OFFROAD Modeling Change Technical Memo

SUBJECT: OFF-ROAD EXHAUST EMISSIONS INVENTORY FUEL CORRECTION FACTORS

LEAD: TESS SICAT

DATE: MARCH 16, 2005

SUMMARY

This memorandum documents the current fuel-related assumptions contained in the OFFROAD emissions inventory model. Staff has identified several areas where we believe improvements can be made and have included our recommendations for those changes.

In general, the proposed changes to the fuel correction factors (FCF) for off-road engines and equipment involves the alignment with those assumptions made for the on-road emission inventory as calculated by EMFAC. Overall the proposed modifications to the FCFs will result in an increase of 14.06 tons per day of NOx exhaust emissions and a reduction in the remaining criteria pollutants statewide in the year 2010. The reduction in ROG, CO, and PM exhaust emissions is 31.41, 215.81, and 3.43 tons per day, respectively. Tables 1 and 2 present the estimated impact of the fuels related changes to the off-road inventory for selected geographic areas, calendar years, and fuel types.

Table 1. Estimated Exhaust Emission Changes from Fuel Correction Factors for Diesel Engines (TPD)

		2010			2020		
Air Basin		**Current**	**Revised**	**Percent Difference**	**Current**	**Revised**	**Percent Difference**
South Coast	**ROG**	14.36	10.34	- 28 %	8.07	5.81	- 28 %
	NOx	122.20	129.34	6 %	76.57	82.58	8 %
	PM	9.21	8.15	- 12 %	5.74	5.28	- 8 %
San Joaquin	**ROG**	10.03	7.22	- 28 %	4.86	3.50	- 28 %
	NOx	85.38	89.42	5 %	49.98	51.57	3 %
	PM	5.78	5.13	- 11 %	3.40	3.19	- 6 %

Note: The final document will include impacts for the Bay Area, Sacramento and San Diego air basins and calendar years 2002, 2010, 2015 and 2020.

Table 2. Estimated Exhaust Emission Changes from Fuel Correction Factors for Gasoline Engines (TPD)

		2010			2020		
Air Basin		**Current**	**Revised**	**Percent Difference**	**Current**	**Revised**	**Percent Difference**
South Coast	**ROG**	252.36	243.46	- 4 %	217.11	211.10	- 3 %
	CO	1,309.57	1,256.75	- 4 %	1,244.98	1,208.30	- 3 %
	NOx	45.47	43.28	- 5 %	39.47	38.11	- 3 %
San Joaquin	**ROG**	74.26	71.80	- 3 %	64.48	58.28	- 10 %
	CO	394.45	376.25	- 5 %	368.35	358.99	- 3 %
	NOx	13.80	13.03	- 6 %	11.94	6.26	- 48 %

Note: The final document will include impacts for the Bay Area, Sacramento and San Diego air basins and calendar years 2002, 2010, 2015 and 2020.

BACKGROUND

The fuel correction factors contained in the OFFROAD model are dimensionless multipliers applied to the basic exhaust emissions rates that account for differences in the properties of certification fuels compared to those of commercially dispensed fuels. In those instances where engines or vehicles are not required to certify, the FCFs reflect the impact of changes in dispensed fuel over time as refiners respond to changes in fuel specific regulations compared to the fuel used to obtain the test data. Currently, OFFROAD does not reflect emissions from ships, and aircrafts. Therefore, the changes described here do not apply to these categories. Fuels related changes to the locomotive emissions inventory are discussed in a separate document entitled “Changes to the Locomotive Inventory” and can be located at: http://www.arb.ca.gov/msei/msei.htm

The Reid Vapor Pressure (RVP) of the fuel impacts evaporative emissions. The sulfur content of the fuel impacts the estimates of oxides of sulfur (SOx) and particulate matter (PM). The aromatic hydrocarbon content of the fuel is assumed to impact both oxides of nitrogen (NOx) and PM, while the cetane number, T50 and T90 distillation temperatures impact exhaust hydrocarbons (HC), carbon monoxide (CO) and NOx.

Sulfur/Lead

Currently SOx emissions are calculated based on a single assumption of sulfur content by fuel type, 151 parts per million by weight (ppmw) for gasoline and 2800 ppmw for diesel. External adjustments have been to the SOx output from OFFROAD to reflect changes in the sulfur content by calendar year and region. The proposed methodology is to incorporate these changes into OFFROAD as outlined in Table 3 in order to be consistent with EMFAC.

Table 3
Assumed Sulfur and Lead Content of Fuels

Cal Year	Fuel Sulfur Content (ppmw)						Lead (g/gal)
	SCAB & Ventura			All Other Areas			Statewide
	Leaded	Unleaded	Diesel	Leaded	Unleaded	Diesel	Leaded
Pre-72	610	380	2650	610	380	2650	2.080
1972	610	380	2650	610	380	2650	1.959
1973	610	380	2650	610	380	2650	1.904
1974	610	380	2650	610	380	2650	1.956
1975	610	380	2650	610	380	2650	1.843
1976-77	620	290	2340	620	290	2340	1.843
1978	350	190	3080	350	190	3080	1.843
1979	380	200	2850	380	200	2850	1.120
1980	330	210	2720	330	210	2720	0.831
1981	290	190	2800	290	190	2800	0.697
1982	310	210	2910	310	210	2910	0.783
1983	420	180	3150	420	180	3150	0.738
1984	360	250	3280	360	250	3280	0.660
1985	340	210	1050	340	210	3000	0.332
1986	400	220	950	400	220	3000	0.324
1987	400	220	850	400	220	3000	0.260
1988	400	220	500	400	220	3000	0.083
1989-90	400	220	500	400	220	3000	0.080
1991	151	151	500	151	151	3000	0.080
1992	151	151	500	151	151	3000	0
1993	151	151	500	151	151	500	0
1994	151	151	150	151	151	150	0
1995	151	151	130	151	151	140	0
1996-02	20	20	130	20	22	140	0
2003-06	15	15	130	15	15	140	0
2007+	15	15	15	15	15	15	0

Reformulated Gasoline

The current fuel correction factors in OFFROAD are based on an older version of EMFAC (EMFAC7F). The modeled benefits of RFGI and II used in the OFFROAD model are given in Table 4 below. The assumed benefits of RFGI are equivalent to those used in EMFAC and are based on the results of the auto/oil studies performed in the early 1990s.

Because uncontrolled gasoline powered off-road engines were not required to certify, they are assumed to benefit from reformulated gasoline beyond the 1996 calendar year. Once the new emission standards are implemented, the benefits

of reformulated fuel are reflected in their lower overall emission rates. Recent certification data shows that engines are certifying either with reformulated fuels or indolene. Given the variety of certification options available to manufacturers, staff continues investigate the appropriateness of the assumption that new vehicles should receive no benefit from fuel reformulation.

Table 4
Current Gasoline Fuel Correction Factors in OFFROAD

Cal Year	Model Year	Summertime			Wintertime		
		HC	CO	NOx	HC	CO	NOx
Pre-92	All	1.000	1.000	1.000	1.000	1.000	1.000
1992-95	All	0.988	0.994	0.997	0.963	0.895	0.997
1996+	Pre-1996	0.921	0.848	1.025	0.921	0.848	1.025
	1996+	1.000	1.000	1.000	1.000	1.000	1.000
	MC/ATV/ Snowmobiles	0.921	0.848	1.025	0.921	0.848	1.025

Proposed Modifications

- The impact of RFGII in OFFROAD was carried over from previous versions and is currently inconsistent with EMFAC. The proposed revisions to the fuel correction factors are presented in Table 5.
- The impact of RFGIII has not yet been reflected in the OFFROAD model.
- The CO fuel correction factor for summertime and wintertime fuel was applied statewide. The months corresponding to the summer and winter fuel seasons vary geographically and are listed in Appendix A.
- Staff has recently incorporated evaporative emissions into the OFFROAD model. As with EMFAC, the emission rates will need to be adjusted to reflect the impact of ethanol in the fuel. These changes are described in a document entitled “Changes in Off-Road Emissions Inventory due to Ethanol in Fuel” located at: http://www.arb.ca.gov/msei/msei.htm.

Diesel Fuel

In the current version of the model, engines of less than 25 horsepower are assumed to certify using California fuel and therefore no benefit is assumed for 1995 and newer engines. All other engines are assumed to certify using federal fuel and therefore benefit from the lower aromatic content of California fuel.

The assumed benefits are divided along technology lines (mechanical vs. electronic fuel injection). In the OFFROAD model, this technology transition is

assumed to occur at different points in time according to horsepower group. For 25 to 50 horsepower engines this transition is assumed to occur in 1999, for 51 to 100 horsepower in 1998, 1997 for 101 to 175 horsepower, and 1996 for 176 to 750 horsepower engines. These years correspond to the implementation of initial emission control standards. The current fuel correction factors applied to diesel engines are listed in Table 6.

Table 5
Proposed Gasoline Fuel Correction Factors for OFFROAD

Cal Year	Hp Group	Model Year	Summertime			Wintertime		
			HC	CO	NOx	HC	CO	NOx
Pre-92	All	All	1.000	1.000	1.000	1.000	1.000	1.000
1992-95			0.988	0.994	1.000	0.988	0.895	0.997
1996+	<25, MC/ATV/ Snowmobile	Pre-1996	0.850	0.795	0.887	0.850	0.795	0.887
		1996+	1.000	1.000	1.000	1.000	1.000	1.000
	>25	Pre-1998	0.850	0.795	0.887	0.850	0.795	0.887
		1998+	1.000	1.000	1.000	1.000	1.000	1.000
	PWC/Outboard	Pre-2001	0.850	0.795	0.887	0.850	0.795	0.887
		2001+	1.000	1.000	1.000	1.000	1.000	1.000
	Sterndrive/ Inboard	Pre-2007	0.850	0.795	0.887	0.850	0.795	0.887
		2007+	1.000	1.000	1.000	1.000	1.000	1.000

Although external adjustments were made to the inventory to reflect the introduction of 15 ppmw sulfur, the fuel correction factors within the model have not been updated to reflect this change.

Proposed Modifications

- The 2003 model year production numbers suggest that 26% of off-road diesel engines certify using California diesel, 60% use federal off-road and 14% use federal on-road diesel fuel. Engines certified using federal on- and off-road diesel fuel receive NOx and PM benefit of 7% and 20% respectively, due to the lower aromatic content of California diesel fuel. Engines certified using federal off-road diesel fuel receive an additional 5% PM benefit due the lower sulfur content of California diesel fuel. These proposed benefits are based on the "Staff Review of the Emission Benefits of California's Diesel Fuel Program" attached as Appendix D of the staff report entitled "Proposed Amendments to the California Diesel Fuel Regulations – Initial Statement of Reasons" dated June 6, 2003.

- A 28% reduction in diesel hydrocarbon emissions will be assumed based on analysis conducted by the Coordinating Research Council in the VE-1 Project and by the U.S. EPA in their HDEWG test program.
- Starting in 2007, California will require the use of ultra low sulfur diesel fuel (ULSD -15 ppmw sulfur). An additional 4% PM benefit is assumed for all engines not certified on this fuel. Engines subject to Tier 4 emission standards are assumed to be certified on ULSD fuel.

Although these tests were limited to larger engines, staff recommends the use of these correction factors for all diesel-powered off-road engines and equipment due to the lack of engine size specific data. The proposed revisions to the fuel correction factors are presented in Table 7 below.

Table 6
Current OFFROAD Diesel Correction Factors

Area	Calendar Yrs	Hp Group	Model Yrs	NOx	PM
South Coast and Ventura	Pre-1985	All	All	1.0000	1.0000
	1985-1992	All	All	1.0000	0.9617
All	1993+	<25	Pre-1995	0.9425	0.8012
			1995+	1.0000	1.0000
		25-50	Pre-1999	0.9425	0.8012
			1999+	0.8749	0.8972
		51-100	Pre-1998	0.9425	0.8012
			1998+	0.8749	0.8972
		101-175	Pre-1997	0.9425	0.8012
			1997+	0.8749	0.8972
		176+	Pre-1996	0.9425	0.8012
			1996+	0.8749	0.8972

Table 7
Proposed OFFROAD Diesel Fuel Correction Factors

Area	Hp Group	Calendar Yrs	Model Yrs	NOx	PM
South Coast and Ventura	All	Pre-1985	All	1.000	1.000
	All	1985-1993	All	1.000	0.950
All	All	Pre-1994	All	1.000	1.000
	<25	1994-2006	Pre-1995	0.930	0.750
			1995+	0.950	0.822
		2007+	Pre-1995	0.930	0.720
			1995-2010	0.948	0.800
	25-50	1994-2006	Pre-1999	0.930	0.750
			1999-2010	0.948	0.822
		2007+	Pre-1999	0.930	0.720
			1999-2010	0.948	0.800
	51-100	1994-2006	Pre-1998	0.930	0.750
			1998-2010	0.948	0.822
		2007+	Pre-1998	0.930	0.720
			1998-2010	0.948	0.800
	101-175	1994-2006	Pre-1997	0.930	0.750
			1997-2010	0.948	0.822
		2007+	Pre-1997	0.930	0.720
			1997-2010	0.948	0.800
	176+	1994-2006	Pre-1996	0.930	0.750
			1996-2010	0.948	0.822
		2007+	Pre-1996	0.930	0.720
			1996-2010	0.948	0.800
	All	2007+	2011+	.948	.852

Recommended Modeling Changes

In order to incorporate the update to the fuel correction factors, GETEMF.for and PRCOFF.for were modified. A majority of the coding changes affected GETEMF.for, which is the subroutine that calculates the emission factors for the year, engine type and horsepower category indicated. A minor change was made to PRCOFF.for to accommodate the geographically specific CO fuel correction factor. PRCOFF.for is the main processing routine for the OFFROAD program.

Appendix A

Summertime and Wintertime Fuel Dispensed by Month and Geographical Region

Air Basin	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GBV	Alpine	2	2	2	2	1	1	1	1	1	2	2	2
GBV	Inyo	2	2	2	2	1	1	1	1	1	2	2	2
GBV	Mono	2	2	2	2	1	1	1	1	1	2	2	2
LC	Lake	2	2	2	2	2	1	1	1	1	2	2	2
LT	El Dorado	2	2	2	2	1	1	1	1	1	1	2	2
LT	Placer	2	2	2	2	1	1	1	1	1	1	2	2
MC	Amador	2	2	2	2	1	1	1	1	1	1	2	2
MC	Calaveras	2	2	2	2	1	1	1	1	1	1	2	2
MC	El Dorado	2	2	2	2	1	1	1	1	1	1	2	2
MC	Mariposa	2	2	2	2	1	1	1	1	1	1	2	2
MC	Nevada	2	2	2	2	1	1	1	1	1	1	2	2
MC	Placer	2	2	2	2	1	1	1	1	1	1	2	2
MC	Plumas	2	2	2	2	1	1	1	1	1	1	2	2
MC	Sierra	2	2	2	2	1	1	1	1	1	1	2	2
MC	Tuolumne	2	2	2	2	1	1	1	1	1	1	2	2
MD	Kern	2	2	2	1	1	1	1	1	1	1	2	2
MD	Los Angeles	2	2	2	1	1	1	1	1	1	1	2	2
MD	Riverside	2	2	2	1	1	1	1	1	1	1	2	2
MD	San Bernardino	2	2	2	1	1	1	1	1	1	1	2	2
NC	Del Norte	2	2	2	2	2	1	1	1	1	2	2	2
NC	Humboldt	2	2	2	2	2	1	1	1	1	2	2	2
NC	Mendocino	2	2	2	2	2	1	1	1	1	2	2	2
NC	Sonoma	2	2	2	2	2	1	1	1	1	2	2	2
NC	Trinity	2	2	2	2	2	1	1	1	1	2	2	2
NCC	Monterey	2	2	2	2	2	1	1	1	1	1	2	2
NCC	San Benito	2	2	2	2	2	1	1	1	1	1	2	2
NCC	Santa Cruz	2	2	2	2	2	1	1	1	1	1	2	2
NEP	Lassen	2	2	2	2	2	1	1	1	1	2	2	2
NEP	Modoc	2	2	2	2	2	1	1	1	1	2	2	2
NEP	Siskiyou	2	2	2	2	2	1	1	1	1	2	2	2
SC	Los Angeles	2	2	2	1	1	1	1	1	1	1	2	2
SC	Orange	2	2	2	1	1	1	1	1	1	1	2	2
SC	Riverside	2	2	2	1	1	1	1	1	1	1	2	2
SC	San Bernardino	2	2	2	1	1	1	1	1	1	1	2	2
SCC	San Luis Obispo	2	2	2	2	2	1	1	1	1	1	2	2
SCC	Santa Barbara	2	2	2	2	2	1	1	1	1	1	2	2
SCC	Ventura	2	2	2	1	1	1	1	1	1	1	2	2
SD	San Diego	2	2	2	1	1	1	1	1	1	1	2	2

Appendix A

Summertime and Wintertime Fuel Dispensed by Month and Geographical Region

SF	Alameda	2	2	2	2	1	1	1	1	1	1	2	2
SF	Contra Costa	2	2	2	2	1	1	1	1	1	1	2	2
SF	Marin	2	2	2	2	1	1	1	1	1	1	2	2
SF	Napa	2	2	2	2	1	1	1	1	1	1	2	2
SF	San Francisco	2	2	2	2	1	1	1	1	1	1	2	2
SF	San Mateo	2	2	2	2	1	1	1	1	1	1	2	2
SF	Santa Clara	2	2	2	2	1	1	1	1	1	1	2	2
SF	Solano	2	2	2	2	1	1	1	1	1	1	2	2
SF	Sonoma	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Fresno	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Kern	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Kings	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Madera	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Merced	2	2	2	2	1	1	1	1	1	1	2	2
SJV	San Joaquin	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Stanislaus	2	2	2	2	1	1	1	1	1	1	2	2
SJV	Tulare	2	2	2	2	1	1	1	1	1	1	2	2
SS	Imperial	2	2	2	1	1	1	1	1	1	1	2	2
SS	Riverside	2	2	2	1	1	1	1	1	1	1	2	2
SV	Butte	2	2	2	2	1	1	1	1	1	1	2	2
SV	Colusa	2	2	2	2	1	1	1	1	1	1	2	2
SV	Glenn	2	2	2	2	1	1	1	1	1	1	2	2
SV	Placer	2	2	2	2	1	1	1	1	1	1	2	2
SV	Sacramento	2	2	2	2	1	1	1	1	1	1	2	2
SV	Shasta	2	2	2	2	1	1	1	1	1	1	2	2
SV	Solano	2	2	2	2	1	1	1	1	1	1	2	2
SV	Sutter	2	2	2	2	1	1	1	1	1	1	2	2
SV	Tehama	2	2	2	2	1	1	1	1	1	1	2	2
SV	Yolo	2	2	2	2	1	1	1	1	1	1	2	2
SV	Yuba	2	2	2	2	1	1	1	1	1	1	2	2

Note: 1 = summer 2=winter