

Methods to Find the Cost-Effectiveness of Funding Air Quality Projects

*For Evaluating
Motor Vehicle Registration Fee Projects
and
Congestion Mitigation and
Air Quality Improvement (CMAQ) Projects*

Emission Factor Tables

May 2013

California Air Resources Board

This page intentionally left blank.

Table of Contents

Preface	1
Table 1 Diesel Bus Emission Factors.....	3
Table 2 Emission Factors for Cleaner Vehicles For Light-Duty and Medium-Duty Vehicles (Chassis Certified) Based on LEV II Exhaust Emission Standards.....	5
Table 3/3A Average Auto Emission Factors.....	7
Table 4 Emission Factors by Speed.....	9
Tables 5A through 5F Medium Heavy and Heavy Duty Trucks and Buses.....	11
5A Medium heavy and heavy heavy duty engines in grams per gallon.....	12
5B Medium heavy and heavy heavy duty alternative fueled engines in grams per gallon.....	13
5C Medium heavy duty diesel vehicles in grams per mile.....	14
5D Heavy heavy duty diesel vehicles in grams per mile	14
5E Diesel urban buses in grams per bhp-hr, grams per mile and grams per gallon.....	15
5F Natural gas urban buses in grams per bhp-hr, grams per mile and grams per gallon.....	15
Table 6 Off-Road Emission Factors for Cleaner Vehicle Projects (2012 – 2013).....	16
Table 7 Medium-Duty Vehicle Emission Factors for Vanpool and Shuttle Evaluations (Model Years 1995 - 2003)	19

This page intentionally left blank

Preface

This document contains updated emission factors to be used with the “Methods to Find the Cost-Effectiveness of Funding Air Quality Projects” document published in May 2005 (the Methods document). The emission factors below are the latest available as of the publication date, and in most cases are based on the Air Resources Board’s on-road emission factor model EMFAC, or in the case of off-road emissions data, the Board’s emission rate model OFFROAD.

Please note that even though the emission factors have changed since the original publication of the Methods document, the actual methods to apply the rates in that document remain valid.

Summary of Changes by Table.

- | | |
|------------|---|
| Table 1 | Updated emission rates to EMFAC 2011. Added 2013 model year and calendar year. Updated re-entrained dust rates to reflect latest U.S. EPA and ARB methodologies.

For bus emission factors through model year 2013, use Table 1 . For emission rates for buses newer than 2013, use emission rates from Table 5E |
| Table 2 | Reworded table headings to make it clearer for the user where to find the appropriate rates for existing and replacement technologies. Emission rates are now expressed in <u>milligrams</u> per mile. Modified formatting to improve readability. PM2.5 rates updated to reflect statewide averages and most recent methodology. |
| Table 3/3A | Updated emission rates to EMFAC 2011. Added 2013 to project life column headings. Updated re-entrained dust rates to reflect latest U.S. EPA and ARB methodologies. |
| Table 4 | Updated emission rates to reflect EMFAC 2011. |
| Table 5 | The original Table 5 has been replaced by Tables 5A through 5F. These tables provide the user with more detail and the ability to choose the rate format to better match the data available to the analyst for completing the calculation. Sources for the emission rates are either engine certification data or EMFAC 2011 (see notes in the individual tables). Yellow border added to help the user navigate the document without getting lost. |
| Table 6 | Updated rates from ARB OFFROAD model. |

Table 7 The rates in the original table were too old (1995-2003) to be useful for current cost effectiveness analysis. Emission rates for 2004 and newer vehicles should be taken from Tables 2 or 5A-5F, as appropriate. If emission rates for older vehicles are needed contact your local air pollution or air quality management district for guidance.

Other Changes

With this revision of emission rates we are no longer adding the rate tables to the Access database tool. This change will enable a faster update process when new rates are released.

There will now be only one version of the database tool on the ARB website available for download. Previously, a version of the Access database tool was created for the South Coast Air Quality Management District which calculated PM2.5, while another version was used in the remaining areas of the state using PM10. With the revisions to the CMAQ program emphasizing PM2.5 contained in MAP-21, there is no longer a need to maintain a separate version of the Access database tool for PM10. .

Table 1 Diesel Bus Emission Factors
(Through model year 2013)

Pollutant	Calendar Year	Model Year	Emission Factor (g/mi)	
			Average	45 MPH
ROG	2013	Entire Fleet	0.64	0.45
	2013	1973-83	0.84	1.30
	2013	1984-90	0.83	0.75
	2013	1991-93	0.82	0.59
	2013	1994-95	0.81	0.69
	2013	1996-2001	0.80	0.46
	2013	2002	0.80	0.43
	2013	2003 - 2006	0.15	0.07
	2013	2007 - 2009	0.03	0.01
	2013	2010 - 2013	0.03	0.01
CO	2013	Entire Fleet	2.95	3.43
	2013	1973-83	6.50	11.78
	2013	1984-90	6.05	7.18
	2013	1991-93	3.47	4.98
	2013	1994-95	2.32	7.24
	2013	1996-2001	1.82	1.76
	2013	2002	1.82	0.92
	2013	2003 - 2006	1.25	0.54
	2013	2007 - 2009	1.07	0.41
	2013	2010 - 2013	1.00	0.33
NOx	2013	Entire Fleet	16.40	12.09
	2013	1973-83	29.79	23.37
	2013	1984-90	27.23	22.06
	2013	1991-93	16.44	14.21
	2013	1994-95	19.25	16.14
	2013	1996-2001	17.61	13.87
	2013	2002	13.15	10.36
	2013	2003 - 2006	3.55	2.28
	2013	2007 - 2009	0.63	0.44
	2013	2010 - 2013	0.59	0.35
PM2.5 - Exhaust	2013	Entire Fleet	0.25	0.12
	2013	1973-83	0.38	0.19
	2013	1984-90	0.37	0.19
	2013	1991-93	0.34	0.18
	2013	1994-95	0.42	0.19
	2013	1996-2001	0.29	0.15
	2013	2002	0.17	0.09
	2013	2003 - 2006	0.03	0.01
	2013	2007 - 2009	0.04	0.01
	2013	2010 - 2013	0.03	0.01
PM2.5 - Tire Wear	All Years	All Years	0.002	Not Speed Dependent
PM2.5 - Brake Wear	All Years	All Years	0.361	Not Speed Dependent
PM2.5 - Road Dust*	All Years	All Years	0.022	Not Speed Dependent

See notes next page.

Notes for Table 1 - Diesel Bus Emission Factors:

* Statewide average annual PM2.5 emission factor, weighted by VMT per road category.

Source: EMFAC2011-LDV, average annual emissions, statewide urban diesel bus fleet, running exhaust emissions only, humidity 50%, temperature 75 degrees F.

Average factors for ROG (MY 2007) and PM2.5 (MY 2007) exhaust were estimated using proportional analysis relative to 45 mph factors because exhaust emissions were too small to show up in EMFAC model output file

The PM2.5 road dust emission factor was calculated using US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), 2008 VMT from EMFAC2011-SG and ARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013).

April 2013

**Table 2 Emission Factors for Cleaner Vehicles
For Light-Duty and Medium-Duty Trucks (Chassis Certified)
Based on LEV II Exhaust Emission Standards**

Baseline (Older) Technology Vehicles:

2003 Trucks, (60% LEV, 40% ULEV) NOTE: Emission factor units are milligrams/mile					
Weight (lbs.) ¹	ROG	NOx	PM2.5 ²		CO
			Exhaust	Total ³	
Up to 8500	205	775	9	49	6,342
8501-10,000	242	875	86	144	7,017
10,001-14,000	316	1292	86	150	8,925

Replacement (Newer) Technology Cleaner Vehicles:

Ultra Low Emission Vehicles 120,000 mile durability. NOTE: Emission factor units are milligrams/mile					
Weight (lbs.)	ROG	NOx	PM2.5		CO
			Exhaust	Total	
Up to 8500	55	70	9	49	2,100
8501-10,000	143	200	54	112	6,400
10,001-14,000	167	400	54	117	7,300
Super-ultra-low-emission vehicle (SULEV) factors in milligrams per mile with 120,000 mile durability NOTE: Emission factor units are milligrams/mile					
Weight (lbs.)	ROG	NOx	PM2.5		CO
			Exhaust	Total	
Up to 8500	10	20	9	49	1,000
8501-10,000	100	100	54	112	3,200
10,001-14,000	117	200	54	117	3,700
Zero-emission light-duty and medium-duty vehicle (ZEV) NOTE: Emission factor units are milligrams/mile					
Weight (lbs.)	ROG	NOx	PM2.5		CO
			Exhaust	Total	
All weights	0	0	0	40	0

See notes next page.

¹ Gross vehicle weights can be associated with passenger capacity as follows: 5751-8500, roughly 8 passengers; 8501-10,000, roughly 10-15 passengers; 10,001-14,000, roughly 20 passengers or more.

² PM2.5 factors are based on standards for diesel vehicles only. There is no applicable standard for gasoline vehicles; gasoline vehicles are known to emit significantly less PM.

³ Total PM2.5 factors include exhaust , brake wear , tire wear , and entrained road dust.

Notes for Table 2, Emission Factors for Cleaner Vehicles:

Sources:

Baseline is California Vehicle Exhaust Standards ("LEV I") for chassis certified vehicles for model year 2003. Factors assume emissions at 50,000 mile standard for the first 50,000 miles of the car's life (assumed to be 120,000 miles) and emission at the 120,000 mile standard for the last 70,000 miles of the car's life.

Cleaner Vehicle Emission Factors are from the California Vehicle Exhaust Standards for MYs after 2004 ("LEV II"). The PM_{2.5} factors have been adjusted from total PM by the fraction of the size distribution less than 2.5 μm . These were taken from EPA size distribution measurements tabulated in EPA's PART5 model. See the EMFAC 2000 Technical Support Document Table 4.12-5. The brake wear emission factors came from a review of recent non-asbestos brake emissions (Section 9 of EMFAC2011 Technical Documentation). The road dust portion of the PM_{2.5} emission factor is based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), 2008 VMT from EMFAC2011-SG, and ARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013).

Vehicle Trip reductions may have little if any effect on road dust emissions from high volume facilities thought to be in equilibrium, i.e., the dust is fully entrained due to the heavy traffic. The road dust PM factor, however, may be multiplied by the total VMT reductions as it has been scaled down to reflect emissions from lower-volume local and collector roads only.

April 2013

Table 3 Average Auto Emission Factors

(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks, and Motor Cycles)

Analysis Period or Project Life	1-5 Years (2011- 2015)	6-10 Years (2011- 2020)	11-15 Years (2011- 2025)	16-20 Years (2011- 2030)
ROG				
VMT (g/mile)	0.191	0.153	0.132	0.119
commute trip ends (g/trip end)	0.764	0.614	0.521	0.462
average trip ends (g/trip end)	0.584	0.470	0.399	0.353
NO_x				
VMT (g/mile)	0.217	0.172	0.146	0.130
commute trip ends (g/trip end)	0.303	0.233	0.189	0.162
average trip ends (g/trip end)	0.298	0.231	0.189	0.162
PM_{2.5}				
VMT (g/mile)	0.087	0.087	0.087	0.087
running exhaust only (g/mile)	0.002	0.002	0.002	0.002
tire and brake wear (g/mile)	0.018	0.018	0.018	0.018
road dust (g/mile)	0.022	0.022	0.022	0.022
commute trip ends (g/trip end)	0.006	0.004	0.004	0.004
average trip ends (g/trip end)	0.003	0.003	0.003	0.004
CO				
VMT (g/mile)	2.239	1.783	1.518	1.356
commute trip ends (g/trip end)	6.046	4.847	4.083	3.593
average trip ends (g/trip end)	4.248	3.396	2.853	2.504

Source: EMFAC2011-LDV, statewide average annual emissions
 EMFAC2011 RTS Output runs use 50% relative humidity and 75 degrees Fahrenheit temperature.
 PM2.5, road dust: statewide average annual PM2.5 emission factor, based on US EPA's Compilation of Air
 Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), 2008 VMT from EMFAC2011-SG, and ARB's
 Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013).

April 2013

Table 3A Average Auto Emission Factors

(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks, and Motor Cycles)

Analysis Period or Project Life	1 Year 2011	1 Year 2012	1 Year 2013
ROG			
VMT (g/mile)	0.237	0.211	0.188
commute trip ends (g/trip end)	0.936	0.840	0.755
average trip ends (g/trip end)	0.713	0.642	0.578
NO_x			
VMT (g/mile)	0.272	0.240	0.213
commute trip ends (g/trip end)	0.381	0.339	0.299
average trip ends (g/trip end)	0.371	0.331	0.295
PM_{2.5}			
VMT (g/mile)	0.088	0.087	0.087
running exhaust only (g/mile)	0.003	0.003	0.002
tire and brake wear (g/mile)	0.018	0.018	0.018
road dust (g/mile)	0.022	0.022	0.022
commute trip ends (g/trip end)	0.007	0.006	0.006
average trip ends (g/trip end)	0.004	0.003	0.003
CO			
VMT (g/mile)	2.784	2.477	2.210
commute trip ends (g/trip end)	7.401	6.657	5.978
average trip ends (g/trip end)	5.215	4.679	4.198

Source: EMFAC2011-LDV, statewide average annual emissions
 EMFAC2011 RTS Output runs use 50% relative humidity and 75 degrees Fahrenheit temperature.
 PM2.5, road dust: statewide average annual PM2.5 emission factor, based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), 2008 VMT from EMFAC2011-SG, and ARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013).

April 2013

Table 4 Emission Factors by Speed

Project Life 1-5 years (2011-2015)

<i>Speed</i>					<i>Grams per Mile</i>				
<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>	<i>Speed</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>
<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>	<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>
5	0.42	4.84	0.53	0.015	35	0.08	2.26	0.32	0.003
6	0.39	4.67	0.51	0.014	36	0.08	2.24	0.32	0.003
7	0.36	4.51	0.50	0.013	37	0.08	2.21	0.32	0.003
8	0.34	4.34	0.48	0.012	38	0.08	2.18	0.32	0.003
9	0.31	4.17	0.47	0.011	39	0.08	2.16	0.32	0.003
10	0.28	4.00	0.45	0.010	40	0.07	2.13	0.32	0.003
11	0.26	3.89	0.44	0.010	41	0.07	2.12	0.32	0.003
12	0.24	3.77	0.43	0.009	42	0.07	2.10	0.32	0.003
13	0.23	3.65	0.42	0.009	43	0.07	2.09	0.32	0.003
14	0.21	3.53	0.41	0.008	44	0.07	2.07	0.32	0.003
15	0.19	3.42	0.40	0.007	45	0.07	2.05	0.32	0.003
16	0.18	3.33	0.39	0.007	46	0.07	2.05	0.33	0.003
17	0.17	3.25	0.39	0.007	47	0.07	2.04	0.33	0.003
18	0.16	3.16	0.38	0.006	48	0.07	2.04	0.33	0.003
19	0.15	3.08	0.37	0.006	49	0.07	2.03	0.34	0.003
20	0.14	2.99	0.36	0.006	50	0.07	2.02	0.34	0.003
21	0.14	2.93	0.36	0.006	51	0.07	2.03	0.35	0.003
22	0.13	2.87	0.35	0.005	52	0.07	2.04	0.35	0.003
23	0.13	2.80	0.35	0.005	53	0.07	2.04	0.36	0.003
24	0.12	2.74	0.34	0.005	54	0.08	2.05	0.36	0.003
25	0.11	2.68	0.34	0.004	55	0.08	2.06	0.37	0.003
26	0.11	2.63	0.34	0.004	56	0.08	2.08	0.37	0.003
27	0.10	2.58	0.33	0.004	57	0.08	2.10	0.38	0.003
28	0.10	2.53	0.33	0.004	58	0.08	2.13	0.39	0.003
29	0.10	2.49	0.33	0.004	59	0.08	2.15	0.40	0.003
30	0.09	2.44	0.32	0.004	60	0.09	2.17	0.41	0.003
31	0.09	2.40	0.32	0.004	61	0.09	2.22	0.42	0.003
32	0.09	2.37	0.32	0.003	62	0.09	2.27	0.43	0.003
33	0.09	2.33	0.32	0.003	63	0.09	2.31	0.44	0.003
34	0.08	2.30	0.32	0.003	64	0.10	2.36	0.45	0.003
					65	0.10	2.41	0.46	0.003

Source: EMFAC2011LDV, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 degrees F.
 ROG includes running exhaust and running evaporative emissions. PM2.5 Ex includes running exhaust emissions only.

April 2013

Table 4 Emission Factors by Speed (Continued)

Project Life 6-10 years (2011-2020)

<i>Speed</i>					<i>Grams per Mile</i>					<i>Speed</i>				
<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>	<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>	<i>(mph)</i>	<i>ROG</i>	<i>CO</i>	<i>NOx</i>	<i>PM2.5 Ex</i>
5	0.34	3.88	0.44	0.014	35	0.06	1.86	0.26	0.003	6	0.31	3.75	0.43	0.013
6	0.31	3.75	0.43	0.013	36	0.06	1.83	0.26	0.003	7	0.29	3.62	0.42	0.012
7	0.29	3.62	0.42	0.012	37	0.06	1.81	0.26	0.003	8	0.27	3.50	0.40	0.011
8	0.27	3.50	0.40	0.011	38	0.06	1.79	0.26	0.003	9	0.24	3.37	0.39	0.010
9	0.24	3.37	0.39	0.010	39	0.06	1.77	0.26	0.002	10	0.22	3.24	0.38	0.009
10	0.22	3.24	0.38	0.009	40	0.06	1.75	0.26	0.002	11	0.21	3.15	0.37	0.009
11	0.21	3.15	0.37	0.009	41	0.06	1.73	0.26	0.002	12	0.19	3.05	0.36	0.008
12	0.19	3.05	0.36	0.008	42	0.06	1.72	0.27	0.002	13	0.18	2.96	0.35	0.008
13	0.18	2.96	0.35	0.008	43	0.06	1.71	0.27	0.002	14	0.17	2.87	0.34	0.007
14	0.17	2.87	0.34	0.007	44	0.06	1.69	0.27	0.002	15	0.15	2.78	0.33	0.007
15	0.15	2.78	0.33	0.007	45	0.06	1.68	0.27	0.002	16	0.15	2.71	0.33	0.006
16	0.15	2.71	0.33	0.006	46	0.06	1.67	0.27	0.002	17	0.14	2.65	0.32	0.006
17	0.14	2.65	0.32	0.006	47	0.06	1.67	0.27	0.002	18	0.13	2.58	0.31	0.006
18	0.13	2.58	0.31	0.006	48	0.06	1.66	0.28	0.002	19	0.12	2.51	0.31	0.005
19	0.12	2.51	0.31	0.005	49	0.06	1.65	0.28	0.002	20	0.11	2.45	0.30	0.005
20	0.11	2.45	0.30	0.005	50	0.06	1.65	0.28	0.002	21	0.11	2.40	0.30	0.005
21	0.11	2.40	0.30	0.005	51	0.06	1.65	0.29	0.002	22	0.10	2.34	0.29	0.005
22	0.10	2.34	0.29	0.005	52	0.06	1.65	0.29	0.002	23	0.10	2.29	0.29	0.004
23	0.10	2.29	0.29	0.004	53	0.06	1.66	0.30	0.002	24	0.09	2.24	0.29	0.004
24	0.09	2.24	0.29	0.004	54	0.06	1.66	0.30	0.002	25	0.09	2.19	0.28	0.004
25	0.09	2.19	0.28	0.004	55	0.06	1.66	0.30	0.002	26	0.09	2.16	0.28	0.004
26	0.09	2.16	0.28	0.004	56	0.06	1.68	0.31	0.002	27	0.08	2.12	0.28	0.004
27	0.08	2.12	0.28	0.004	57	0.06	1.69	0.32	0.002	28	0.08	2.08	0.27	0.004
28	0.08	2.08	0.27	0.004	58	0.07	1.71	0.32	0.002	29	0.08	2.04	0.27	0.003
29	0.08	2.04	0.27	0.003	59	0.07	1.73	0.33	0.002	30	0.07	2.00	0.27	0.003
30	0.07	2.00	0.27	0.003	60	0.07	1.74	0.34	0.002	31	0.07	1.97	0.27	0.003
31	0.07	1.97	0.27	0.003	61	0.07	1.78	0.35	0.002	32	0.07	1.94	0.27	0.003
32	0.07	1.94	0.27	0.003	62	0.07	1.81	0.36	0.003	33	0.07	1.91	0.27	0.003
33	0.07	1.91	0.27	0.003	63	0.08	1.85	0.37	0.003	34	0.07	1.88	0.26	0.003
34	0.07	1.88	0.26	0.003	64	0.08	1.88	0.38	0.003					
					65	0.08	1.92	0.39	0.003					

Source: EMFAC2011LDV, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 degrees F.
 ROG includes running exhaust and running evaporative emissions. PM2.5 Ex includes running exhaust emissions only.

April 2013

Tables 5A through 5F. Emission Rates for Medium-Heavy and Heavy-Heavy Duty Trucks and Buses.

The original Table 5 has been replaced by Tables 5A through 5F. These tables provide the user with more detail and the ability to choose the rate format (e.g. grams per mile, grams per gallon of fuel or grams per brake-horsepower-hour) to better match the data available to the analyst for completing the calculation. Sources for the emission rates are either engine certification data or EMFAC 2011 (see notes in the individual tables). Rates are provided for diesel or natural gas fuel.

To use these tables, find the emission rate of the model year (or certification rate, if known) of the engine that is to be replaced expressed in the units desired. Second, find the emission rate of the new engine based on its model year or certification rate (if known) expressed in the units desired (usually the same units as for the existing engine). Calculate the cost effectiveness using the rates and appropriate method as described in the Methods document.

Table 5-A
 Diesel Engines
 Medium Heavy-Duty and Heavy Heavy-Duty
 Converted Emission Standards for Fuel Based Usage Calculations

Model Year	EO Certification Standards g/bhp-hr		NOx	ROG ^(a)	PM2.5
			g/gal ^{(b)(c)(d)}		
pre-1990	6.0 NOx	0.6 PM10	103.23	5.33	7.353
1990	6.0 NOx	0.6 PM10	103.23	5.33	3.064
1991 - 1993	5.0 NOx	0.25 PM10	86.03	4.44	1.225
1994 - 1997	5.0 NOx	0.1 PM10	86.03	4.44	1.225
1998 - 2001	4.0 NOx	0.1 PM10	68.82	3.55	1.225
2002 - 2006	2.5 NOx + NMHC	0.1 PM10	40.86	2.11	0.136
2007-2009	1.8 NOx + NMHC	0.01 PM10	29.42	1.52	0.136
2007-2009	1.5 NOx + NMHC	0.01 PM10	24.52	1.27	0.136
2007-2009	1.2 NOx + NMHC	0.01 PM10	19.61	1.01	0.136
2007-2009	0.84 NOx + NMHC	0.01 PM10	13.73	0.71	0.136
2007-2009	0.5 NOx	0.01 PM10	8.60	0.44	0.136
2010 +	0.2 NOx	0.01 PM10	3.44	0.18	0.136

a - $ROG = HC * 1.26639$.

b - Fuel based emissions factors were calculated using fuel consumption rate factors from Table D-24 of the Moyer guidelines

c - Fuel based factors are for engines less than 750 horsepower only.

d - Emission standards were converted where appropriate, using the NMHC and NOx fraction default

values and the ultra low-sulfur diesel fuel correction factors listed in Tables D-25 and D-26, respectively.

Table 5-B

**Alternative Fuel Engines
Medium Heavy-Duty and Heavy Heavy-Duty
Converted Emission Standards for Fuel Based Usage Calculations**

Model Year	EO Certification Standards g/bhp-hr		NOx	ROG ^(a)	PM2.5
			g/gal ^{(b)(c)(d)}		
pre-1990	6.0 NOx	0.6 PM10	111.00	35.14	10.212
1990	6.0 NOx	0.6 PM10	111.00	35.14	4.255
1991 - 1993	5.0 NOx	0.25 PM10	92.50	29.29	1.702
1994 - 1997	5.0 NOx	0.1 PM10	92.50	29.29	1.702
1998 - 2001	4.0 NOx	0.1 PM10	74.00	23.43	1.702
2002 - 2006	2.5 NOx + NMHC	0.1 PM10	37.00	11.71	0.170
2007-2009	1.8 NOx + NMHC	0.01 PM10	26.64	8.43	0.170
2007-2009	1.5 NOx + NMHC	0.01 PM10	22.20	7.03	0.170
2007-2009	1.2 NOx + NMHC	0.01 PM10	17.76	5.62	0.170
2007-2009	0.84 NOx + NMHC	0.01 PM10	12.43	3.94	0.170
2007-2009	0.5 NOx	0.01 PM10	9.25	2.93	0.170
2010 +	0.2 NOx	0.01 PM10	3.70	1.17	0.170

a - $ROG = HC * 1.26639$.

b - Fuel based emissions factors were calculated using fuel consumption rate factors from Table D-24 of the Moyer guidelines.

c - Fuel based factors are for engines less than 750 horsepower only.

d - Emission standards were converted where appropriate, using the NMHC and NOx fraction default

values listed in Table D-25.

Table 5-C
Medium Heavy-Duty Vehicles
Emission Factors for Mileage Based Calculations (g/ mile)^(a)

Model Year	Diesel ^(b)		
	NOx	ROG ^(c)	PM2.5
Pre-1987	14.52	0.75	0.64
1987-1990	14.31	0.59	0.69
1991-1993	10.70	0.26	0.38
1994-1997	10.51	0.20	0.21
1998-2002	10.33	0.20	0.23
2003-2006	6.84	0.13	0.14
2007-2009	4.01	0.11	0.02
2007-2009 (0.5 g/bhp-hr NOx or Cleaner) ^(d)	1.73 ^(d)	0.10 ^(d)	0.02 ^(d)
2010+	0.74	0.09	0.02

Table 5-D
Heavy Heavy-Duty Vehicles
Emission Factors for Mileage Based Calculations (g/ mile)^(a)

Model Year	Diesel ^(b)		
	NOx	ROG ^(c)	PM2.5
Pre-1987	21.37	1.09	1.15
1987-1990	21.07	0.86	1.25
1991-1993	18.24	0.56	0.52
1994-1997	17.92	0.42	0.34
1998-2002	89	0.43	0.37
2003-2006	11.64	0.27	0.23
2007-2009	6.62	0.23	0.03
2007-2009 (0.5 g/bhp-hr NOx or Cleaner)	2.88 ^(d)	0.20 ^(d)	0.03 ^(d)
2010+	1.27	0.19	0.03

a - EMFAC2011 Zero-Mile Based Emission Factors.

b - Emission factors incorporate the ultra low-sulfur diesel fuel correction factors listed in Table D-26 of the Moyer guidelines.

c - $ROG = HC * 1.26639$.

d - These values are interpolated between 1.2 g/bhp-hr NOx standard for 2007-2009 model years and 0.2 g/bhp-hr NOx standard for 2010+ model years.

**Table 5-E
Diesel Urban Buses
Converted Emission Standards**

EO Certification Standards ^(f) g/bhp-hr		NOx	ROG ^(a)	PM2.5	NOx	ROG ^(a)	PM2.5
		g/mile ^(b)			g/gal ^{(c)(d)(e)}		
6.0 NOx	0.6 PM10	22.32	1.15	1.59	103.23	5.33	7.35
5.0 NOx	0.1 PM10	18.60	0.96	0.26	86.03	4.44	1.23
5.0 NOx	0.07 PM10	18.60	0.96	0.19	86.03	4.44	0.86
4.0 NOx	0.05 PM10	14.88	0.77	0.13	68.82	3.55	0.61
2.5 NOx + NMHC	0.05 PM10	8.84	0.46	0.13	40.86	2.11	0.61
1.20 NOx	0.01 PM10	4.46	0.23	0.03	20.65	1.07	0.14
0.20 NOx	0.01 PM10	0.74	0.04	0.03	3.44	0.18	0.14

a - $ROG = HC * 1.26639$.

b - Mileage based emissions factors were calculated using conversion factors from Table D-28 of the Moyer guidelines.

c - Fuel based emissions factors were calculated using fuel consumption rate factors from Table D-24 of the Moyer guidelines.

d - Fuel based factors are for engines less than 750 horsepower only.

e - Emission standards were converted where appropriate using the NMHC and NOx fraction default values listed in Table D-25 of the Moyer guidelines.

f - No diesel buses have been certified to the 0.5 g/bhp/hr for the 2004-2006 model year emission standard.

**Table 5-F
Natural Gas Urban Buses
Converted Emission Standards**

EO Certification Standards g/bhp-hr		NOx	ROG ^(a)	PM2.5	NOx	ROG ^(a)	PM2.5
		g/mile ^(b)			g/gal ^{(c)(d)(e)}		
5.0 NOx	0.10 PM10	20.00	6.33	0.37	92.50	29.29	1.70
5.0 NOx	0.07 PM10	20.00	6.33	0.26	92.50	29.29	1.19
4.0 NOx	0.05 PM10	16.00	5.07	0.18	74.00	23.43	0.85
2.5 NOx + NMHC	0.05 PM10	8.00	2.53	0.18	37.00	11.71	0.85
1.8 NOx + NMHC ^{(f)(g)}	0.02 PM10	5.76	1.82	0.07	26.64	8.43	0.34
1.2 NOx	0.01 PM10	4.80	1.52	0.04	22.20	7.03	0.17
0.2 NOx	0.01 PM10	0.80	0.25	0.04	3.70	1.17	0.17

a - $ROG = HC * 1.26639$.

b - Mileage based emissions factors were calculated using conversion factors from Table D-28 of the Moyer guidelines.

c - Fuel based emissions factors were calculated using fuel consumption rates from Table D-24 of the Moyer guidelines..

d - Fuel based factors are for engines less than 750 horsepower only.

e - Emission standards were converted where appropriate, using the NMHC and NOx fraction default values listed in Table D-25 of the Moyer guidelines.

f - A majority of the natural gas urban buses have been certified to the optional standards. Therefore, these values are based on the optional standards.

g - Many natural gas urban buses have been certified to optional standards below this level.

**Table 6 Off-Road Emission Factors
for Cleaner Vehicle Projects**

Find the horsepower and model year for the engine that best describes the engine being replaced to determine the “before project” baseline emission factors. Find the horsepower and model year for the newer engine. These factors represent the “after project” cleaner engine emission factors.

Grams per brake-horsepower-hour					
Horsepower	Model Year	HC	CO	NOx	PM2.5
26 - 50	1987 or older	1.32	5.00	6.51	0.50
26 - 50	1988 - 1998	1.30	5.00	6.42	0.50
26 - 50	1999 - 2003	1.04	4.10	5.26	0.44
26 - 50	2004	0.46	3.27	4.83	0.32
26 - 50	2005	0.27	3.00	4.69	0.28
26 - 50	2006 - 2007	0.17	2.86	4.63	0.26
26 - 50	2008 - 2010	0.07	2.72	4.55	0.12
26 - 50	2011 -2012	0.07	2.72	4.55	0.13
26 - 50	2013 and newer	0.07	2.72	2.75	0.01
51 - 120	1987 or older	1.04	4.80	12.09	0.56
51 - 120	1988 - 1997	0.71	3.49	8.14	0.46
51 - 120	1998 -2003	0.71	3.49	6.54	0.51
51 - 120	2004	0.33	3.23	5.35	0.29
51 - 120	2005	0.20	3.14	4.95	0.21
51 - 120	2006 - 2007	0.14	3.09	4.75	0.18
51 - 120	2008 -2011	0.07	3.05	2.74	0.16
51 - 120	2012 - 2014	0.06	3.05	2.40	0.05
51 - 120	2015 and newer	0.05	3.05	1.33	0.01
121 - 175	1969 and older	0.95	4.40	13.02	0.51
121 - 175	1970 - 1971	0.79	4.40	12.09	0.44
121 - 175	1972 - 1979	0.72	4.40	11.16	0.36
121 - 175	1980 - 1984	0.68	4.30	10.23	0.36
121 - 175	1985 - 1987	0.63	4.20	10.23	0.36
121 - 175	1988 - 1996	0.49	2.70	7.60	0.25
121 - 175	1997 - 2002	0.49	2.70	6.54	0.28
121 - 175	2003	0.24	2.70	4.99	0.18
121 - 175	2004	0.16	2.70	4.47	0.14
121 - 175	2005 - 2006	0.12	2.70	4.21	0.12
121 - 175	2007 - 2010	0.07	2.70	2.32	0.10
121 - 175	2011	0.07	2.70	2.32	0.11
121 - 175	2012 - 2014	0.06	2.70	2.15	0.01
121 - 175	2015 and newer	0.04	2.70	0.26	0.01

Table 6 (cont.)

Grams per brake-horsepower-hour					
Horsepower	Model Year	HC	CO	NOx	PM2.5
176 - 250	1969 and older	0.95	4.40	13.02	0.51
176 - 250	1970 - 1971	0.79	4.40	12.09	0.44
176 - 250	1972 - 1979	0.72	4.40	11.16	0.36
176 - 250	1980 - 1984	0.68	4.30	10.23	0.36
176 - 250	1985 - 1987	0.63	4.20	10.23	0.36
176 - 250	1988 - 1995	0.49	2.70	7.60	0.25
176 - 250	1996 - 2002	0.23	0.92	5.93	0.11
176 - 250	2003	0.14	0.92	4.74	0.09
176 - 250	2004	0.10	0.92	4.34	0.08
176 - 250	2005- -2006	0.09	0.92	4.15	0.08
176 - 250	2007 - 2010	0.07	0.92	2.32	0.08
176 - 250	2011 - 2013	0.05	0.92	1.29	0.01
176 - 250	2014 and newer	0.04	0.92	0.26	0.01
251 - 500	1969 and older	0.91	4.20	13.02	0.49
251 - 500	1970 - 1971	0.76	4.20	12.09	0.42
251 - 500	1972 - 1979	0.68	4.20	11.16	0.35
251 - 500	1980 - 1984	0.65	4.20	10.23	0.35
251 - 500	1985 - 1987	0.60	4.10	10.23	0.35
251 - 500	1988 - 1995	0.49	2.70	7.60	0.25
251 - 500	1996 - 2000	0.23	0.92	5.93	0.11
251 - 500	2001	0.14	0.92	4.69	0.09
251 - 500	2002	0.10	0.92	4.28	0.08
251 - 500	2003 - 2004	0.09	0.92	4.07	0.08
251 - 500	2005	0.07	0.92	3.79	0.08
251 - 500	2006 - 2010	0.07	0.92	2.32	0.08
251 - 500	2011 - 2013	0.05	0.92	1.29	0.01
251 - 500	2014 and newer	0.04	0.92	0.26	0.01
501 - 750	1969 and older	0.91	4.20	13.02	0.49
501 - 750	1970 - 1971	0.76	4.20	12.09	0.42
501 - 750	1972 - 1979	0.68	4.20	11.16	0.35
501 - 750	1980 - 1984	0.65	4.20	10.23	0.35
501 - 750	1985 - 1987	0.60	4.10	10.23	0.35
501 - 750	1988 - 1995	0.49	2.70	7.60	0.25
501 - 750	1996 - 2001	0.23	0.92	5.93	0.11
501 - 750	2002	0.14	0.92	4.69	0.09
501 - 750	2003	0.10	0.92	4.28	0.08
501 - 750	2004 - 2005	0.09	0.92	4.07	0.08

Table 6 (cont.)

Grams per brake-horsepower-hour

Horsepower	Model Year	HC	CO	NOx	PM2.5
501 - 750	2006 - 2010	0.07	0.92	2.32	0.08
501 - 750	2011 - 2013	0.05	0.92	1.29	0.01
501 - 750	2014 and newer	0.04	0.92	0.26	0.01

751 - 1000	1969 and older	0.91	4.20	13.02	0.49
751 - 1000	1970 - 1971	0.76	4.20	12.09	0.42
751 - 1000	1972 - 1979	0.68	4.20	11.16	0.35
751 - 1000	1980 - 1984	0.65	4.20	10.23	0.35
751 - 1000	1985 - 1987	0.60	4.10	10.23	0.35
751 - 1000	1988 - 1995	0.49	2.70	7.60	0.25
751 - 1000	1996 - 1999	0.49	2.70	7.75	0.28
751 - 1000	2000 - 2005	0.23	0.92	5.93	0.11
751 - 1000	2006	0.14	0.92	4.69	0.09
751 - 1000	2007	0.10	0.92	4.28	0.08
751 - 1000	2008 - 2009	0.09	0.92	4.07	0.08
751 - 1000	2010	0.07	0.92	3.87	0.08
751 - 1000	2011 - 2014	0.05	0.92	2.24	0.05
751 - 1000	2015 and newer	0.04	0.92	2.24	0.02

Sources: Air Resources Board, OFFROAD Modeling Change Technical Memo, OFF-ROAD EXHAUST EMISSIONS INVENTORY FUEL CORRECTION FACTORS, 2005

http://www.arb.ca.gov/msei/offroad/techmemo/arb_offroad_fuels.pdf

OFFROAD2007 Off-Road Emissions Inventory. Software and instructions can be downloaded at <http://www.arb.ca.gov/msei/offroad/offroad.htm>

Other information needed to estimate emissions are operating hours and load factor. Operating hours for construction equipment can range from 535 to 1641 hours per year and the load factor can vary between 0.43 and 0.78. Operating hours for agricultural equipment can range from 90 to 790 hours per year and the load factor can vary between 0.43 to 0.70.

April 2013

**Table 7 Medium-Duty Vehicle Emission Factors
For Vanpool and Shuttle Evaluations
(Model Years 1995 - 2003)**

Note: Table 7 is now obsolete and has been deleted.

Please refer to Table 2 or Tables 5-A through 5-F, as appropriate for medium and heavy-duty emission factors.