TECHNICAL NOTES

U.S. Department of Agriculture **Natural Resources Conservation Service**

TN – Air Quality – CA – 04 March 2018

Estimating Emission Reductions for the California State Implementation Plan Annual Report

CPS 372 – Combustion Systems Improvement

NRCS reports to EPA-Region 9 and the San Joaquin Valley Air Pollution Control District (SJVAPCD) annually of the voluntary, incentive-based emissions reductions achieved from San Joaquin Valley producers replacing their off-road mobile agricultural equipment through the Environmental Quality Incentive Program (EQIP). The annual report is prepared, certified and submitted by March 31 of each year according to the agreements described in NRCS California Air Quality Technical Note 3, void of any information deemed as confidential, to help fulfill California's State Implementation Plan (SIP) requirements under the Clean Air Act.

The methodologies for calculating SIP-creditable emissions reductions relies on the Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program), defined by Sections 44275-44299.2 of the California Health and Safety Code and administered by the California Air Resources Board (ARB). NRCS applies the Carl Moyer Program Guidelines for estimating and reporting the emission reductions from EQIP projects to ensure the emission reduction methodologies match other SIP-creditable state and local incentive-based projects in California.

NRCS applies the "*Equipment Hours of Operation per Pollutant*" methodology for calculating NOx, ROG and PM emissions (see Appendix A, B and C). As ARB periodically updates the Carl Moyer Program, NRCS will utilize the most current method to estimate the emissions reductions for SIP consideration.

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References

Air Resources Board, *2017 Carl Moyer Program Guidelines*, approved April 2017
http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm

Air Resources Board, *2011 Carl Moyer Program Guidelines*, approved April 2011
http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm

Air Resources Board, *2008 Carl Moyer Program Guidelines*, approved March 2008
https://www.arb.ca.gov/msprog/moyer/guidelines/current.htm

San Joaquin Valley Air Pollution Control District, *Manual of Procedures – SIP Creditability of Incentive-Based Emissions Reductions*
http://www.valleyair.org/MOP/mop9610_idx.htm

USDA Natural Resources Conservation Service, *Glossary for California Off-Road Agricultural Engines*, California Air Quality Technical Note 1, April 2014, Updated November 2016

USDA Natural Resources Conservation Service, *State Implementation Plan Creditability of Voluntary Incentive-Based Emission Reductions from Replacing Off-Road Mobile Farm Equipment*, California Air Quality Technical Note 3, December 2015

Appendix A: **NRCS Diesel Engine Emissions Calculations**
Based on the 2017 Carl Moyer Program – applied to NRCS reports beginning in 2018.

Appendix B: **NRCS Diesel Engine Emissions Calculations**
Based on the 2011 Carl Moyer Program – applied to NRCS reports from 2012-2017.

Appendix C: NRCS Diesel Engine Emissions Calculations
Based on the 2008 Carl Moyer Program – applied to NRCS reports from 2009-2011.

Appendix A

NRCS Diesel Engine Emissions Calculations

Based on the 2017 Carl Moyer Program Guidelines and applied to NRCS emissions reports beginning in 2018

Estimating Annual Emissions based on Hours of Operation per Pollutant (tons/year)

$$\text{Tons/year} = \frac{[(\text{EF (g/bhp-hr)} + \text{DP* (g/bhp-hr)}) \times \text{Horsepower (bhp)} \times \text{Annual Activity (hours/year)} \times \text{Load Factor}]}{907{,}200 \text{ g/ton}}$$

Calculating a Deterioration Product (DP)* Value

DP (g/bhp-hr) = DR (g/bhp-hr-hr) x Total Equipment Activity (hours)

1. Total Equipment Activity (hours) = Annual Activity (hours/year) x DL (years)

   Note: Total Equipment Activity is limited to a maximum of 12,000 hours for diesel engines.

2. Baseline Equipment DL (years) =

   Expected 1st Year of Operation – Baseline Engine Model-Year + (Project Life / 2)

3. Reduced Equipment DL (years) = Project Life / 2

   Note: Project Life is 10 years - equivalent to the 10-year CPS 372 practice lifespan.

2017 Carl Moyer Guidelines, Formula C-6

*ARB applies the DP values "*as applicable*". For NRCS purposes, the DP values are applicable to the emissions calculations for annual reporting and SIP consideration.

Variables

- Deterioration Life (DL): a factor calculated from the period of time the engine has deteriorated, plus half the project life, to estimate deterioration of the entire project life.
- Deterioration Product (DP): the result of multiplying the deterioration rate, equipment activity, and the deterioration life for a technology.
- Deterioration Rate (DR): rates that estimate increased NOx, ROG and PM emissions from engine wear and tear and other variables that increase engine emissions over time. Table A-2 lists the DR rates for uncontrolled diesel engines and Table A-4 for emission-controlled diesel engines.
- Emission Factor (EF): a category specific estimate of NOx, ROG and PM emissions per unit of activity. Table A-2 lists the emission factors for uncontrolled diesel engines and Table A-4 for emission-controlled diesel engines.
- Horsepower (bhp): is the manufacture-advertised brake horsepower (bhp) rating of the engine or equipment the engine powers (see CPS 372 Specifications and CA Air Quality Technical Note 1).
- Load Factor: is a fraction of the rated engine horsepower based on the nominal work performed by the engine for a particular application. Table A-1 lists the load factors for a variety of equipment types.

Table A-1
NRCS Default Load Factors for Off-Road Diesel-Powered Equipment used in Agriculture

Equipment Type	Load Factor	Category
Ag-Baggers	0.51	Agricultural - “Other Agriculture” Load Factor
Backhoe Loaders	0.37	Construction
Balers	0.53	Agricultural
Bin Carrier	0.51	Agricultural - “Other Agriculture” Load Factor
Chippers/Stump Grinders	0.73	Agricultural
Combines/Choppers	0.70	Agricultural
Conditioners	0.51	Agricultural - “Other Agriculture” Load Factor
Cranes	0.29	Construction
Crawler Tractor/Dozers	0.43	Construction
Excavators	0.38	Construction
Fellers/Bunchers	0.71	Logging
Forage Harvesters	0.70	Agricultural - “Combines/Choppers” Load Factor
Forklifts	0.20	Industrial
Generator Sets	0.74	Agricultural
Graders	0.41	Construction
Harrowbed/Bale Wagons	0.51	Agricultural - “Other Agriculture” Load Factor
Hydro Power Units	0.48	Agricultural
Irrigation Pumps	0.65	Agricultural
Mowers	0.43	Agricultural
Nut Bankouts	0.51	Agricultural - “Other Agriculture” Load Factor
Nut Harvesters	0.51	Agricultural - “Other Agriculture” Load Factor
Other Agriculture	0.51	Agricultural
Rough Terrain Forklifts	0.40	Construction
Rubber Tired Loaders	0.36	Construction
Shakers	0.51	Agricultural - “Other Agriculture” Load Factor
Shredders	0.40	Agriculture
Shuttles	0.51	Agricultural - “Other Agriculture” Load Factor
Skid Steer Loaders	0.37	Construction
Skidders	0.74	Logging
Sprayers	0.50	Agricultural
Swathers	0.55	Agricultural
Sweepers	0.51	Agricultural - “Other Agriculture” Load Factor
Tillers	0.78	Agricultural
Tractors	0.70	Agricultural
Trenchers	0.50	Construction

2017 Carl Moyer Program Guidelines – Table D-7

Table A-2
Uncontrolled Off-Road Compression-Ignition Engine Model Years

Horsepower	Engine Model Year
Greater than 750	1999 and earlier
25-49	1998 and earlier
50-99	1997 and earlier
100-174	1996 and earlier
175-750	1995 and earlier

NRCS California Air Quality Technical Note 1

Table A-3
Uncontrolled Off-Road Diesel Engines
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr-hr) (DR)

Horsepower	Model Year	NOx		ROG		PM10	
		EF	DR	EF	DR	EF	DR
25-49	Pre 1988	6.51	0.000098	1.68	0.000210	0.547	0.0000424
	1988+	6.42	0.000097	1.64	0.000210	0.547	0.0000424
50-119	Pre 1988	12.09	0.000280	1.31	0.000061	0.605	0.0000440
	1988+	8.17	0.000190	0.90	0.000042	0.497	0.0000361
120+	Pre 1970	13.02	0.000300	1.20	0.000056	0.554	0.0000403
	1970-1979	11.16	0.000260	0.91	0.000042	0.396	0.0000288
	1980-1987	10.23	0.000240	0.80	0.000037	0.396	0.0000288
	1988+	7.60	0.000180	0.62	0.000029	0.274	0.0000199

2017 Carl Moyer Program Guidelines – Table D-8

Table A-4
Controlled Off-Road Diesel Engines
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr-hr) (DR)

Horsepower	Tier	NOx		ROG		PM10	
		EF	DR	EF	DR	EF	DR
25-49	1	5.26	0.0000980	1.32	0.000170	0.480	0.0000372
	2	4.63	0.0000930	0.22	0.000050	0.280	0.0000218
	4 Interim	4.55	0.0000950	0.09	0.000036	0.128	0.0000096
	4 Final	2.75	0.0000570	0.09	0.000036	0.009	0.0000010
50-74	1	6.54	0.0001500	0.90	0.000042	0.552	0.0000402
	2	4.75	0.0000710	0.17	0.000025	0.192	0.0000141
	3	2.74	0.0000360	0.09	0.000023	0.192	0.0000141
	4 Interim	2.74	0.0000360	0.09	0.000023	0.112	0.0000080
	4 Final	2.74	0.0000360	0.09	0.000023	0.009	0.0000009
75-99	1	6.54	0.0001500	0.90	0.000042	0.552	0.0000402
	2	4.75	0.0000710	0.17	0.000025	0.192	0.0000141
	3	2.74	0.0000360	0.09	0.000023	0.112	0.0000080
	4 Phase-Out	2.74	0.0000360	0.09	0.000030	0.009	0.0000009
	4 Phase-In/Alt NOx	2.15	0.0000270	0.08	0.000021	0.009	0.0000009
	4 Final	0.26	0.0000035	0.05	0.000015	0.009	0.0000009
100-174	1	6.54	0.0001500	0.62	0.000029	0.304	0.0000221
	2	4.15	0.0000600	0.15	0.000023	0.128	0.0000094
	3	2.32	0.0000300	0.09	0.000030	0.112	0.0000080
	4 Phase-Out	2.32	0.0000300	0.09	0.000030	0.009	0.0000004
	4 Phase-In/Alt NOx	2.15	0.0000270	0.08	0.000020	0.009	0.0000004
	4 Final	0.26	0.0000040	0.05	0.000011	0.009	0.0000004
175-299	1	5.93	0.0001400	0.29	0.000013	0.120	0.0000064
	2	4.15	0.0000600	0.11	0.000022	0.088	0.0000046
	3	2.32	0.0000300	0.09	0.000023	0.088	0.0000046
	4 Phase-Out	2.32	0.0000300	0.09	0.000023	0.009	0.0000003
	4 Phase-In/Alt NOx	1.29	0.0000170	0.06	0.000017	0.009	0.0000003
	4 Final	0.26	0.0000036	0.05	0.000011	0.009	0.0000003
300-750	1	5.93	0.0000990	0.29	0.000010	0.120	0.0000064
	2	3.79	0.0000500	0.09	0.000023	0.088	0.0000044
	3	2.32	0.0000300	0.09	0.000023	0.088	0.0000044
	4 Phase-Out	2.32	0.0000300	0.09	0.000023	0.009	0.0000003
	4 Phase-In/Alt NOx	1.29	0.0000170	0.06	0.000017	0.009	0.0000003
	4 Final	0.26	0.0000036	0.05	0.000011	0.009	0.0000003
751+	1	5.93	0.0000990	0.29	0.000010	0.120	0.0000064
	2	3.79	0.0000500	0.09	0.000023	0.088	0.0000044
	4 Interim	2.24	0.0000280	0.06	0.000017	0.051	0.0000021
	4 Final	2.24	0.0000280	0.05	0.000011	0.017	0.0000009

2017 Carl Moyer Program Guidelines – Table D-9

Appendix B

NRCS Diesel Engine Emissions Calculations

Based on the 2011 Carl Moyer Program Guidelines and applied to NRCS emissions reports from 2012-2017

Estimating Annual Emissions based on Hours of Operation per Pollutant (tons/year)

$$\text{Tons/year} = \frac{[\text{EF (g/bhp-hr)} \times \text{Horsepower (bhp)} \times \text{Annual Activity (hours/year)} \times \text{Load Factor}]}{907{,}200 \text{ g/ton}}$$

2011 Carl Moyer Program Guidelines, Formula C-6

Table B-1
Diesel Agricultural Equipment Default Load Factors

Tillers	0.78	Swather	0.55
Combines	0.70	Sprayers	0.50
Tractors	0.70	Hydro Power Units	0.48
Irrigation Pumps	0.65	Mowers	0.43
Balers	0.58	Other Agricultural	0.51

2011 Carl Moyer Program Guidelines, Table D-10

Table B-2
Diesel Powered Construction & Industrial Equipment used in Agriculture Default Load Factors

Crawler Tractors	0.43	Backhoes/Loaders	0.37
Graders	0.41	Rubber-Tired Loaders	0.36
Rough Terrain Forklifts	0.40	Forklifts	0.20

2011 Carl Moyer Program Guidelines, Table D-10

Table B-3
Diesel Powered Logging Equipment Default Load Factors

Skidders	0.74	Fellers/Bunchers	0.71

2011 Carl Moyer Program Guidelines, Table D-10

Table B-4
Uncontrolled (Tier 0) Off-Road Compression-Ignition (Diesel) Engines
Emission Factors (g/bhp-hr)

Horsepower	Model Year	NOx	ROG	PM10
25 – 49	Pre 1988	6.51	2.21	0.547
	1988 +	6.42	2.17	0.547
50 – 119	Pre 1988	12.09	1.73	0.605
	1988 +	8.14	1.19	0.497
120 +	Pre 1970	13.02	1.59	0.554
	1970 – 1979	11.16	1.20	0.396
	1980 – 1987	10.23	1.06	0.396
	1988 +	7.60	0.82	0.274

2011 Carl Moyer Program Guidelines, Table D-11

Table B-5
Controlled Off-Road Compression-Ignition (Diesel) Engines
Emission Factors (g/bhp-hr)

Horsepower	Tier	NOx	ROG	PM10
25 – 49	1	5.26	1.74	0.480
	2	4.63	0.29	0.280
	4 Interim	2.75	0.12	0.128
	4 Final	2.75	0.12	0.008
50 – 74	1	6.54	1.19	0.552
	2	4.75	0.23	0.192
	3	2.74	0.12	0.192
	4 Interim	2.74	0.12	0.112
	4 Final	2.74	0.12	0.008
75 – 99	1	6.54	1.19	0.522
	2	4.75	0.23	0.192
	3	2.74	0.12	0.192
	4 Phase-Out	2.74	0.12	0.008
	4 Phase-In/Alt NOx	2.14	0.11	0.008
	4 Final	0.26	0.06	0.008
100 – 174	1	6.54	0.82	0.274
	2	4.17	0.19	0.128
	3	2.32	0.12	0.112
	4 Phase-Out	2.32	0.12	0.008
	4 Phase-In/Alt NOx	2.15	0.06	0.008
	4 Final	0.26	0.06	0.008
175 – 299	1	5.93	0.38	0.108
	2	4.15	0.12	0.088
	3	2.32	0.12	0.088
	4 Phase-Out	2.32	0.12	0.008
	4 Phase-In/Alt NOx	1.29	0.08	0.008
	4 Final	0.26	0.06	0.008
300 – 750	1	5.93	0.38	0.108
	2	3.79	0.12	0.088
	3	2.32	0.12	0.088
	4 Phase-Out	2.32	0.12	0.008
	4 Phase-In/Alt NOx	1.29	0.08	0.008
	4 Final	0.26	0.06	0.008
751 +	1	5.93	0.38	0.108
	2	3.79	0.12	0.088
	4 Interim	2.24	0.12	0.048
	4 Final	2.24	0.06	0.016

2011 Carl Moyer Program Guidelines, Table D-12

Appendix C

NRCS Diesel Engine Emissions Calculations

Based on the 2008 Carl Moyer Program Guidelines and applied to NRCS emissions reports from 2009-2011

Estimating Annual Emissions based on Hours of Operation per Pollutant (tons/year)

$$\text{Tons/year} = \frac{[\text{EF (g/bhp-hr)} \times \text{Horsepower (bhp)} \times \text{Annual Activity (hours/year)} \times \text{Load Factor}]}{907{,}200 \text{ g/ton}}$$

2008 Carl Moyer Program Guidelines, Formula C-4

Table C-1
Diesel Agricultural Equipment Default Load Factors

Tillers	0.78	Swather	0.55
Combines	0.70	Sprayers	0.50
Tractors	0.70	Hydro Power Units	0.48
Irrigation Pumps	0.65	Mowers	0.43
Balers	0.58	Other Agricultural	0.51

2008 Carl Moyer Program Guidelines, Table B-11

Table C-2
Diesel Powered Construction & Industrial Equipment used in Agriculture Default Load Factors

Crawler Tractors	0.64	Backhoes/Loaders	0.55
Graders	0.61	Rubber-Tired Loaders	0.54
Rough Terrain Forklifts	0.60	Forklifts	0.30

2008 Carl Moyer Program Guidelines, Table B-11

Table C-3
Diesel Powered Logging Equipment Default Load Factors

Skidders	0.74	Fellers/Bunchers	0.71

2008 Carl Moyer Program Guidelines, Table B-11

Table C-4
Uncontrolled (Tier 0) Off-Road Compression-Ignition (Diesel) Engines
Emission Factors (g/bhp-hr)

Horsepower	Model Year	NOx	ROG	PM10
25 – 49	Pre 1988	6.51	2.21	0.547
	1988 +	6.42	2.17	0.547
50 – 119	Pre 1988	12.09	1.73	0.605
	1988 +	8.14	1.19	0.497
120 +	Pre 1970	13.02	1.59	0.554
	1970 – 1979	11.16	1.20	0.396
	1980 – 1987	10.23	1.06	0.396
	1988 +	7.60	0.82	0.274

2008 Carl Moyer Program Guidelines, Table B-12

Table C-5
Controlled Off-Road Compression-Ignition (Diesel) Engines
Emission Factors (g/bhp-hr)

Tier	Horsepower	NOx	ROG	PM10
1	25-49	5.26	1.74	0.480
	50-119	6.54	1.19	0.552
	120-174	6.54	0.82	0.274
	175+	5.93	0.38	0.108
2	25-49	4.63	0.29	0.280
	50-119	4.75	0.23	0.192
	120-174	4.17	0.19	0.128
	175-250	4.15	0.12	0.088
	251+	3.79	0.12	0.088
3	50-120	2.74	0.12	0.160
	121-750	2.32	0.12	0.112
4 Interim	25-49	4.55	0.12	0.128
	50-120	2.40	0.11	0.056
	121-174	2.15	0.11	0.008
	175-750	1.29	0.08	0.008
	751+	2.24	0.12	0.048
4 Final	25-49	2.75	0.12	0.008
	50-120	1.33	0.08	0.008
	121-750	0.26	0.06	0.008
	751+	2.24	0.06	0.016

2008 Carl Moyer Program Guidelines, Table B-13