

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
November 2021*



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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. Eliminated model year ranges with no vehicles.
Table 2	Updated Table 2.
Table 3/3A	Updated emission rates to reflect EMFAC2017.
Table 4	Updated emission rates to reflect EMFAC2017.
Table 5	Updated emission rates to reflect EMFAC2017.

Table 1 Diesel Bus Emission Factors
(through Model Year 2020)

Pollutant	Calendar Year	Model Year	Emission Factor (gram/mile) Average	Emission Factor (gram/mile) 45 MPH
ROG	2020	Entire Fleet	0.003	0.003
	2020	2003 - 2006	0.010	0.003
	2020	2007 - 2009	0.005	0.001
	2020	2010 - 2014	0.003	0.003
	2020	2015 - 2020	0.003	0.003
	2020	2020	0.009	0.003
CO	2020	Entire Fleet	0.23	0.06
	2020	2003 - 2006	0.60	0.35
	2020	2007 - 2009	0.56	0.09
	2020	2010 - 2014	0.14	0.05
	2020	2015 - 2020	0.13	0.04
	2020	2020	0.13	0.04
NOx	2020	Entire Fleet	2.03	0.79
	2020	2003 - 2006	7.60	4.31
	2020	2007 - 2009	5.90	3.66
	2020	2010 - 2014	0.79	0.13
	2020	2015 - 2020	0.78	0.12
	2020	2020	0.70	0.11
PM2.5 - Exhaust*	2020	Entire Fleet	0.007	0.007
	2020	2003 - 2006	0.01	0.008
	2020	2007 - 2009	0.01	0.006
	2020	2010 - 2014	0.006	0.008
	2020	2015 - 2020	0.006	0.007
	2020	2020	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	0.033	Not Speed Dependent
PM2.5 – Road Dust**	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.

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

** The PM10 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).

[PM2.5 = 0.15*PM10]

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)

Weight ¹	ROG	NOx	PM2.5 Exhaust	PM2.5 Total ²	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 ¹	ROG	NOx	PM2.5 Exhaust	PM2.5 Total ²	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 vehicle (ZEV) (note: emission factor units are grams per mile)

Weight ¹	ROG	NOx	PM2.5 Exhaust	PM2.5 Total ²	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

See notes next page

¹ 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.

² Total PM2.5 factors include motor vehicle exhaust, tire wear, brake wear, and entrained road dust.

Sources:

Baseline is California Vehicle Exhaust Standards ("LEV II") for average chassis-certified trucks for model year 2010. 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 emissions 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 2016 ("LEV III") evaluated for calendar year 2020.

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 road dust portion of the PM_{2.5} 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. 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. The brake wear emission factors came from a review of recent 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 Motor Cycles)

Analysis Period or Project Life	1-5 Years (2019- 2023)	6-10 Years (2019- 2028)	11-15 Years (2019- 2033)	16-20 Years (2019- 2038)
ROG				
VMT (g/mile)	0.079	0.071	0.065	0.060
commute trip ends (g/trip end)	0.295	0.244	0.208	0.180
average trip ends (g/trip end)	0.471	0.397	0.343	0.303
NOx				
VMT (g/mile)	0.075	0.059	0.050	0.044
commute trip ends (g/trip end)	0.083	0.065	0.053	0.044
average trip ends (g/trip end)	0.245	0.208	0.184	0.168
PM_{2.5}				
VMT (g/mile)	0.047	0.047	0.047	0.046
running exhaust only (g/mile)	0.0016	0.0014	0.0013	0.0011
tire and brake wear (g/mile)	0.0177	0.0177	0.0177	0.0177
road dust (g/mile)	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	0.002	0.001
CO				
VMT (g/mile)	1.004	0.856	0.765	0.705
commute trip ends (g/trip end)	2.154	1.788	1.526	1.328
average trip ends (g/trip end)	2.537	2.335	2.171	2.046

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

PM_{2.5}, road dust: statewide average annual 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), and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

[PM_{2.5} = 0.15*PM₁₀]

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 2019	1 Year 2020	1 Year 2021
ROG			
VMT (g/mile)	0.090	0.083	0.078
commute trip ends (g/trip end)	0.355	0.320	0.291
average trip ends (g/trip end)	0.554	0.507	0.466
NOx			
VMT (g/mile)	0.096	0.083	0.073
commute trip ends (g/trip end)	0.106	0.092	0.081
average trip ends (g/trip end)	0.287	0.264	0.243
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)	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)	1.201	1.083	0.988
commute trip ends (g/trip end)	2.592	2.332	2.121
average trip ends (g/trip end)	2.709	2.617	2.532

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

PM_{2.5}, road dust: statewide average annual 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), and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

[PM_{2.5} = 0.15*PM₁₀]

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

Project Life 1-5 years (2019-2023)

Speed	ROG	CO	NO x	PM2.5 Ex	Speed	ROG	CO	NO x	PM2.5 Ex
5	0.25	2.30	0.83	0.02	35	0.04	1.14	0.27	0.004
6	0.23	2.23	0.79	0.02	36	0.04	1.12	0.26	0.004
7	0.22	2.16	0.76	0.01	37	0.03	1.10	0.26	0.004
8	0.20	2.10	0.73	0.01	38	0.03	1.09	0.25	0.003
9	0.18	2.03	0.70	0.01	39	0.03	1.07	0.25	0.003
10	0.17	1.97	0.67	0.01	40	0.03	1.05	0.24	0.003
11	0.15	1.92	0.63	0.01	41	0.03	1.04	0.24	0.003
12	0.14	1.86	0.60	0.01	42	0.03	1.03	0.23	0.003
13	0.13	1.81	0.56	0.01	43	0.03	1.01	0.23	0.003
14	0.12	1.75	0.53	0.01	44	0.03	1.00	0.23	0.003
15	0.11	1.70	0.50	0.01	45	0.03	0.99	0.22	0.003
16	0.10	1.66	0.48	0.01	46	0.03	0.98	0.22	0.004
17	0.09	1.62	0.47	0.01	47	0.03	0.96	0.22	0.004
18	0.09	1.58	0.45	0.01	48	0.03	0.95	0.22	0.004
19	0.08	1.54	0.43	0.01	49	0.03	0.94	0.22	0.004
20	0.07	1.50	0.42	0.01	50	0.03	0.93	0.22	0.004
21	0.07	1.47	0.40	0.01	51	0.03	0.93	0.22	0.004
22	0.07	1.44	0.39	0.01	52	0.03	0.92	0.22	0.004
23	0.06	1.41	0.38	0.01	53	0.03	0.91	0.22	0.004
24	0.06	1.38	0.37	0.00	54	0.03	0.90	0.22	0.004
25	0.06	1.35	0.36	0.00	55	0.03	0.89	0.22	0.004
26	0.05	1.33	0.34	0.00	56	0.03	0.89	0.22	0.004
27	0.05	1.31	0.33	0.00	57	0.03	0.88	0.23	0.004
28	0.05	1.28	0.33	0.00	58	0.03	0.88	0.23	0.004
29	0.05	1.26	0.32	0.00	59	0.03	0.88	0.23	0.004
30	0.04	1.23	0.31	0.004	60	0.03	0.87	0.23	0.005
31	0.04	1.21	0.30	0.004	61	0.03	0.87	0.24	0.005
32	0.04	1.19	0.29	0.004	62	0.03	0.87	0.24	0.005
33	0.04	1.17	0.28	0.004	63	0.03	0.87	0.25	0.005
34	0.04	1.15	0.28	0.004	64	0.03	0.87	0.25	0.005
					65	0.03	0.87	0.26	0.005

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

ROG includes running exhaust and running evaporative emissions. PM2.5 Ex includes running exhaust emissions only.

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

Project Life 6-10 years (2019-2028)

Speed	ROG	CO	NO x	PM2.5 Ex	Speed	ROG	CO	NO x	PM2.5 Ex
5	0.20	1.94	0.77	0.01	35	0.03	0.96	0.22	0.003
6	0.18	1.89	0.73	0.01	36	0.03	0.95	0.21	0.003
7	0.17	1.83	0.70	0.01	37	0.03	0.93	0.21	0.003
8	0.16	1.77	0.67	0.01	38	0.03	0.92	0.20	0.003
9	0.14	1.72	0.64	0.01	39	0.03	0.91	0.19	0.003
10	0.13	1.67	0.61	0.01	40	0.03	0.89	0.19	0.003
11	0.12	1.62	0.57	0.01	41	0.02	0.88	0.18	0.003
12	0.11	1.57	0.54	0.01	42	0.02	0.87	0.18	0.003
13	0.10	1.53	0.51	0.01	43	0.02	0.86	0.18	0.003
14	0.09	1.48	0.48	0.01	44	0.02	0.85	0.17	0.003
15	0.09	1.44	0.45	0.01	45	0.02	0.83	0.17	0.003
16	0.08	1.40	0.43	0.01	46	0.02	0.82	0.17	0.003
17	0.07	1.37	0.42	0.01	47	0.02	0.82	0.17	0.003
18	0.07	1.33	0.40	0.00	48	0.02	0.81	0.17	0.003
19	0.06	1.30	0.39	0.00	49	0.02	0.80	0.16	0.003
20	0.06	1.27	0.37	0.00	50	0.02	0.79	0.16	0.003
21	0.05	1.24	0.36	0.004	51	0.02	0.78	0.16	0.003
22	0.05	1.22	0.34	0.004	52	0.02	0.77	0.16	0.003
23	0.05	1.19	0.33	0.004	53	0.02	0.77	0.16	0.003
24	0.05	1.17	0.32	0.004	54	0.02	0.76	0.16	0.003
25	0.04	1.15	0.31	0.003	55	0.02	0.75	0.17	0.003
26	0.04	1.12	0.30	0.003	56	0.02	0.75	0.17	0.003
27	0.04	1.10	0.29	0.003	57	0.02	0.74	0.17	0.003
28	0.04	1.08	0.28	0.003	58	0.02	0.74	0.17	0.003
29	0.04	1.06	0.27	0.003	59	0.02	0.74	0.18	0.003
30	0.03	1.05	0.26	0.003	60	0.02	0.73	0.18	0.003
31	0.03	1.03	0.25	0.003	61	0.02	0.73	0.18	0.004
32	0.03	1.01	0.24	0.003	62	0.02	0.73	0.19	0.004
33	0.03	0.99	0.23	0.003	63	0.03	0.73	0.19	0.004
34	0.03	0.98	0.23	0.003	64	0.03	0.72	0.20	0.004
					65	0.03	0.72	0.20	0.004

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

ROG includes running exhaust and running evaporative emissions. 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 ¹ (lbs)	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)	Conversion Factors	ROG (g/bhp-hr)	CO (g/bhp-hr)	NOx (g/bhp-hr)	PM2.5 (g/bhp-hr)
Urban Transit Buses	> 33,000	2007-2009	0.005	0.56	5.90	0.05	4.0	0.001	0.139	1.476	0.0133
		2010-2012	0.005	0.15	0.78	0.04	4.0	0.001	0.037	0.196	0.0111
		2013-2015	0.001	0.13	0.79	0.04	4.0	0.0003	0.032	0.197	0.0111
		2016+	0.003	0.13	0.78	0.04	4.0	0.0007	0.033	0.194	0.0112
Transit Buses ¹ , School Buses, and Trucks ²	14,001-33,000	2007-2009	0.34	0.95	6.27	0.22	1.8	0.187	0.530	3.481	0.121
		2010-2012	0.03	0.19	2.61	0.08	1.8	0.017	0.106	1.452	0.044
		2013-2015	0.01	0.14	1.78	0.07	1.8	0.006	0.080	0.988	0.040
		2016+	0.01	0.13	1.29	0.07	1.8	0.005	0.070	0.718	0.038
Class 8 Trucks ³	> 33,000	2007-2009	0.46	1.42	10.43	0.18	2.9	0.159	0.489	3.596	0.061
		2010-2012	0.16	0.97	5.94	0.08	2.9	0.054	0.334	2.049	0.028
		2013-2015	0.06	0.84	3.24	0.06	2.9	0.022	0.289	1.118	0.021
		2016+	0.06	0.78	2.29	0.05	2.9	0.020	0.271	0.789	0.018

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

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

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 also, formaldehyde.

**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 ¹ (lbs)	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)	Conversion Factors	ROG (g/bhp- hr)	CO (g/bhp- hr)	NOx (g/bhp- hr)	PM2.5 (g/bhp- hr)
Urban Transit Buses	>33,000	2003-2006	0.01	0.60	7.60	0.06	4.0	0.002	0.151	1.901	0.015
		2007-2009	0.005	0.56	5.90	0.05	4.0	0.001	0.139	1.476	0.013
Transit Buses ¹ , School Buses, and Trucks ²	14,001- 33,000	1994-1997	0.72	1.81	16.01	0.42	1.8	0.400	1.004	8.893	0.235
		1998-2002	1.08	2.58	15.78	0.47	1.8	0.602	1.434	8.769	0.263
		2003-2006	0.80	2.54	8.50	0.50	1.8	0.444	1.410	4.720	0.280
		2007-2009	0.34	0.95	6.27	0.22	1.8	0.187	0.530	3.481	0.121
Class 8 Trucks ³	>33,000	1994-1997	1.15	3.66	20.66	0.44	2.9	0.395	1.261	7.125	0.153
		1998-2002	1.42	3.69	24.43	0.46	2.9	0.488	1.272	8.423	0.159
		2003-2006	0.94	3.36	13.14	0.59	2.9	0.323	1.158	4.532	0.205
		2007-2009	0.46	1.42	10.43	0.18	2.9	0.159	0.489	3.596	0.061

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

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

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 also, formaldehyde.

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 ¹ (lbs)	Model Year	ROG (g/mi)	CO (g/mi)	NOx (g/mi)	PM2.5 (g/mi)	Conversion Factors	ROG (g/bhp- hr)	CO (g/bhp- hr)	NOx (g/bhp- hr)	PM2.5 (g/bhp- hr)
Urban Transit Buses	> 33,000	2012-2014	0.001	0.13	0.79	0.04	4.0	0.0003	0.032	0.199	0.0110
		2015-2017	0.003	0.13	0.79	0.04	4.0	0.0006	0.033	0.197	0.0110
		2018+	0.003	0.13	0.76	0.05	4.0	0.0007	0.032	0.190	0.0114
Transit Buses ¹ School Buses, and Trucks ²	14,001 - 33,000	2012-2014	0.011	0.15	2.15	0.07	1.8	0.006	0.086	1.194	0.041
		2015-2017	0.01	0.13	1.46	0.07	1.8	0.005	0.074	0.809	0.039
		2018+	0.01	0.12	1.19	0.07	1.8	0.005	0.067	0.659	0.037
Class 8 Trucks ³	> 33,000	2012-2014	0.07	0.88	4.14	0.07	2.9	0.023	0.303	1.429	0.023
		2015-2017	0.06	0.81	2.52	0.06	2.9	0.021	0.278	0.870	0.020
		2018+	0.06	0.76	2.03	0.05	2.9	0.020	0.263	0.699	0.017

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

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

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 also, formaldehyde.

Table 6 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 taking into account 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).

Equation 1:

$$EF_{DR} = (\text{Hrs}_{\text{Cumulative}} * DR) + EF$$

EF_{DR} = Emission factor with deterioration rate (to be calculated)

$\text{Hrs}_{\text{Cumulative}}$ = 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 (<https://www.arb.ca.gov/regact/2010/offroadlsi10/offroadappd.pdf>):

Equation 2:

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

LF = Load Factor (unitless, see Carl Moyer Guidelines Appendix D for values <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-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: $PM_{2.5} = PM_{10} \times 0.92$
 (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