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STUDY OF THE EMISSIONS IMPACTS OF B5-B10 BLENDS FOR CALIFORNIA

Thomas D. Durbin, George Karavalakis, Kent C. Johnson, and Maryam Hajbabaei
University of California, College of Engineering, Center for Environmental Research and Technology (CE-CERT), Riverside, CA 92521

Previous CE-CERT Biodiesel Activity

- **Biodiesel emissions characterization study**
  - Soy-based and animal-based biodiesel, renewable diesel (Neste Oil), and GTL
  - Blend levels B0, B5, B20, B50, B100 --- R20, R50, R100
    - Engine dynamometer testing at CE-CERT
    - CARB chassis dynamometer facility in Los Angeles
    - Primary toxic testing with UC Davis
    - Testing off-road engines at CARB's Stockton facility, light-duty vehicles, and transportation refrigeration units (TRUs)
    - Multi-media and Durability Studies
- **Certification of B5/B20+Additives biodiesel study**
  - Soy-based, animal-based, and waste vegetable oil biodiesel
  - Blend levels B0, B5, and B20
  - Five additives used in B20 testing
  - 2006 Cummins ISM
  - FTP cycle
- **Some uncertainty in impacts of biodiesel on NO_x emissions for lower blend levels**

B5-B10 Comprehensive Emissions Study

- Evaluating the effects of B5/B10 biodiesel blends on criteria emissions (with emphasis on NO_x emissions)
- Add to growing database of information in this area

Test Fuels

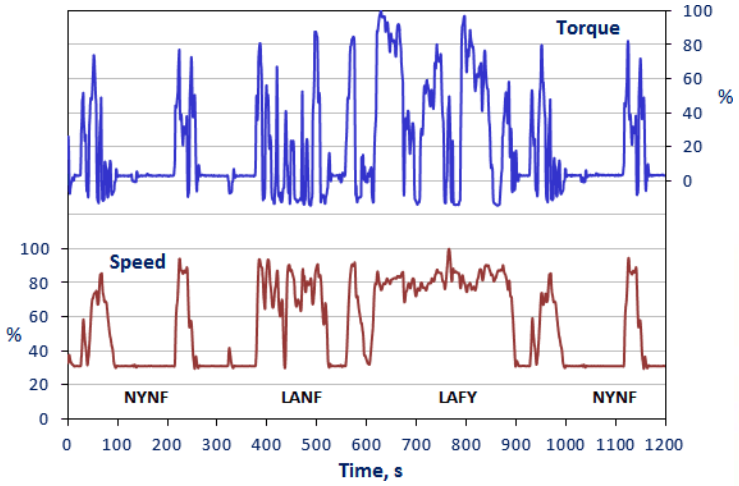
- Soy-based and animal tallow biodiesel
- B0, B5, and B10 blend levels
- A commercial CARB diesel fuel

Test Engines

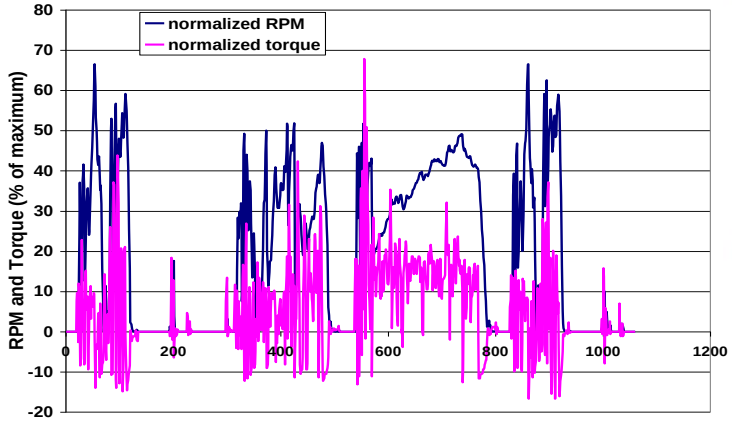
- 2006 Cummins ISM
- 1991 Detroit Diesel Corporation Series 60

Test Cycles

1- FTP



2- UDDS



3- Supplemental Emissions Test (SET)

RMC mode	Time in mode (seconds)	Engine speed [1,2]	Torque (percent) [2,3]
1a Steady-state	170	Warm Idle	0
1b Transition	20	Linear Transition	Linear Transition
2a Steady-state	170	A	100
2b Transition	20	A	Linear Transition
3a Steady-state	102	A	25
3b Transition	20	A	Linear Transition
4a Steady-state	100	A	75
4b Transition	20	A	Linear Transition
5a Steady-state	103	A	50
5b Transition	20	Linear Transition	Linear Transition
6a Steady-state	194	B	100
6b Transition	20	B	Linear Transition
7a Steady-state	219	B	25
7b Transition	20	B	Linear Transition
8a Steady-state	220	B	75
8b Transition	20	B	Linear Transition
9a Steady-state	219	B	50
9b Transition	20	Linear Transition	Linear Transition
10a Steady-state	171	C	100
10b Transition	20	C	Linear Transition
11a Steady-state	102	C	25
11b Transition	20	C	Linear Transition
12a Steady-state	100	C	75
12b Transition	20	C	Linear Transition
13a Steady-state	102	C	50
13b Transition	20	Linear Transition	Linear Transition
14 Steady-state	168	Warm Idle	0

[1] Speed terms are defined in 40 CFR part 1065.
[2] Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the speed or torque setting of the current mode to the speed or torque setting of the next mode.
[3] The percent torque is relative to maximum torque at the commanded engine speed.

Emission Testing

CE-CERT Heavy-duty Engine Dynamometer Lab / Mobile Emissions Lab

- THC, CO, NO_x , CO_2, PM, Fuel Consumption (Carbon Balance Method)
- Carbonyls, EC/OC, Ions, Trace Elements and Metals

Testing Protocol

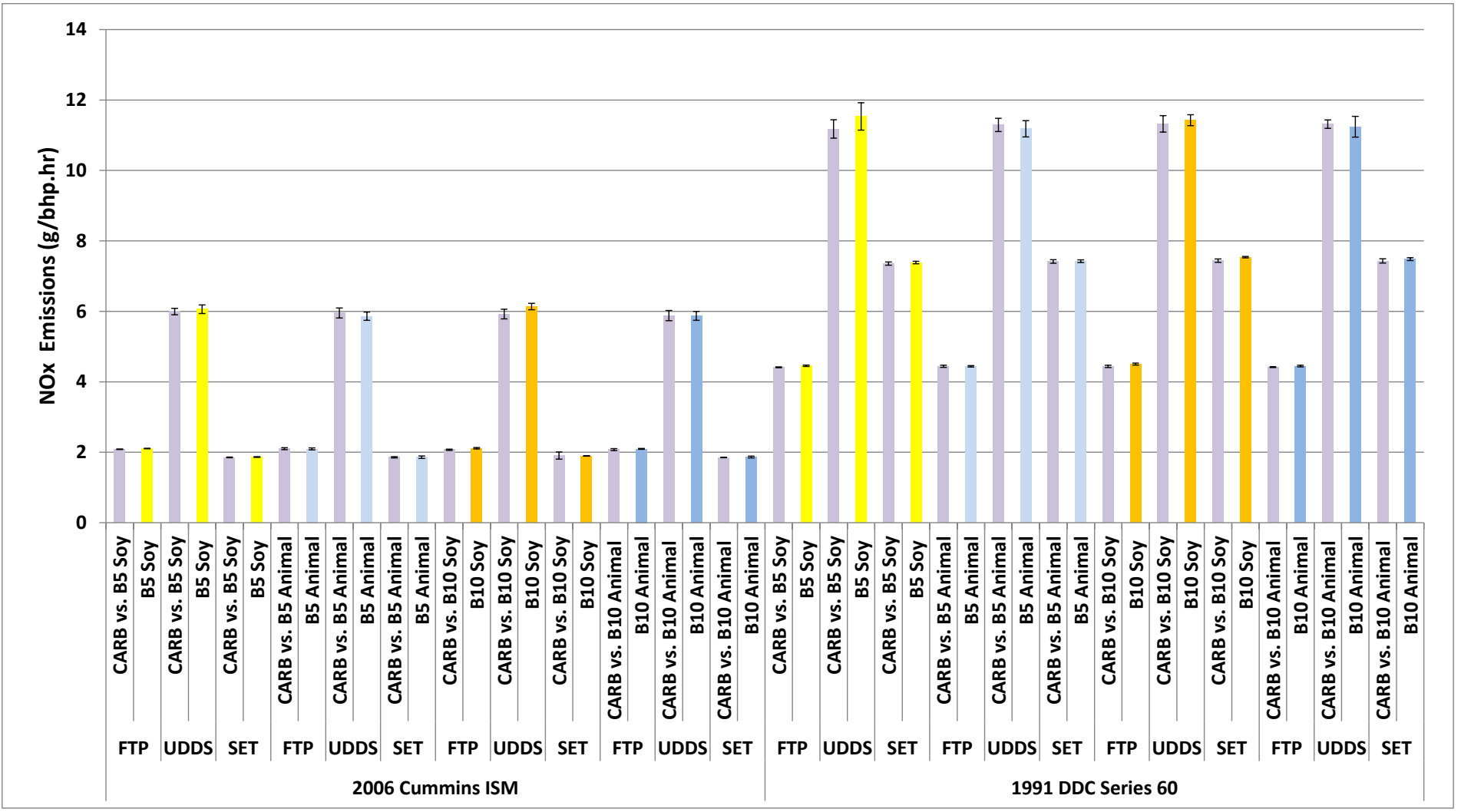
1- Testing Protocol for FTP and UDDS

Day	Fuel Test Sequence
1	RC CR RC CR
2	RC CR RC CR

2- Testing Protocol for SET Cycle

Day	Fuel Test Sequence
1	RC CR
2	RC CR

NO_x Emissions Results



NO_x Emissions Results

	Test Cycle	Fuel Type			
			Ave. (g/bhp.hr)	% Diff vs. CARB	P-values
2006 Cummins ISM	FTP	CARB vs. B5 Soy	2.086		
		B5 Soy	2.107	**1.0%**	**0.000**
	UDDS	CARB vs. B5 Soy	5.994		
		B5 Soy	6.059	1.1%	0.227
	SET	CARB vs. B5 Soy	1.853		
		B5 Soy	1.864	0.6%	0.162
	FTP	CARB vs. B5 Animal	2.101		
		B5 Animal	2.094	-0.3%	0.615
	UDDS	CARB vs. B5 Animal	5.954		
		B5 Animal	5.861	-1.6%	0.165
	SET	CARB vs. B5 Animal	1.857		
		B5 Animal	1.860	0.1%	0.909
	FTP	CARB vs. B10 Soy	2.072		
		B10 Soy	2.112	**1.9%**	**0.000**
	UDDS	CARB vs. B10 Soy	5.924		
		B10 Soy	6.136	**3.6%**	**0.003**
	SET	CARB vs. B10 Soy	1.906		
		B10 Soy	1.896	-0.5%	0.858
	FTP	CARB vs. B10 Animal	2.077		
		B10 Animal	2.095	0.8%	0.125
	UDDS	CARB vs. B10 Animal	5.880		
		B10 Animal	5.872	-0.1%	0.910
	SET	CARB vs. B10 Animal	1.851		
		B10 Animal	1.863	0.6%	0.401

NO_x Emissions Results

	Test Cycle	Fuel Type			
			Ave. (g/bhp.hr)	% Diff vs. CARB	P-values
1991 DDC Series 60	FTP	CARB vs. B5 Soy	4.411		
		B5 Soy	4.456	**1.0%**	**0.000**
	UDDS	CARB vs. B5 Soy	11.178		
		B5 Soy	11.532	**3.2%**	**0.050**
	SET	CARB vs. B5 Soy	7.356		
		B5 Soy	7.386	0.4%	0.363
	FTP	CARB vs. B5 Animal	4.438		
		B5 Animal	4.441	0.1%	0.813
	UDDS	CARB vs. B5 Animal	11.294		
		B5 Animal	11.182	-1.0%	0.306
	SET	CARB vs. B5 Animal	7.416		
		B5 Animal	7.426	0.1%	0.771
	FTP	CARB vs. B10 Soy	4.437		
		B10 Soy	4.504	**1.5%**	**0.008**
	UDDS	CARB vs. B10 Soy	11.322		
		B10 Soy	11.428	0.9%	0.298
	SET	CARB vs. B10 Soy	7.440		
		B10 Soy	7.540	**1.3%**	**0.008**
	FTP	CARB vs. B10 Animal	4.415		
		B10 Animal	4.447	**0.7%**	**0.003**
	UDDS	CARB vs. B10 Animal	11.314		
		B10 Animal	11.243	-0.6%	0.535
	SET	CARB vs. B10 Animal	7.433		
		B10 Animal	7.485	0.7%	0.209

Conclusions

- NO_X Emissions Results

  2006 Cummins ISM engine

  – Statistically significant increase of **1.0% and 1.9%**, respectively, for the **B5-soy and the B10-soy** blends compared to the CARB diesel fuel for the **FTP** cycle

  – Statistically significant increase of **3.6%** for the **B10-soy** blend compared to the CARB diesel fuel for the **UDDS**.

  1991 DDC Series engine

  – Statistically significant increase of **1.0% and 3.2%,** respectively, for the **B5-soy** blend for the **FTP and UDDS** cycles.

  – **B10-soy** blend showed a statistically significant increase of **1.5% and 1.3%,** respectively, for the **FTP and SET** cycles.

  Animal biodiesel blends didn't show more consistent NO_x increases like for the soy biodiesel blends

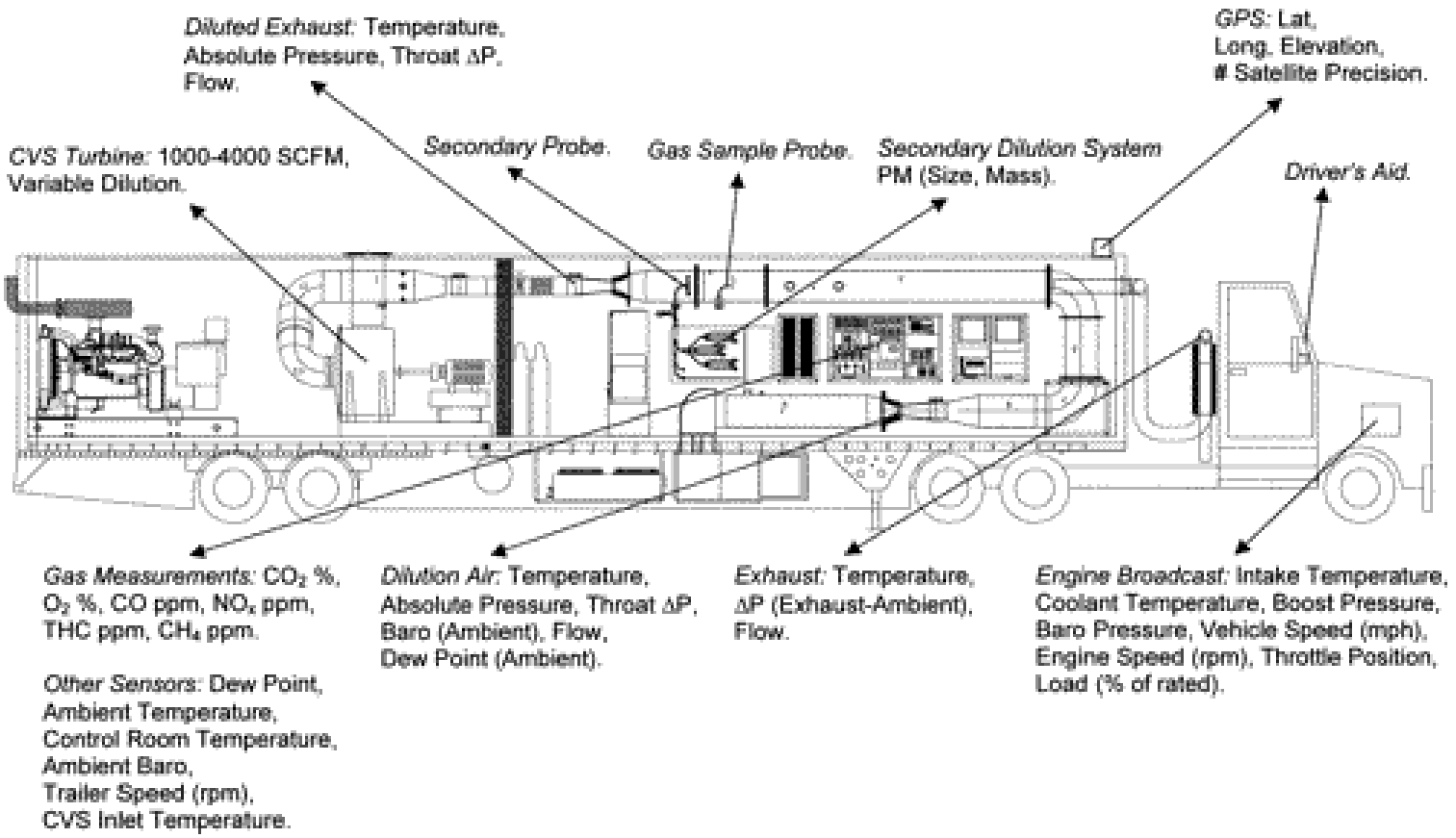
  – Only the B10-animal blend showed a statistically significant increase of **0.7%** for the **FTP** on the **1991 DDC** engine.

- Other Pollutants showing fuel trends included:
  – PM showed consistent reductions for biodiesel blends for both engines for FTP and SET cycles.
  – THC showed general decreasing trend for most biodiesel blends, but most differences were not statistically significant.
  – CO showed a general trend of reductions with the biodiesel blends, although these differences were not statistically significant for all biodiesel blends or cycles.
  – BSFC showed general increasing trend with the biodiesel blends, although this was not seen for all biodiesel blend, cycle, and engine combinations.

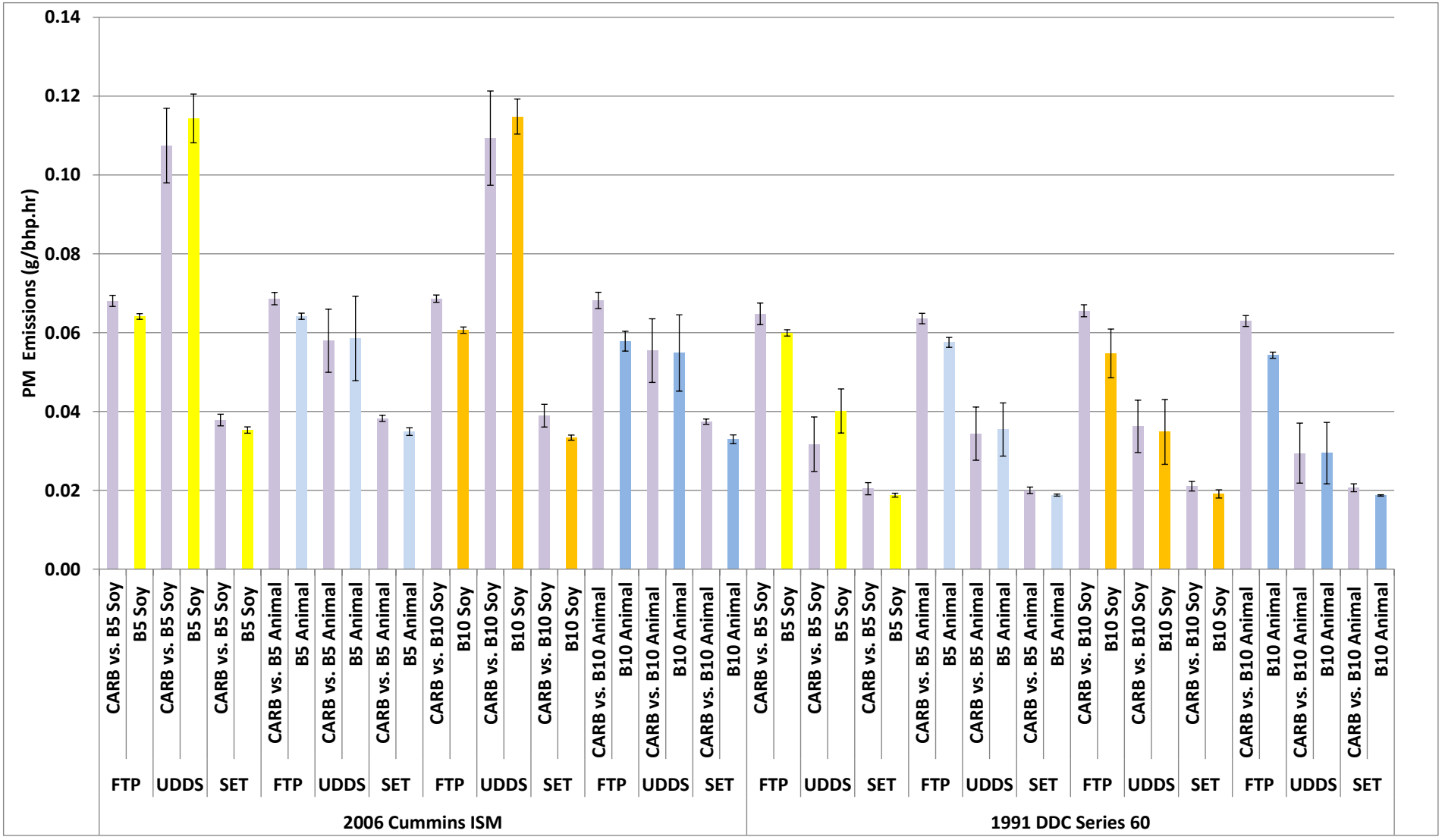
- No strong & consistent trends for CO_2, EC/OC, carbonyls, ions, and trace elements emissions.

Supporting Information

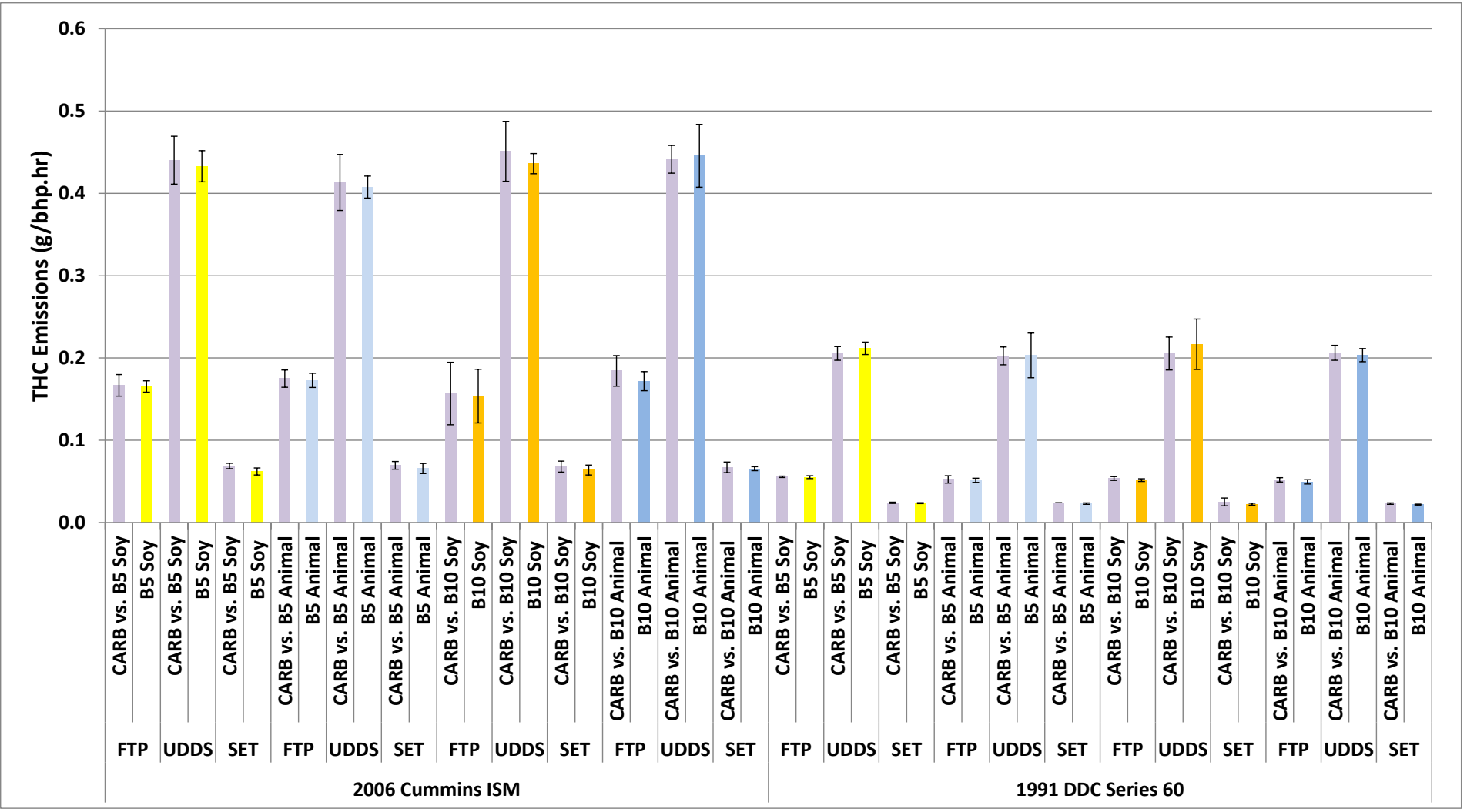
Schematic of MEL



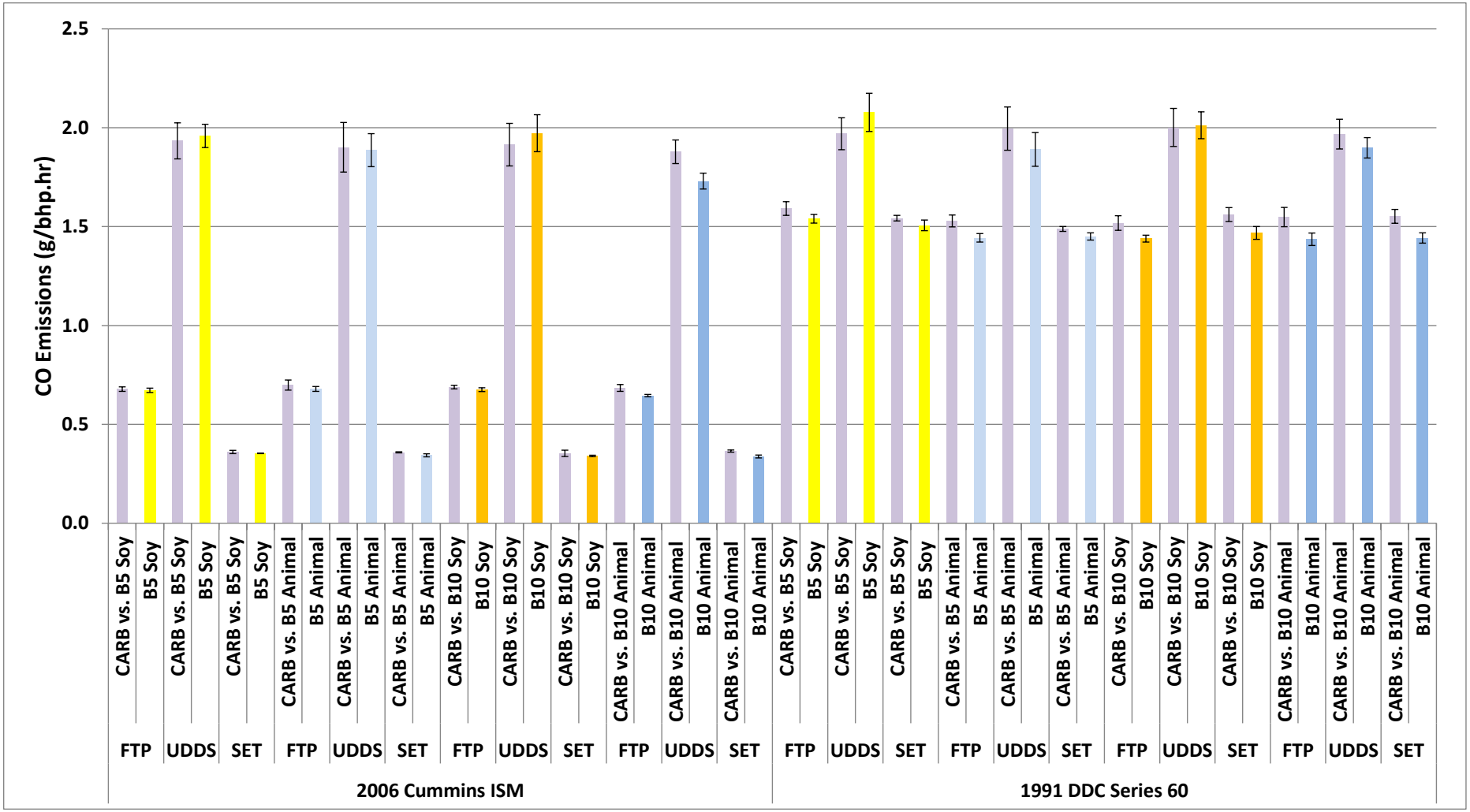
PM Emissions Results



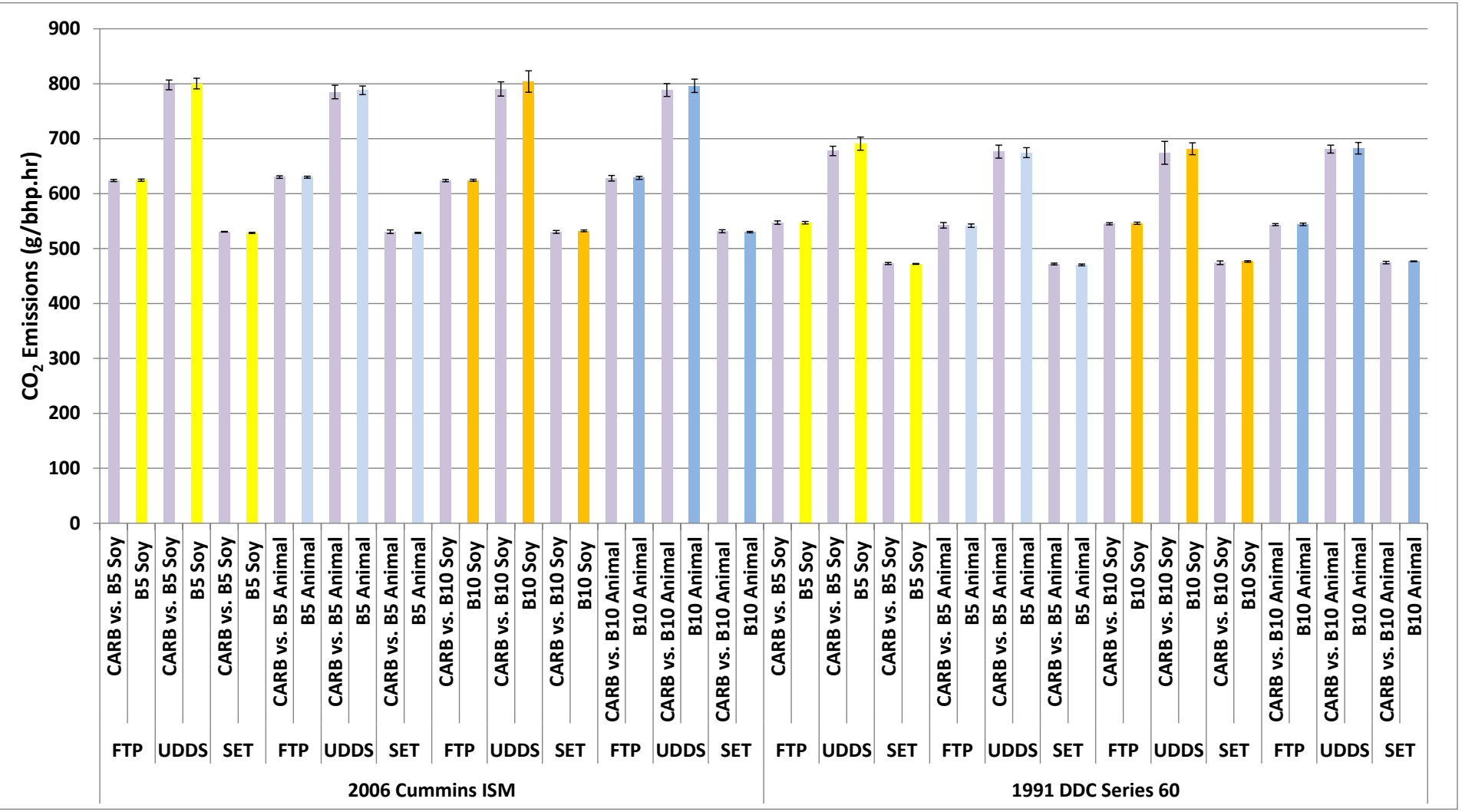
THC Emissions Results



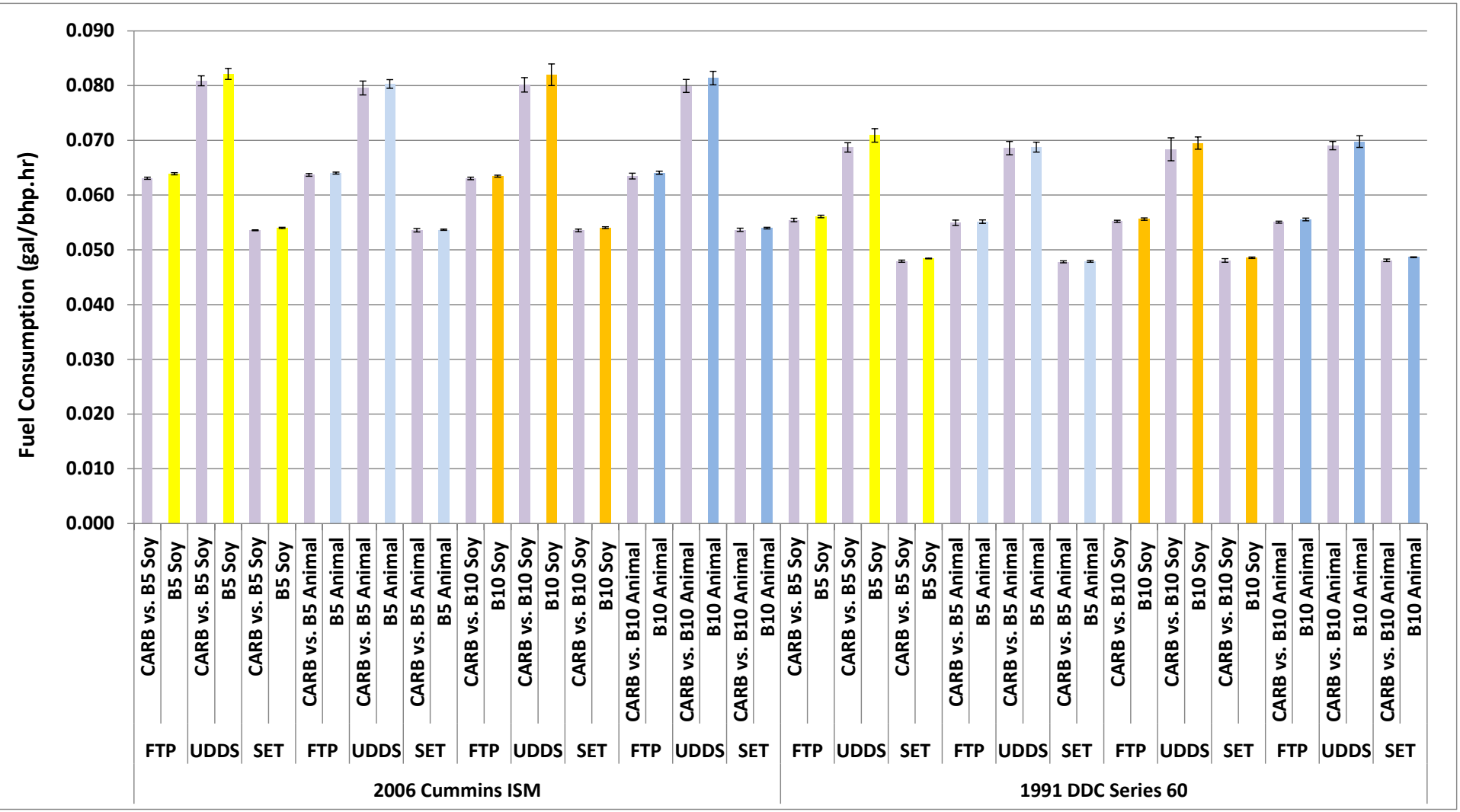
CO Emissions Results



CO_2 Emissions Results

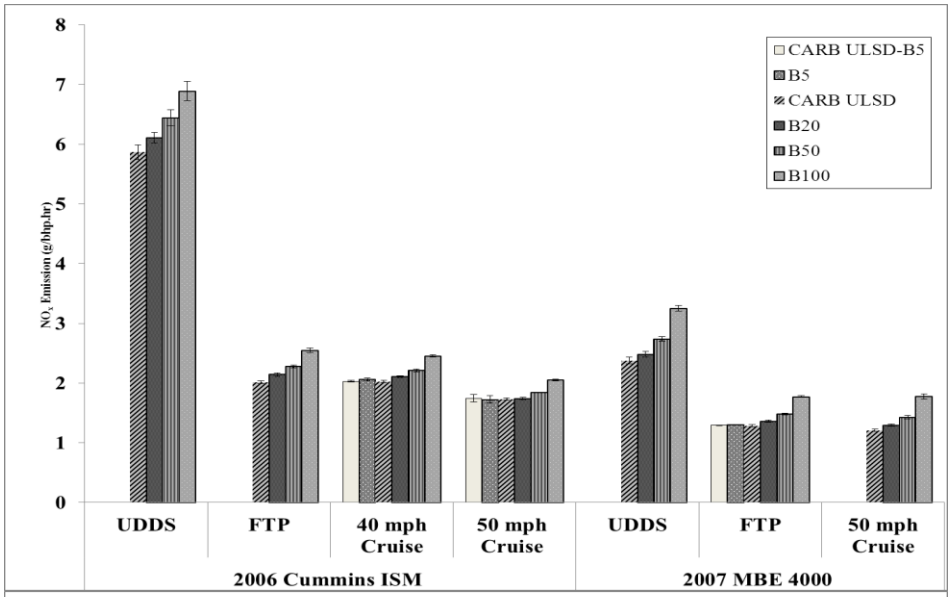


BSFC Results

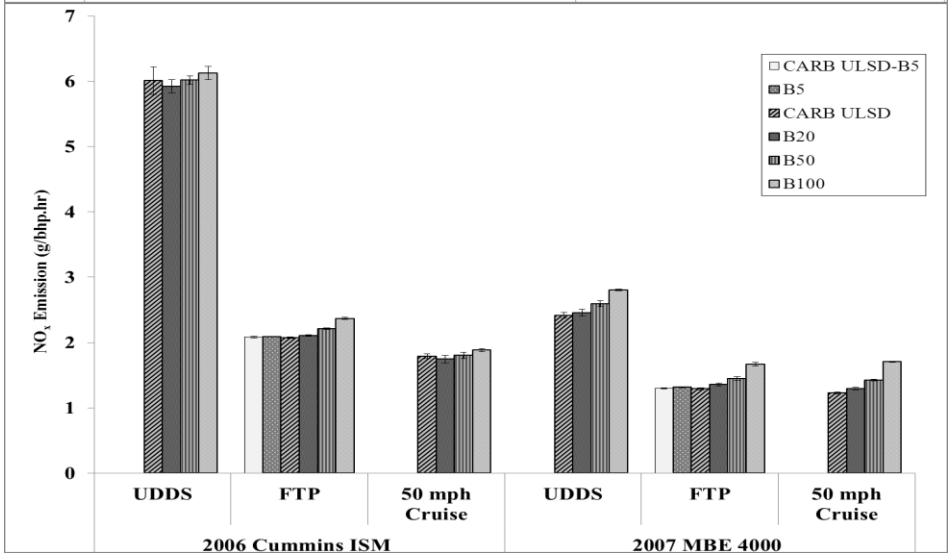


NO_x Emissions Results – Initial Study

Soy-based biodiesel



Animal-based biodiesel



NO_x Emissions Results – B5/B20+Additives