Appendix M
Offroad Vehicle Emissions Inventory and CO Credits

Offroad Exhaust Emissions

Based on data from the U.S. EPA Office of Mobile Sources Report No. NR-003, "Exhaust Emission Effects of Fuel Sulfur and Oxygen on Gasoline Nonroad Engines," staff estimated average emission decreases in exhaust CO and ROG when the oxygen content of the fuel is increased. Using emission data from four 4-stroke engines and one 2-stroke engine tested at 0, 2.7, and 3.5 percent by weight oxygen; staff interpolated emissions to 2.0 percent by weight oxygen. Data are available from a single 2-stroke engine based on testing by the ARB. Also, from SAE paper 972108, "Emissions from Snowmobile Engines Using Bio-based Fuels and Lubricants," data regarding emissions at 3.5 percent by weight oxygen are available.

A summary of data given in Table K-1. Due to the paucity of engine test data, it is not possible to reliably estimate changes in emissions. Figures K-1 and K-2 are plots of the available data. Figure K-3 is a plot of the expected percent change in HC versus NOx associated with increasing fuel oxygen from 2 percent to 3.5 percent. Figures K-1 through K-3 provide an indications of the large variability in the percent changes in emissions. Tables K-2 and K-3 summarize emission projections for onroad and offroad gasoline engines for years 2000 and 2005, respectively. The projections are based on ARB-adopted inventory models and current inventory data with the exceptions noted. The offroad evaporative emissions and container emissions are being investigated further, and may be revised.

Bishop and Stedman collected remote sensing data on 2-stroke snowmobiles operating in Yellowstone National Park. Part of their study involved measuring the emission differences between an non-oxygenated gasoline and a 10 volume percent ethanol gasoline for in-use snowmobiles. Bishop and Stedman report a 7 percent reduction in CO from in-use snowmobiles and no statistically significant difference in hydrocarbon emissions. Bishop and Stedman's data were collected during the winter in Yellowstone National Park and may not reflect actual in-use applications in California.

Offroad Evaporative Emissions

There currently is very little information regarding evaporative hydrocarbon emissions from off-road applications. Most off-road engines do not have evaporative control systems. This implies that the database of information relating to evaporative hydrocarbon emission from on-road vehicles may not be directly applicable. As part of the portable fuel contain emissions control measure, evaporative hydrocarbon emissions from portable fuel containers for 2007 are estimated to be about 90 tons per day, statewide. Diurnal evaporative hydrocarbon emissions testing of these container found that the hydrocarbon emissions tend to have reactivities that are significantly higher than those estimated for diurnal evaporative emissions from on-road vehicles.

Staff found that the estimated increase in diurnal evaporative emissions associated with an increase in the RVP based on the proposed CaRFG3 Predictive Model is less that what is predicted from the U.S. EPA's MOBILE5b off-road diurnal emissions model.

Details of the portable fuel container spillage control regulations and supporting analysis are available in the Initial Statement of Reasons for Proposed Rule Making, Public Hearing to Consider the Adoption of Portable Fuel Container Spillage Control Regulations or from the California Air Resources Board web page.

<u>Summary</u>

The staff believes that there are insufficient data to quantify how evaporative hydrocarbon emissions could be offset by CO emissions. However, based on staff's analysis, the predicted decrease in CO emissions, on a reactivity adjusted basis in tons per day, is basically offset by the large predicted increase in evaporative emissions. We would expect that directionally, exhaust hydrocarbon emissions should decrease and NOx emissions should increase. However, there are insufficient test data to reliably quantify these effects.

What little data are available, though, suggests that the most effective way to reduce emissions from off-road vehicles is to implement control standards as was done in recent years by the U.S. EPA and the ARB. Tighter vehicle emissions standards should lead to the use of more sophisticated emissions control technology such as advanced fuel control systems, catalytic converters, and evaporative controls. As the number of newer off-road vehicles increase, the effect of fuel property changes on their emissions will be more like automobile emissions. Because of the lack of information and because emissions from off-road vehicles will be more similar to automobile emissions in 2005, staff does not believe it is feasible to model the effects of CaRFG3 on off-road engines and include these effects as part of the equivalency determination made using the CaRFG3 Predictive Model.

Table K-1

Summary of OffRoad Test Data

Off-Road Test Data (g/kWh)			Nonoxygenated			2.0 % Oxygen			2.7 % Oxygen			3.5 % Oxygen			% Dif. / (% Oxy – 2.0)		
SOURCE	ENGINE	CYCLE	NOx	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx	CO	HC	NOx	CO	HC
USEPA	Tecumseh	4-stroke	1.7	480	24.2	1.63*	456*	22.6*	1.6	447	22.1	1.7	433	20.4	**2.9**	**-3.4**	**-6.5**
USEPA	B&S-new	4-stroke	2.3	763	46.4	2.30*	754*	46.6*	2.3	751	46.7	3.1	658	44.5	**23.2**	**-8.5**	**-3.0**
USEPA	B&S-old	4-stroke	1.2	1079	71.0	1.27*	1018*	66.6*	1.3	997	65.0	1.7	949	65.8	**22.6**	**-4.5**	**-0.8**
USEPA	Khler-new	4-stroke	3.0	339	5.8	3.15*	327*	5.5*	3.2	323	5.4	5.0	239	4.3	**39.2**	**-17.9**	**-14.5**
USEPA	Yahama	2-stroke	2.44	184	183.6	3.34*	183*	182.0*	3.65	182	181.5	4.05**	95**	178.0**	**14.2**	**-32.1**	**-1.5**
CARB	1.45 hp	2-stroke	0.79	404	192	1.03	290	177							**9.2**	**-19.7**	**-4.2**
SAE972108	Arctco	2-stroke	0.66	487	209	0.66*	487*	209*				0.70	459	220	**4.0**	**-3.8**	**3.5**
SAE972108	Polaris	2-stroke	0.59	558	202	0.59*	558*	202*				0.59	506	170	**0**	**-6.2**	**-10.6**

*Interpolation or estimation. **Extrapolated from 3% oxygen.4

Table K-2

GASOLINE ENGINE POPULATION, FUEL CONSUMPTION (gallons/day), AND ASSOCIATED EMISSIONS (tons/day)

	Engine Population	Fuel Consump.	Statewide Exhaust PM	2000 Exhaust NOx	Exhaust CO	Exhaust ROG	Evap. ROG	Container ROG	Dist. S&T ROG	Sum ROG
ONROAD ENGINES TOTAL	**25539105**	**34930270**	**5.37**	**1057.81**	**8013.39**	**619.94**	**281.32**	**0.00**	**63.51**	**964.77**
Percent of Onroad + Offroad	*79.59*	*95.61*	*25.12*	*92.07*	*73.75*	*62.26*	*78.20*	*0.00*	*95.61*	*66.78*
OFFROAD ENGINES (2-stroke < 25 hp)	2230939	83789	1.67	0.56	143.54	60.17	3.01	2.51	0.15	65.84
Construction	3445	805	0.02	0.01	1.34	0.20	0.01	0.02	0.00	0.24
Industrial	88	82	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.01
Lawn and Garden	2000499	58799	0.79	0.36	96.51	35.78	1.79	1.76	0.11	39.44
Light-duty Commercial	22502	4287	0.07	0.04	8.87	2.57	0.13	0.13	0.01	2.83
Logging	9591	8395	0.19	0.03	12.47	5.79	0.29	0.25	0.02	6.35
Pleasure Craft	194814	11421	0.61	0.11	24.22	15.83	0.79	0.34	0.02	16.98
OFFROAD ENGINES (4-stroke < 25 hp)	3387509	249337	1.34	4.89	640.63	26.86	13.43	7.48	0.45	48.22
Agricultural	151674	22430	0.07	0.61	59.22	1.98	0.99	0.67	0.04	3.69
Airport Ground Support	26	9	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Construction	74072	23854	0.46	0.56	61.01	2.22	1.11	0.72	0.04	4.09
Industrial	1486	950	0.00	0.02	2.39	0.07	0.04	0.03	0.00	0.14
Lawn and Garden	2875549	109565	0.15	1.50	271.05	12.36	6.18	3.29	0.20	22.02
Light-duty Commercial	259881	74034	0.41	1.79	200.01	8.64	4.32	2.22	0.13	15.32
Logging	15049	9315	0.23	0.21	23.46	0.77	0.38	0.28	0.02	1.45
Transport Refrigeration	5062	9105	0.01	0.20	23.35	0.81	0.40	0.27	0.02	1.50
Pleasure Craft	4710	74	0.00	0.01	0.12	0.01	0.00	0.00	0.00	0.01
OFFROAD ENGINES (< 25 hp) TOTAL	**5618448**	**333126**	**3.01**	**5.45**	**784.17**	**87.03**	**16.44**	**9.99**	**0.61**	**114.06**
Percent of Onroad + Offroad	*17.51*	*0.91*	*14.07*	*0.47*	*7.22*	*8.74*	*4.57*	*43.99*	*0.91*	*7.90*
OFFROAD ENGINES (2-stroke ≥ 25 hp)	341217	221298	11.52	2.77	332.38	183.12	9.16	2.21	0.40	194.89
Lawn and Garden	461	2013	0.00	0.02	3.10	0.17	0.01	0.02	0.00	0.20
Light-duty Commercial	47	72	0.00	0.00	0.13	0.03	0.00	0.00	0.00	0.04
Pleasure Craft	340709	219214	11.51	2.74	329.15	182.91	9.15	2.19	0.40	194.65
OFFROAD ENGINES (4-stroke ≥ 25 hp)	589033	1051118	1.48	82.88	1735.61	105.68	52.84	10.51	1.91	170.94
Agricultural	12304	12735	0.04	1.71	11.38	0.53	0.26	0.13	0.02	0.94
Airport Ground Support	2391	21293	0.01	3.36	10.70	0.66	0.33	0.21	0.04	1.24
Construction	10216	19687	0.26	1.52	34.52	1.23	0.62	0.20	0.04	2.08
Industrial	19164	139260	0.03	19.71	112.31	6.73	3.36	1.39	0.25	11.73
Lawn and Garden	59027	28349	0.12	1.44	70.12	2.20	1.10	0.28	0.05	3.64
Light-duty Commercial	129280	97915	0.46	6.25	204.77	6.83	3.41	0.98	0.18	11.40
Pleasure Craft	356651	731880	0.57	48.89	1291.81	87.50	43.75	7.32	1.33	139.90
OFFROAD ENGINES (≥ 25hp) TOTAL	**930250**	**1272416**	**13.00**	**85.64**	**2067.98**	**288.79**	**61.99**	**12.72**	**2.31**	**365.82**
Percent of Onroad + Offroad	*2.90*	*3.48*	*60.81*	*7.45*	*19.03*	*29.00*	*17.23*	*56.01*	*3.48*	*25.32*
OFFROAD ENGINES TOTAL	**6548698**	**1605542**	**16.01**	**91.10**	**2852.16**	**375.82**	**78.43**	**22.72**	**2.92**	**479.89**
Percent of Onroad + Offroad	*20.41*	*4.39*	*74.88*	*7.93*	*26.25*	*37.74*	*21.80*	*100.00*	*4.39*	*33.22*
ONROAD + OFFROAD ENGINES TOTAL	**32087803**	**36535812**	**21.38**	**1148.91**	**10865.55**	**995.76**	**359.75**	**22.72**	**66.43**	**1444.66**

NOTES:

1. Off-road evap. ROG assumed to be 5% of exhaust ROG for 2-stroke engines and 50% of exhaust ROG for 4-stroke engines.
2. Container ROG assumed to be 0.06 lbs/gal for off-road engines < 25 hp and 0.02 lbs/gal for off-road engines ≥ 25 hp

Table K-3

GASOLINE ENGINE POPULATION, FUEL CONSUMPTION (gallons/day), AND ASSOCIATED EMISSIONS (tons/day)
Statewide 2005

	Engine Population	Fuel Consump.	Exhaust PM	Exhaust NOx	Exhaust CO	Exhaust ROG	Evap. ROG	Container ROG	Dist. S&T ROG	Sum ROG
ONROAD ENGINES TOTAL	**27650939**	**37554830**	**5.40**	**820.22**	**5830.65**	**380.56**	**222.26**	**0.00**	**64.71**	**667.53**
Percent of Onroad + Offroad	*79.69*	*95.59*	*19.78*	*89.26*	*68.58*	*55.86*	*75.50*	*0.00*	*95.59*	*62.52*
OFFROAD ENGINES (2-stroke < 25 hp)	2381657	88814	1.04	0.90	111.67	42.65	2.13	2.66	0.15	47.60
Construction	3701	865	0.02	0.02	1.04	0.03	0.00	0.03	0.00	0.06
Industrial	93	88	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.01
Lawn and Garden	2153439	63293	0.16	0.61	71.78	23.33	1.17	1.90	0.11	26.50
Light-duty Commercial	24034	4579	0.06	0.07	6.33	0.74	0.04	0.14	0.01	0.92
Logging	10079	8821	0.20	0.04	13.03	6.08	0.30	0.26	0.02	6.66
Pleasure Craft	190311	11168	0.60	0.17	19.38	12.48	0.62	0.34	0.02	13.46
OFFROAD ENGINES (4-stroke < 25 hp)	3640736	266744	1.49	6.18	573.67	21.75	10.87	8.00	0.46	41.08
Agricultur al	159537	23593	0.07	0.60	56.78	1.92	0.96	0.71	0.04	3.63
Airport Ground Support	28	11	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Construction	79581	25628	0.53	0.66	52.38	1.78	0.89	0.77	0.04	3.48
Industrial	1579	1010	0.00	0.03	1.90	0.04	0.02	0.03	0.00	0.09
Lawn and Garden	3097046	117964	0.13	2.42	241.63	9.33	4.66	3.54	0.20	17.74
Light-duty Commercial	277579	79076	0.48	1.89	184.29	7.83	3.91	2.37	0.14	14.25
Logging	15813	9788	0.27	0.28	18.52	0.46	0.23	0.29	0.02	0.99
Transport Refrigeration	5343	9610	0.01	0.31	18.04	0.39	0.20	0.29	0.02	0.90
Pleasure Craft	4230	66	0.00	0.00	0.11	0.01	0.00	0.00	0.00	0.01
OFFROAD ENGINES (< 25 hp) TOTAL	**6022393**	**355558**	**2.53**	**7.09**	**685.34**	**64.40**	**13.01**	**10.67**	**0.61**	**88.69**
Percent of Onroad + Offroad	*17.36*	*0.91*	*9.27*	*0.77*	*8.06*	*9.45*	*4.42*	*43.67*	*0.91*	*8.31*
OFFROAD ENGINES (2-stroke ≥ 25 hp)	412237	287254	17.43	14.71	239.67	131.11	6.56	2.87	0.49	141.03
Lawn and Garden	497	2167	0.00	0.04	2.84	0.07	0.00	0.02	0.00	0.10
Light-duty Commercial	51	76	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.01
Pleasure Craft	411689	285011	17.43	14.67	236.73	131.03	6.55	2.85	0.49	140.92
OFFROAD ENGINES (4-stroke ≥ 25 hp)	610515	1088779	1.94	76.85	1746.25	105.16	52.58	10.89	1.88	170.50
Agricultur al	12537	12831	0.06	1.37	10.15	0.42	0.21	0.13	0.02	0.78
Airport Ground Support	2694	23985	0.01	2.51	10.60	0.51	0.25	0.24	0.04	1.05
Construction	10748	20399	0.32	1.25	28.88	0.88	0.44	0.20	0.04	1.56
Industrial	20364	147995	0.04	14.81	114.15	5.35	2.68	1.48	0.25	9.76
Lawn and Garden	63540	30515	0.17	1.10	65.21	1.75	0.88	0.31	0.05	2.98
Light-duty Commercial	138084	104582	0.77	5.77	194.70	6.52	3.26	1.05	0.18	11.01
Pleasure Craft	362548	748472	0.58	50.04	1322.56	89.72	44.86	7.48	1.29	143.35
OFFROAD ENGINES (≥ 25hp) TOTAL	**1022752**	**1376033**	**19.37**	**91.56**	**1985.93**	**236.27**	**59.14**	**13.76**	**2.37**	**311.53**
Percent of Onroad + Offroad	*2.95*	*3.50*	*70.95*	*9.96*	*23.36*	*34.68*	*20.09*	*56.33*	*3.50*	*29.18*
OFFROAD ENGINES TOTAL	**7045145**	**1731591**	**21.90**	**98.65**	**2671.27**	**300.67**	**72.14**	**24.43**	**2.98**	**400.22**
Percent of Onroad + Offroad	*20.31*	*4.41*	*80.22*	*10.74*	*31.42*	*44.14*	*24.50*	*100.00*	*4.41*	*37.48*
ONROAD + OFFROAD ENGINES TOTAL	**34696084**	**39286421**	**27.30**	**918.87**	**8501.92**	**681.23**	**294.40**	**24.43**	**67.69**	**1067.74**

NOTES:

1. Off-road evap. ROG assumed to be 5% of exhaust ROG for 2-stroke engines and 50% of exhaust ROG for 4- stroke engines
2. Container ROG assumed to be 0.06 lbs/gal for off-road engines < 25 hp and 0.02 lbs/gal for off-road engines ≥ 25 hp.

Figure K-1
HC vs NOx for 3.5% Oxygen Fuel

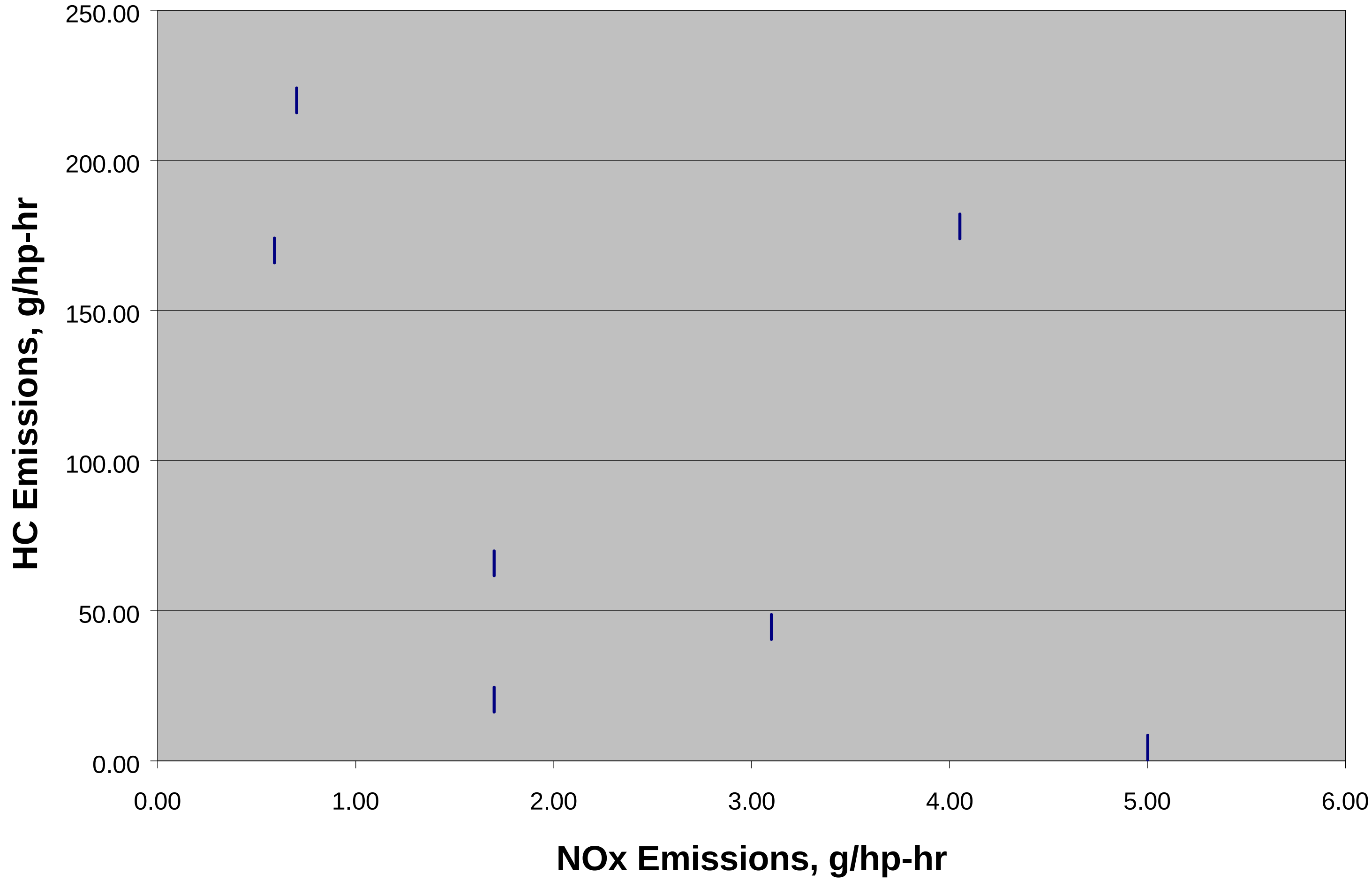

Figure K-2
HC vs NOx for 2.0% Oxygen Fuel

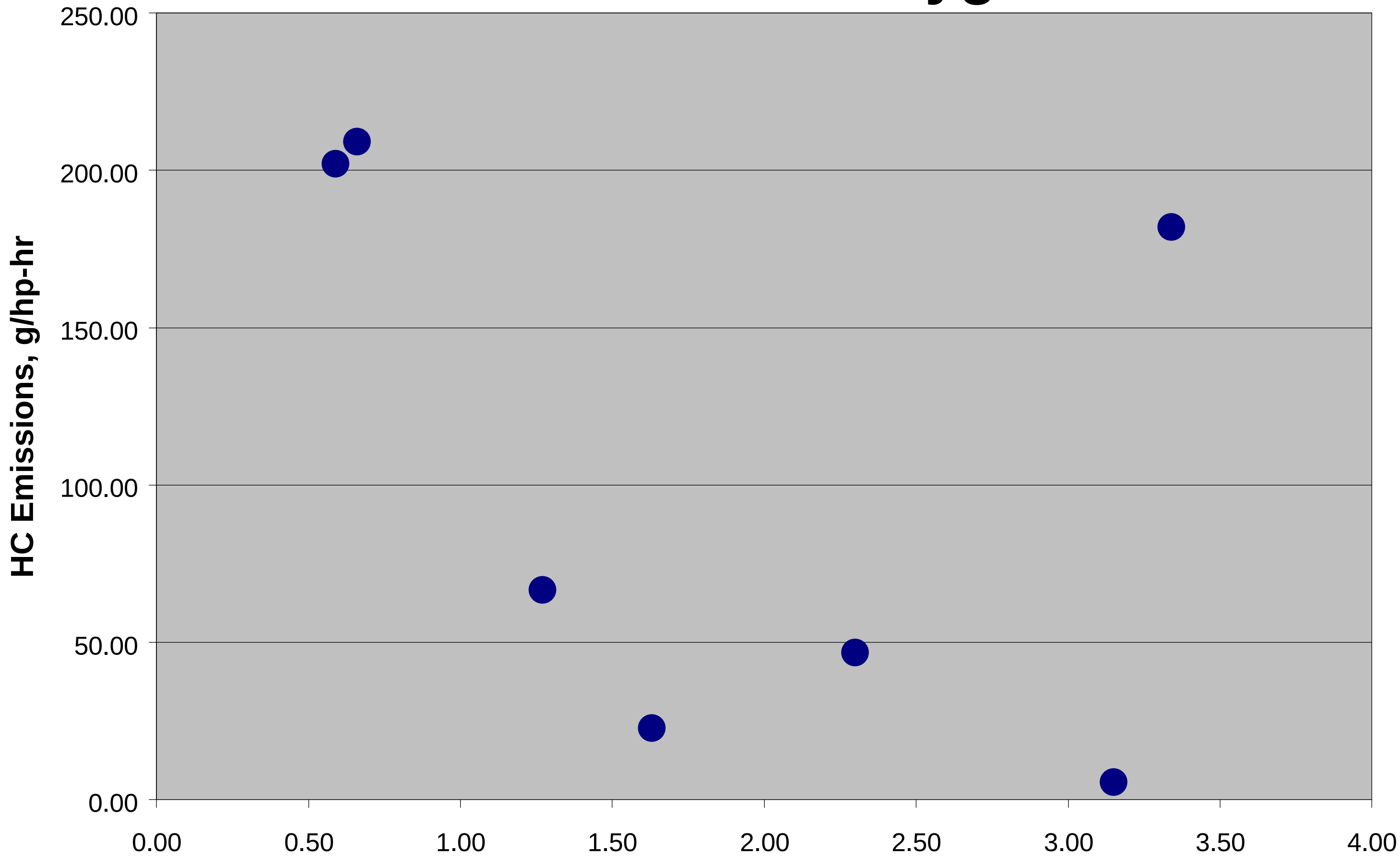

Figure K-3
% change in HC vs % Change in NOx