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
December 2022

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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 California 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 reflect EMFAC2017 for Calendar Year 2021.
Table 3/3A	Updated emission rates to reflect EMFAC2017 for Calendar Year 2021.
Table 4	Updated emission rates to reflect EMFAC2017 for Calendar Year 2021.
Table 5	Updated emission rates to reflect EMFAC2017 for Calendar Year 2021, added emission rates for Zero Emission Buses

Table 1 Diesel Bus Emission Factors
(Through Model Year 2021)

Pollutant	Calendar Year	Model Year	Emission Factor (gram/mile) Average	Emission Factor (gram/mile) 45 MPH
ROG	2021	Entire Fleet	0.003	0.002
	2021	2007 - 2009	0.005	0.001
	2021	2010 - 2014	0.001	0.002
	2021	2015 - 2020	0.003	0.003
	2021	2021	0.011	0.003
CO	2021	Entire Fleet	0.207	0.053
	2021	2007 - 2009	0.556	0.091
	2021	2010 - 2014	0.130	0.048
	2021	2015 - 2020	0.131	0.044
	2021	2021	0.105	0.040
NOx	2021	Entire Fleet	1.707	0.675
	2021	2007 - 2009	5.905	3.664
	2021	2010 - 2014	0.793	0.133
	2021	2015 - 2020	0.776	0.120
	2021	2021	0.577	0.112
PM2.5 - Exhaust[1]	2021	Entire Fleet	0.006	0.007
	2021	2007 - 2009	0.010	0.006
	2021	2010 - 2014	0.006	0.008
	2021	2015 - 2020	0.006	0.007
	2021	2021	0.005	0.007
PM2.5 – Tire Wear	All Years	All Years	0.008	Not Speed Dependent
PM2.5 – Brake Wear	All Years	All Years	0.032	Not Speed Dependent
PM2.5 – Road Dust[2]	All Years	All Years	0.028	Not Speed Dependent

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

[PM2.5 = 0.15*PM10]

[1] Statewide average annual PM2.5 emission factor, weighted by VMT per road category.
[2] 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), and ARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013).

Table 2 Emission Factors for Cleaner Vehicles for Light-Duty and Medium-Duty Trucks/SUVs (Chassis-Certified)

Baseline (Older) Technology Vehicles

Average New Truck in 2010 (note: emission factor units are grams/mile and weight units are pound)

Weight[3]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[4]	CO
Up to 8,500	0.051	0.060	0.010	0.056	2.1
8,501-10,000	0.148	0.195	0.068	0.132	6.2
10,001-14,000	0.173	0.390	0.068	0.137	7.1

Replacement (Newer) Technology Cleaner Vehicles

Projected Average New Trucks in 2020 (note: emission factor units are grams per mile)

Weight[3]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[4]	CO
Up to 8,500	0.043	0.054	0.003	0.049	1.8
8,501-10,000	0.104	0.149	0.008	0.072	5.7
10,001-14,000	0.155	0.245	0.010	0.079	6.4

Replacement (Newer) Technology Cleaner Vehicles

Zero-emission light-duty and medium-duty vehicles (note: emission factor units are grams per mile)

Weight[3]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[4]	CO
Up to 8,500	0	0	0	0.046	0
8,501-10,000	0	0	0	0.064	0
10,001-14,000	0	0	0	0.069	0

Sources:

The baseline California Vehicle Exhaust Standards ("LEV II") for average chassis-certified trucks is for the model year 2010. Emission factors above assume emissions at the 50,000-mile (Durability Vehicle Basis) standard for the first 50,000 miles of the car's life (assumed to be 120,000 miles), and emissions at the 120,000-mile (Durability Vehicle Basis) standard for the last 70,000 miles of the car's life. Please see the latest amendments to LEV II and CAP 2000 adopted regulations for more details.

[3] Gross vehicle weights can be associated with payload capacity as follows: 5751-8500 lb, roughly 1-ton payload; 8501-10,000 lb, roughly 1.8-ton payload; 10,001-14,000 lb, 2.5-ton payload.

[4] Total PM2.5 factors include motor vehicle exhaust, tire wear, brake wear, and entrained road dust.

The replacement vehicle emission factors are from the California Vehicle Exhaust Standards for MYs after 2016 ("LEV III") evaluated for the calendar year 2020.

The road dust portion of the PM2.5 emission factor was calculated from equation 1 of Chapter 13.2.1.3 of AP-42 Compilation of Air Pollutant Emission Factors Vol 5. US EPA Jan 1995. The silt loading and other parameters for the equation came from MRI, 1996. Improvement of Specific Emission Factors, (BACM Project No 1). 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. However, the road dust PM factor 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. The brake wear emission factors came from a review of non-asbestos brake emissions (Section 9 of the EMFAC2011 Technical Documentation).

Table 3 Average Auto Emission Factors
(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks, and Motorcycles)

Analysis Period or Project Life	1-5 Years (2020-2024)	6-10 Years (2020-2029)	11-15 Years (2020-2034)	16-20 Years (2020-2039)
ROG				
VMT[5] (g/mile)	0.075	0.067	0.062	0.058
commute trip ends (g/trip end)	0.269	0.224	0.192	0.167
average trip ends (g/trip end)	0.434	0.368	0.320	0.284
NOx				
VMT (g/mile)	0.066	0.053	0.045	0.040
commute trip ends (g/trip end)	0.074	0.058	0.047	0.040
average trip ends (g/trip end)	0.227	0.194	0.173	0.160
$PM_{2.5}$				
VMT (g/mile)	0.047	0.047	0.046	0.046
running exhaust only (g/mile)	0.0015	0.0014	0.0012	0.0011
tire and brake wear (g/mile)	0.0177	0.0177	0.0177	0.0177
road dust (g/mile)[6]	0.028	0.028	0.028	0.028
commute trip ends (g/trip end)	0.005	0.004	0.004	0.004
average trip ends (g/trip end)	0.002	0.002	0.001	0.001
CO				
VMT (g/mile)	0.922	0.798	0.721	0.670
commute trip ends (g/trip end)	1.965	1.643	1.408	1.231
average trip ends (g/trip end)	2.453	2.258	2.105	1.991

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

[PM2.5 = 0.15*PM10]

[5] Vehicle miles traveled
[6] PM2.5, road dust: statewide average annual PM2.5 emission factor is based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011, and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

Table 3A Average Auto Emission Factors
(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks, and Motorcycles)

Analysis Period or Project Life	1 Year 2020	1 Year 2021	1 Year 2022
ROG			
VMT (g/mile)	0.083	0.078	0.074
commute trip ends (g/trip end)	0.320	0.291	0.266
average trip ends (g/trip end)	0.507	0.466	0.430
NOx			
VMT (g/mile)	0.083	0.073	0.064
commute trip ends (g/trip end)	0.092	0.081	0.072
average trip ends (g/trip end)	0.264	0.243	0.225
$PM_{2.5}$			
VMT (g/mile)	0.047	0.047	0.047
running exhaust only (g/mile)	0.002	0.002	0.002
tire and brake wear (g/mile)	0.018	0.018	0.018
road dust (g/mile)[7]	0.028	0.028	0.028
commute trip ends (g/trip end)	0.005	0.005	0.005
average trip ends (g/trip end)	0.002	0.002	0.002
CO			
VMT (g/mile)	1.083	0.988	0.909
commute trip ends (g/trip end)	2.332	2.121	1.944
average trip ends (g/trip end)	2.617	2.532	2.452

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.
[PM2.5 = 0.15*PM10]

[7] PM2.5, road dust: statewide average annual PM2.5 emission factor is based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

Table 4 Emission Factors (grams per mile) by Speed (mph)

Project Life 1-5 years (2020-2024)

Speed	ROG[8]	CO	NOx	PM2.5 Ex[9]	Speed	ROG[8]	CO	NOx	PM2.5 Ex[9]
5	**0.22**	**2.09**	**0.78**	**0.01**	***35***	**0.03**	**1.04**	**0.23**	**0.003**
6	0.20	2.03	0.74	0.01	*36*	0.03	1.02	0.23	0.003
7	0.19	1.97	0.71	0.01	*37*	0.03	1.01	0.22	0.003
8	0.17	1.91	0.68	0.01	*38*	0.03	0.99	0.22	0.003
9	0.16	1.85	0.65	0.01	*39*	0.03	0.98	0.21	0.003
10	**0.14**	**1.80**	**0.62**	**0.01**	***40***	**0.03**	**0.96**	**0.21**	**0.003**
11	0.13	1.74	0.59	0.01	*41*	0.03	0.95	0.20	0.003
12	0.12	1.69	0.55	0.01	*42*	0.03	0.94	0.20	0.003
13	0.11	1.64	0.52	0.01	*43*	0.03	0.92	0.20	0.003
14	0.10	1.60	0.49	0.01	*44*	0.03	0.91	0.19	0.003
15	**0.09**	**1.55**	**0.47**	**0.01**	***45***	**0.03**	**0.90**	**0.19**	**0.003**
16	0.09	1.51	0.45	0.01	*46*	0.03	0.89	0.19	0.003
17	0.08	1.48	0.43	0.01	*47*	0.02	0.88	0.19	0.003
18	0.07	1.44	0.42	0.01	*48*	0.02	0.87	0.18	0.003
19	0.07	1.40	0.40	0.01	*49*	0.02	0.86	0.18	0.003
20	**0.06**	**1.37**	**0.38**	**0.00**	***50***	**0.02**	**0.85**	**0.18**	**0.003**
21	0.06	1.34	0.37	0.00	*51*	0.02	0.84	0.18	0.003
22	0.06	1.31	0.36	0.00	*52*	0.02	0.84	0.18	0.003
23	0.05	1.29	0.35	0.00	*53*	0.02	0.83	0.18	0.003
24	0.05	1.26	0.34	0.00	*54*	0.02	0.82	0.18	0.003
25	**0.05**	**1.24**	**0.32**	**0.00**	***55***	**0.02**	**0.81**	**0.18**	**0.003**
26	0.05	1.21	0.31	0.00	*56*	0.02	0.81	0.19	0.003
27	0.04	1.19	0.30	0.00	*57*	0.02	0.80	0.19	0.004
28	0.04	1.17	0.29	0.00	*58*	0.03	0.80	0.19	0.004
29	0.04	1.15	0.28	0.00	*59*	0.03	0.80	0.20	0.004
30	**0.04**	**1.13**	**0.27**	**0.003**	***60***	**0.03**	**0.79**	**0.20**	**0.004**
31	0.04	1.11	0.27	0.003	*61*	0.03	0.79	0.20	0.004
32	0.04	1.09	0.26	0.003	*62*	0.03	0.79	0.21	0.004
33	0.03	1.07	0.25	0.003	*63*	0.03	0.79	0.21	0.004
34	0.03	1.06	0.24	0.003	*64*	0.03	0.79	0.22	0.004
					65	**0.03**	**0.78**	**0.22**	**0.004**

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

[8] ROG includes running exhaust and running evaporative emissions.
[9] PM2.5 Ex includes running exhaust emissions only.

Table 4 Emission Factors (grams per mile) by Speed (mph) (continued)

Project Life 6-10 years (2020-2029)

Speed	ROG[10]	CO	NOx	PM2.5 Ex[11]		Speed	ROG[10]	CO	NOx	PM2.5 Ex[11]
5	**0.18**	**1.81**	**0.74**	**0.01**		***35***	**0.03**	**0.89**	**0.20**	**0.002**
6	0.16	1.75	0.71	0.01		*36*	0.03	0.88	0.19	0.002
7	0.15	1.70	0.68	0.01		*37*	0.02	0.87	0.19	0.002
8	0.14	1.65	0.64	0.01		*38*	0.02	0.85	0.18	0.002
9	0.13	1.60	0.61	0.01		*39*	0.02	0.84	0.17	0.002
10	**0.12**	**1.55**	**0.59**	**0.01**		***40***	**0.02**	**0.83**	**0.17**	**0.002**
11	0.11	1.51	0.55	0.01		*41*	0.02	0.82	0.16	0.002
12	0.10	1.46	0.52	0.01		*42*	0.02	0.81	0.16	0.002
13	0.09	1.42	0.49	0.01		*43*	0.02	0.80	0.16	0.002
14	0.08	1.38	0.46	0.01		*44*	0.02	0.79	0.15	0.002
15	**0.08**	**1.34**	**0.43**	**0.01**		***45***	**0.02**	**0.78**	**0.15**	**0.002**
16	0.07	1.30	0.42	0.00		*46*	0.02	0.77	0.15	0.002
17	0.07	1.27	0.40	0.00		*47*	0.02	0.76	0.15	0.002
18	0.06	1.24	0.38	0.00		*48*	0.02	0.75	0.14	0.002
19	0.06	1.21	0.37	0.00		*49*	0.02	0.74	0.14	0.002
20	**0.05**	**1.18**	**0.35**	**0.00**		***50***	**0.02**	**0.73**	**0.14**	**0.002**
21	0.05	1.16	0.34	0.004		*51*	0.02	0.72	0.14	0.002
22	0.05	1.13	0.33	0.003		*52*	0.02	0.72	0.14	0.003
23	0.04	1.11	0.32	0.003		*53*	0.02	0.71	0.14	0.003
24	0.04	1.09	0.30	0.003		*54*	0.02	0.71	0.14	0.003
25	**0.04**	**1.06**	**0.29**	**0.003**		***55***	**0.02**	**0.70**	**0.14**	**0.003**
26	0.04	1.05	0.28	0.003		*56*	0.02	0.69	0.15	0.003
27	0.04	1.03	0.27	0.003		*57*	0.02	0.69	0.15	0.003
28	0.03	1.01	0.26	0.003		*58*	0.02	0.69	0.15	0.003
29	0.03	0.99	0.25	0.003		*59*	0.02	0.68	0.15	0.003
30	**0.03**	**0.97**	**0.24**	**0.002**		***60***	**0.02**	**0.68**	**0.16**	**0.003**
31	0.03	0.96	0.23	0.002		*61*	0.02	0.67	0.16	0.003
32	0.03	0.94	0.22	0.002		*62*	0.02	0.67	0.17	0.003
33	0.03	0.92	0.21	0.002		*63*	0.02	0.67	0.17	0.003
34	0.03	0.91	0.21	0.002		*64*	0.02	0.67	0.18	0.003
						65	**0.02**	**0.67**	**0.18**	**0.003**

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

[10] ROG includes running exhaust and running evaporative emissions.
[11] PM2.5 Ex includes running exhaust emissions only.

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile)

BEFORE PROJECT Baseline Emission Factors – New Diesel Vehicles

Vehicle Type	GVWR (lbs)[12]	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)[13]	Conversion Factors	ROG (g/bhp-hr)[14]	CO (g/bhp-hr)	NOx (g/bhp-hr)	PM2.5 (g/bhp-hr)
Urban Transit Buses	> 33,000	2007-2009	0.005	0.556	5.905	0.053	4.0	0.001	0.139	1.476	0.0133
		2010-2012	0.002	0.132	0.795	0.044	4.0	0.000	0.033	0.199	0.0110
		2013-2015	0.001	0.128	0.790	0.044	4.0	0.0003	0.032	0.197	0.0111
		2016-2018	0.002	0.132	0.788	0.044	4.0	0.0005	0.033	0.197	0.0111
		2019+	0.010	0.115	0.619	0.052	4.0	0.0026	0.029	0.155	0.0130
Transit Buses,[15] School Buses, and Trucks[16]	14,001-33,000	2007-2009	0.342	0.968	6.341	0.219	1.8	0.190	0.538	3.523	0.122
		2010-2012	0.033	0.200	2.727	0.081	1.8	0.018	0.111	1.515	0.045
		2013-2015	0.011	0.151	1.891	0.073	1.8	0.006	0.084	1.051	0.040
		2016-2018	0.009	0.134	1.463	0.070	1.8	0.005	0.074	0.813	0.039
		2019+	0.008	0.121	1.190	0.067	1.8	0.005	0.067	0.661	0.037
Class 8 Trucks[17]	> 33,000	2007-2009	0.466	1.420	10.445	0.171	2.9	0.161	0.490	3.602	0.059
		2010-2012	0.164	0.998	6.070	0.083	2.9	0.056	0.344	2.093	0.029
		2013-2015	0.066	0.867	3.409	0.063	2.9	0.023	0.299	1.175	0.022
		2016-2018	0.062	0.828	2.585	0.057	2.9	0.022	0.286	0.891	0.020
		2019+	0.054	0.719	2.005	0.049	2.9	0.019	0.248	0.691	0.017

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and formaldehyde.

[12] Gross vehicle weight rating
[13] PM2.5 includes exhaust, tire wear, and brake wear
[14] Grams per brake horsepower-hour
[15] Other buses
[16] Medium heavy-duty trucks
[17] Heavy heavy-duty trucks

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile) (Continued)

Retrofit Diesel Vehicles

Vehicle Type	GVWR (lbs) [18]	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)[19]	Conversion Factors	ROG (g/bhp-hr)[20]	CO (g/bhp-hr)	NOx (g/bhp-hr)	PM2.5 (g/bhp-hr)
Urban Transit Buses	>33,000	2007-2009	0.005	0.556	5.905	0.053	4.0	0.001	0.139	1.476	0.013
Transit Buses[21], School Buses, and Trucks[22]	14,001-33,000	1998-2002	1.112	2.642	15.937	0.495	1.8	0.618	1.468	8.854	0.275
		2003-2006	0.827	2.619	8.616	0.517	1.8	0.460	1.455	4.787	0.287
		2007-2009	0.342	0.968	6.341	0.219	1.8	0.190	0.538	3.523	0.122
Class 8 Trucks[23]	>33,000	1998-2002	1.480	3.868	24.237	0.478	2.9	0.510	1.334	8.358	0.165
		2003-2006	0.946	3.376	13.121	0.593	2.9	0.326	1.164	4.525	0.204
		2007-2009	0.466	1.420	10.445	0.171	2.9	0.161	0.490	3.602	0.059

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and formaldehyde.

[18] Gross vehicle weight rating
[19] PM2.5 includes exhaust, tire wear, and brake wear.
[20] Grams per brake horsepower-hour
[21] Other buses
[22] Medium heavy-duty trucks
[23] Heavy heavy-duty trucks

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile) (Continued)

AFTER PROJECT Emission Factors – New Cleaner Vehicle Purchase or Repowers

Vehicle Type	GVWR[24] (lbs)	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)[25]	Conversion Factors	ROG (g/bhp-hr)[26]	CO (g/bhp-hr)	NOx (g/bhp-hr)	PM2.5 (g/bhp-hr)
Urban Transit Buses	> 33,000	2012-2014	0.001	0.129	0.795	0.044	4.0	0.0003	0.032	0.199	0.0110
		2015-2017	0.003	0.134	0.790	0.044	4.0	0.0006	0.034	0.197	0.0110
		2018+	0.003	0.127	0.759	0.046	4.0	0.0008	0.032	0.190	0.0114
Transit Buses[27], School Buses, and Trucks[28]	14,001 - 33,000	2012-2014	0.011	0.105	0.577	0.054	4.0	0.0027	0.026	0.144	0.0135
		2015-2017	0.012	0.162	2.242	0.073	1.8	0.007	0.090	1.246	0.041
		2018+	0.01	0.14	1.54	0.07	1.8	0.005	0.076	0.856	0.039
Class 8 Trucks[29]	> 33,000	2012-2014	0.01	0.12	1.26	0.07	1.8	0.005	0.068	0.701	0.037
		2015-2017	0.01	0.12	1.10	0.07	1.8	0.004	0.066	0.613	0.037
		2018+	0.07	0.90	4.30	0.07	2.9	0.024	0.312	1.482	0.023

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and formaldehyde.

[24] Gross vehicle weight rating
[25] PM2.5 includes exhaust, tire wear, and brake wear.
[26] Grams per brake horsepower-hour
[27] Other buses
[28] Medium heavy-duty trucks
[29] Heavy heavy-duty trucks

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile) (Continued)

Emission Factors – New Zero Emission Vehicle Purchase

Vehicle Type	GVWR[30] (lbs)	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)[31]	Conversion Factors	ROG (g/bhp-hr[32])	CO (g/bhp-hr)	NOx (g/bhp-hr)	PM2.5 (g/bhp-hr)
Urban Transit Buses	> 33,000	2008-2014	0	0	0	0.046	4.0	n/a	n/a	n/a	0.0115

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

Zero emission vehicles refer to electric vehicles with technology to reduce PM2.5.

[30] Gross vehicle weight rating
[31] PM2.5 includes exhaust, tire wear, and brake wear.
[32] Grams per brake horsepower-hour

Off-Road Emission Factors for Cleaner Vehicle Projects
In Table 6, find the horsepower (hp) and model year for the engine that best describes the engine being replaced to determine the "before project" baseline emission factors. In Table 6, find the hp and model year for the newer engine to determine the "after project" cleaner engine baseline emission factors.

To calculate an engine's emission factor considering deterioration from the engine's cumulative operating hours:

1. First, multiply the engine's cumulative operating hours by the deterioration rate (DR).
2. Then add that to the emission factor (EF).

$EF_{DR} = (Hrs_{Cumulative} * DR) + EF$ Eq. 1

EF_{DR} = Emission factor with deterioration rate (to be calculated)
$Hrs_{Cumulative}$ = Total operating hours to date
DR = Deterioration Rate (from Table 6)

For example, based on Equation 1 and data presented in Table 6, a pre-1988 25 horsepower engine that has 1,000 operating hours to date would have the following NOx emission factor:

$$6.608 = (1{,}000 * 0.000098) + 6.51$$

To estimate the reduction in annual emissions (in grams) from replacing the engine, use the equation below, obtained from the Carl Moyer Guidelines, Appendix D[33].

Annual Reductions = $(EF_{Before\ Project} - EF_{After\ Project}) * (Hours/Year) * hp * (LF)$ Eq. 2

LF = Load Factor (unitless), see Carl Moyer Guidelines Appendix D for values.
hp= horsepower

[33] https://www.arb.ca.gov/regact/2010/offroadlsi10/offroadappd.pdf

Table 6 Uncontrolled Off-Road Diesel Engines
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr) (DR)

Before Project: Baseline Emission

Horsepower	Model Year	NOx EF	NOx DR	ROG EF	ROG DR	PM2.5 EF	PM2.5 DR
25-49	Pre-1988	6.51	0.000098	1.68	0.000210	0.503	0.0000390
	1988+	6.42	0.000097	1.64	0.000210	0.503	0.0000390
50-119	Pre-1988	12.09	0.00028	1.31	0.000061	0.557	0.0000405
	1988+	8.14	0.00019	0.90	0.000042	0.457	0.0000332
120+	Pre-1970	13.02	0.00030	1.20	0.000056	0.510	0.0000371
	1970-1979	11.16	0.00026	0.91	0.000042	0.364	0.0000265
	1980-1987	10.23	0.00024	0.80	0.000037	0.364	0.0000265
	1988+	7.60	0.00018	0.62	0.000029	0.252	0.0000183

Source: The Carl Moyer program Guidelines 2017 Revisions, Appendix D, Table D-8

For use in calculating cost effectiveness of diesel engines: PM2.5 = PM10 * 0.92

(https://www.arb.ca.gov/msei/ordiesel/pm25_pm10reference.pdf)

Table 6 Uncontrolled Off-Road Diesel Engines (continued)
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr-hr) (DR)

After Project: Cleaner Engine

Horsepower	Tier	NOx EF	NOx DR	ROG EF	ROG DR	PM2.5 EF	PM2.5 DR
25-49	1	5.26	0.0000980	1.32	0.000170	0.442	0.0000342
	2	4.63	0.0000930	0.22	0.000050	0.258	0.0000201
	4 (Interim)	4.55	0.0000950	0.09	0.000036	0.118	0.0000088
	4 (Final)	2.75	0.0000570	0.09	0.000036	0.008	0.0000009
50-74	1	6.54	0.0001500	0.90	0.000042	0.508	0.0000370
	2	4.75	0.0000710	0.17	0.000025	0.177	0.0000130
	3	2.74	0.0000360	0.09	0.000023	0.177	0.0000130
	4 (Interim)	2.74	0.0000360	0.09	0.000023	0.103	0.0000074
	4 (Final)	2.74	0.0000360	0.09	0.000023	0.008	0.0000008
75-99	1	6.54	0.0001500	0.90	0.000042	0.508	0.0000370
	2	4.75	0.0000710	0.17	0.000025	0.177	0.0000130
	3	2.74	0.0000360	0.09	0.000023	0.103	0.0000074
	4 (Phase-Out)	2.74	0.0000360	0.09	0.000030	0.008	0.0000008
	(Phase-In or Alt. NOx)	2.15	0.0000270	0.08	0.000021	0.008	0.0000008
	4 (Final)	0.26	0.0000035	0.05	0.000015	0.008	0.0000008
100-174	1	6.54	0.0001500	0.62	0.000029	0.280	0.0000203
	2	4.15	0.0000600	0.15	0.000023	0.118	0.0000086
	3	2.32	0.0000300	0.09	0.000030	0.103	0.0000074
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000030	0.008	0.0000004
	(Phase-In or Alt. NOx)	2.15	0.0000270	0.08	0.000020	0.008	0.0000004
	4 (Final)	0.26	0.0000040	0.05	0.000011	0.008	0.0000004
175-299	1	5.93	0.0001400	0.29	0.000013	0.110	0.0000059
	2	4.15	0.0000600	0.11	0.000022	0.081	0.0000042
	3	2.32	0.0000300	0.09	0.000023	0.081	0.0000042
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000023	0.008	0.0000003
	(Phase-In or Alt. NOx)	1.29	0.0000170	0.06	0.000017	0.008	0.0000003
	4 (Final)	0.26	0.0000036	0.05	0.000011	0.008	0.0000003
300-750	1	5.93	0.0000990	0.29	0.000010	0.110	0.0000059
	2	3.79	0.0000500	0.09	0.000023	0.081	0.0000040
	3	2.32	0.0000300	0.09	0.000023	0.081	0.0000040
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000023	0.008	0.0000003
	(Phase-In or Alt. NOx)	1.29	0.0000170	0.06	0.000017	0.008	0.0000003
	4 (Final)	0.26	0.0000036	0.05	0.000011	0.008	0.0000003
751+	1	5.93	0.0000990	0.29	0.000010	0.110	0.0000059
	2	3.79	0.0000500	0.09	0.000023	0.081	0.0000040
	4 (Interim)	2.24	0.0000280	0.06	0.000017	0.047	0.0000019
	4 (Final)	2.24	0.0000280	0.05	0.000011	0.016	0.0000008