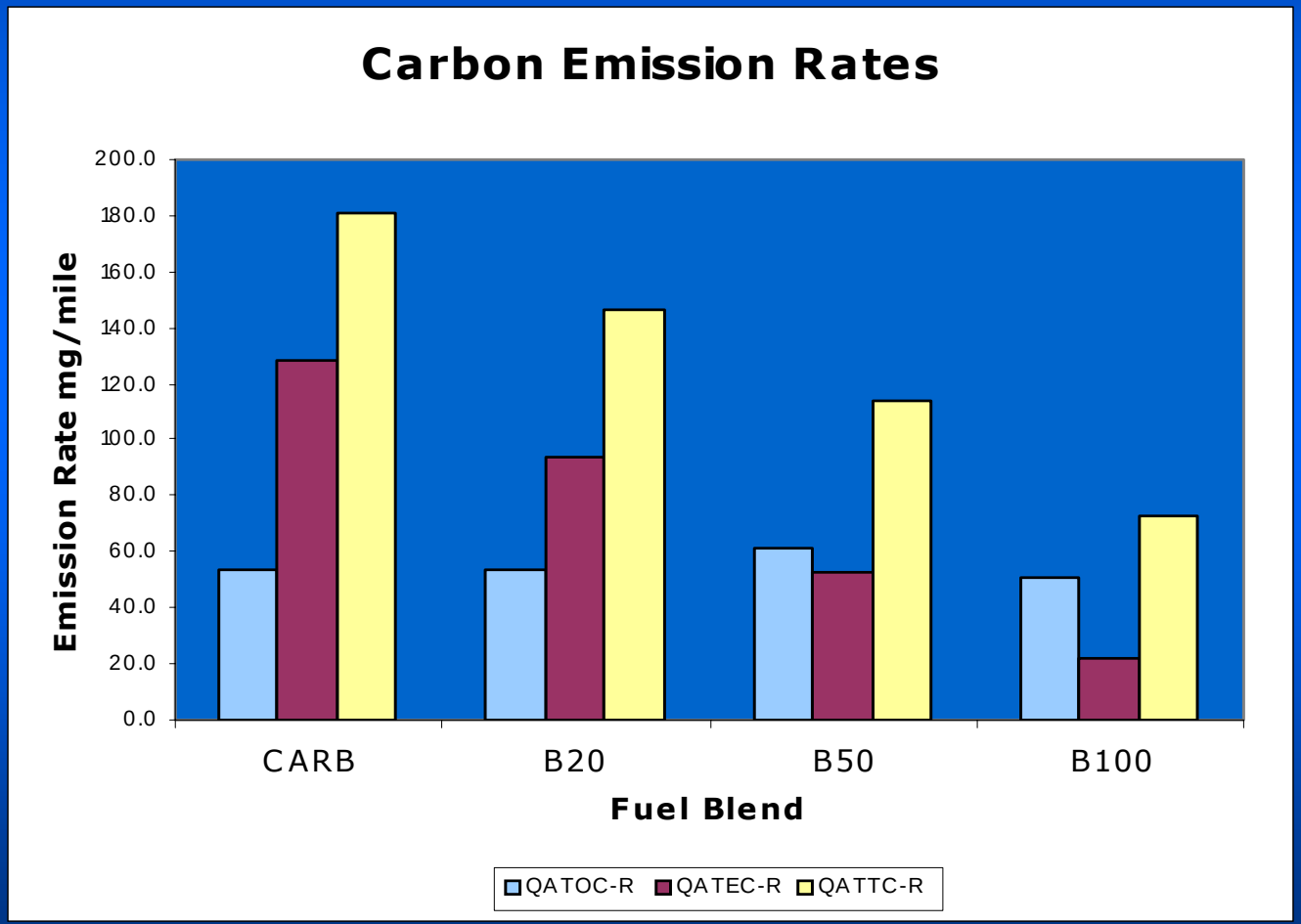
Preliminary Draft Data

UDDS: EC/OC

	CARB mg/mile	B20 mg/mile	B50 mg/mile	B100 mg/mile		CARB Stdev	B20 Stdev	B50 Stdev	B100 Stdev
QAOC1	29.8	29.0	38.0	32.7		11.4	2.69	1.98	4.99
QAOC2	10.2	10.0	9.6	7.6		0.38	0.82	0.31	0.40
QAOC3	10.0	10.6	10.0	7.6		0.76	0.80	1.52	0.51
QAOC4	3.2	3.5	3.6	2.8		0.29	0.21	0.29	0.20
QAEC1	10.3	10.1	9.8	5.9		0.30	1.39	2.74	0.91
QAEC2	117.1	82.5	42.5	16.3		3.45	5.02	4.77	2.25
QAEC3	0.4	0.7	0.2	0.2		0.06	0.59	0.25	0.18
QAPYOC	ND	ND	ND	ND		NA	NA	NA	NA
QATOC-R	53.2	53.2	61.1	50.6		12.79	3.57	4.01	5.39
QATEC-R	127.8	93.3	52.5	22.4		3.20	3.61	2.80	2.84
QATTC-R	181.1	146.5	113.6	73.0		16.0	7.13	6.68	8.22

Preliminary Draft Data

UDDS: Carbon Emission Rates



Preliminary Results

- No immediately visible trends for VOCs and Ions
  - The effect of background levels of ions needs to be evaluated
- Total Carbon emissions decreases with increasing biodiesel blend levels
  - Mainly due to decreasing EC

Discussion

Transportation Refrigeration Unit (TRU) Biodiesel Test Program

TRU Test Program Update

- Engine mapping completed
- Plan to start first test series next week
- Two 8-mode test series
  - Eng. No. 1 w/ CA v. $B50_S$, $B100_S$ & CA v. $B5_S$, $B20_S$
- Six 4-mode test series
  - Eng. Nos. 1, 2, & 3 w/ CA v. $B100_S$ & CA v. $B100_A$
- Minimum of 8 tests per fuel per series
- One 8-mode or two 4-mode tests per day
- Total test days = 96

Discussion

Biodiesel/Renewable Diesel Multimedia Evaluation

Multimedia Evaluation

- Biodiesel Tier I
- Biodiesel Tier II Test Protocol
- Biodiesel Tier III Report
- Renewable Diesel Tier I
  - Hypothesis: Finished product is diesel
    - ASTM D975
  - Upstream from the refinery is different than diesel

Biodiesel/Renewable Diesel Multimedia Evaluation

- Biodiesel Tier One
  - Dr. Thomas McKone

Biodiesel/Renewable Diesel Multimedia Evaluation

- Biodiesel Tier Two Test Protocol
  - Dr. Tim Ginn

Comment Period

- Tier One Report
  - Extended to March 25, 2009
- Tier Two Test Protocol

Biodiesel and Renewable Diesel Advisory Group

- May 2009

Open Discussion