Appendix A
San Joaquin Valley Agricultural Equipment Incentive Measure Quantification Methodology and Sample Calculations

The 2011 and 2017 Moyer, NRCS, and FARMER Guidelines include the methodology for calculating project emission reductions such as emission reduction equations, emission factors, and deterioration rates. Additional information about the method used to calculate future emission reductions is in the **V. Quantifiable** section of Chapters 4, 5 and 6 of this measure. Example 1 shows how CARB staff calculated the emission reductions associated with implemented projects with the 2011 and 2017 Moyer and NRCS Guidelines and Example 2 shows how FARMER emission reductions are calculated.

The percent operation of the vehicle in the District is reported and included in the emission reduction calculation. This ensures credit is given for emission reductions actually occurring in the District. Example 1 below includes agricultural equipment in the Valley so the agricultural equipment operates solely in the District; therefore, 100 percent of the total emission reductions are credited.

As highlighted throughout this document, emission reductions accounted for in this measure will be reductions from off-road mobile agricultural equipment replacement projects.

Load Factor Adjustment

In December 2018, CARB publicly released the 2011 Emission Inventory for Agricultural Diesel Vehicles[1] (2011 Ag Emission Inventory). CARB developed the 2011 Ag Emissions Inventory based on a 2008 survey of agricultural producers, custom operators, and first processors for self-propelled diesel agricultural equipment over 25 horsepower in size. The Valley State SIP Strategy is based on the 2011 Ag Emission Inventory. The 2011 Ag Emission Inventory included changes to load factor based on survey data and was one of the largest modifications with the most impact, reducing emissions by approximately 30%. A load factor represents the proportion of maximum horsepower an engine produces on average under a particular use. A load fact is unit-less and part of the emissions calculation for projects in this measure.

All the projects in this measure follow the 2011 and 2017 Moyer Guideline emission calculations and include load factors in Appendix D of the Moyer Guidelines and the applicable Moyer Guidelines. The Moyer Program Guidelines reflect load factors before the 2011 Ag Emission Inventory, but the Valley State SIP Strategy is based on the 2011 Ag Emission Inventory. CARB staff developed a load factor adjustment to address this inconsistency.

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[1] CARB's 2011 Agricultural Emission Inventory https://ww3.arb.ca.gov/msei/ordiesel/ag2011invreport.pdf

The load factor adjustment is based on the previous agriculture emission inventory and the 2011 Agriculture Emission Inventory load factor tables. The tables and calculations below demonstrate how CARB staff developed the load factor adjustment. The load factor adjustment will be applied to each project's final emission reduction based on equipment type. The load factor adjustment will ensure the emission reductions calculated in this measure align with the Valley State SIP Strategy and 2011 Ag Emission Inventory. It is important to note that the load factor adjustment discounts the emissions and does not inflate.

Table A-1: Load Factor Adjustment

Equipment Type	2011 Ag Emission Inventory	2011 and 2017 Moyer Guidelines	Load Factor Adjustment
Agricultural Tractors	0.48	0.70	0.48 / 0.70 = 0.69
ATVs	0.40	0.51	0.40 / 0.51 = 0.78
Bale Wagons (Self-Propelled)	0.50	0.58	0.50 / 0.58 = 0.86
Balers (Self-Propelled)	0.50	0.58	0.50 / 0.58 = 0.86
Combine Harvesters	0.44	0.70	0.44 / .70 = 0.63
Cotton Pickers	0.44	0.51	0.44 / 0.51 = 0.86
Crawler/Backhoe/Loader/Dozer/Grader	0.40	0.51	0.40 / 0.51 = 0.78
Forage &Silage Harvester	0.44	0.51	0.44 / 0.51 = 0.86
Forklifts	0.40	0.51	0.40 / 0.51 = 0.78
Hay Squeeze/Stack Retriever	0.42	0.51	0.42 / 0.51 = 0.82
Nut Harvester	0.44	0.51	0.44 / 0.51 = 0.86
Other Harvester	0.44	0.51	0.44 / 0.51 = 0.86
Others	0.40	0.51	0.40 / 0.51 = 0.78
Sprayers/Spray Rigs	0.42	0.50	0.42 / 0.50 = 0.84
Swathers/Windrowers/Hay Conditioners	0.48	0.55	0.48 / 0.55 = 0.87

Example 1 – Calculating Implemented Project Emission Reductions

For implemented projects, staff calculated emissions based on the Moyer and NRCS Guidelines which follow the 2011 and 2017 Moyer Guidelines for calculating emission reductions. Examples 1a and 1b calculates an implemented individual project using formulas[2] and emissions factors[3] found in Appendix C and D of the 2011 and 2017

[2] Formula C-5: *Estimated Annual Emissions Based on Mileage*
[3] Table D-2: *Heavy-Duty Vehicles over 33,000 pounds (lbs.) GVWR Emission Factors*

Moyer Guidelines, respectively. While NRCS follows the 2011 and 2017 Moyer Guidelines, for Examples 1c and 1d please refer to the formulas[4] and emissions factors[17] found in NRCS California Air Quality Technical Notes. The list of the data points can be found above in the **V. Quantifiable** sections in Chapters 4, 5 and 6.

Example 1a. – 2011 Moyer Guidelines Agricultural Tractor Replacement

In the example, an applicant will scrap a 1985 engine model year diesel-powered agricultural tractor and replace it with a new agricultural tractor certified to the current CARB emission standard at the time or Tier 3 engine. Emission rates for all agricultural equipment will be based on 2011 Moyer Guidelines Appendix D Tables D-11: *Uncontrolled Off-Road Diesel Engines Emission Factors* and D-12: *Controlled Off-Road Diesel Engines Emission Factors.*

Appendix C of the 2011 Moyer Guidelines includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table D-10: *Off-Road Diesel Engines Default Load Factors*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

<u>Equipment Information</u>
Region: San Joaquin Valley APCD
Calendar Year: 2015
Guideline: 2011 Moyer Guideline
Vehicle Class: Off-Road Equipment Replacement

<u>Old Equipment Information</u>
Engine: Model Year (MY) 1985/Tier 0/Uncontrolled
Engine Horsepower: 170 horsepower (hp)
Hours of operation: 1,000 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 10.23 g/bhp-hr NOx, 0.396 g/bhp-hr PM10

[4] NRCS California Air Quality Technical Notes Appendix A and B

New Equipment Information
Engine: Tier 3
Engine Horsepower: 170 hp
Hours of operation: 1,000 hr/yr
Load factor: 0.70
Emission factors: 2.32 g/bhp-hr NOx, 0.112 g/bhp-hr PM10

(a) Determine emission reductions calculations for an uncontrolled to Tier 3 engine:

2011 Moyer Guidelines Formula C-6: Estimated Annual Emission Reductions based on hours of Operation (tons/year)

*Annual emissions by pollutant (tons/yr) = emission factor (g/bhp-hr) * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   Old Equipment:
   Annual NOx emissions (tons/yr)
   = [10.23 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =1.34 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.396 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =.05 tons/yr

   New Equipment:
   Annual NOx emissions (tons/yr)
   = [2.32 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =0.30 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.112 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =0.015 tons/yr

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Formula C-13: Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =
   Annual Emissions for the Old Equipment – Annual Emissions for the New Equipment

Annual NOx surplus emission reductions (tons/yr)
= 1.34 tons/yr – 0.30 tons/yr = 1.04 tons/yr

Annual PM10 surplus emission reductions (tons/yr)
= 0.05 tons/yr – 0.015 tons/yr = 0.035 tons/yr

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

Annual NOx surplus emission reductions (tpd) =
1.04 tons/yr * yr/ 365 days = 0.003 tons/day

Annual PM10 surplus emission reductions (tpd) =
0.35 tons/yr * yr/365 days = 0.0001 tons/day

(b) Load Factor Adjustment[5]

Annual NOx surplus emission reductions (tpd) =
0.003 tpd * 0.69 = .002 tpd

Annual PM10 surplus emission reductions (tpd) =
0.01 tpd * 0.69 = 0.00007 tpd

(c) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[6] =
0.00007 tpd PM10 * 0.92 = 0.000064 tpd PM2.5

Example 1b. – 2011 Moyer Guidelines 2 for 1 Agricultural Tractor Replacement

In the example, an applicant will scrap two 1985 and 1990 engine model year diesel-powered agricultural tractors and replace it with one new agricultural tractor certified to the current CARB emission standard at the time or Tier 3 engine. Emission rates for all agricultural equipment will be based on 2011 Moyer Guidelines Appendix D Tables D-11: *Uncontrolled Off-Road Diesel Engines Emission Factors* and D-12: *Controlled Off-Road Diesel Engines Emission Factors.*

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[5] Refer to Table 1: Load Factor Adjustment; This particular project is an agricultural tractor so the load factor adjustment is 0.69

[6] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

Appendix C of the 2011 Moyer Guidelines includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table D-10: *Off-Road Diesel Engines Default Load Factors*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

Equipment Information
Region: San Joaquin Valley APCD
Calendar Year: 2015
Guideline: 2011 Moyer Guideline
Vehicle Class: Off-Road Equipment Replacement

Old Equipment Information 1
Engine: Model Year (MY) 1985/Tier 0/Uncontrolled
Engine Horsepower: 170 horsepower (hp)
Hours of operation: 350 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 10.23 g/bhp-hr NOx, 0.396 g/bhp-hr PM10

Old Equipment Information 2
Engine: Model Year (MY) 1990/Tier 0/Uncontrolled
Engine Horsepower: 170 horsepower (hp)
Hours of operation: 700 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 10.23 g/bhp-hr NOx, 0.396 g/bhp-hr PM10

New Equipment Information
Engine: Tier 3
Engine Horsepower: 170 hp
Hours of operation: 1,050 hr/yr
Load factor: 0.70
Emission factors: 2.32 g/bhp-hr NOx, 0.112 g/bhp-hr PM10

(a) Determine emission reductions calculations for an uncontrolled to Tier 3 engine:

2011 Moyer Guidelines Formula C-6: Estimated Annual Emission Reductions based on hours of Operation (tons/year)

*Annual emissions by pollutant (tons/yr) = emission factor (g/bhp-hr) * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   Old Equipment 1:
   Annual NOx emissions (tons/yr)
   = [10.23 g/bhp-hr * 170 hp * 0.70 * 350 hr * 100%] * ton/907,200g
   =0.46 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.396 g/bhp-hr * 170 hp * 0.70 * 350 hr * 100%] * ton/907,200g
   =0.01 tons/yr

   Old Equipment 2:
   Annual NOx emissions (tons/yr)
   = [10.23 g/bhp-hr * 170 hp * 0.70 * 700 hr * 100%] * ton/907,200g
   =0.93 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.396 g/bhp-hr * 170 hp * 0.70 * 700 hr * 100%] * ton/907,200g
   =0.03tons/yr

   New Equipment:
   Annual NOx emissions (tons/yr)
   = [2.32 g/bhp-hr * 170 hp * 0.70 * 1,050 hr * 100%] * ton/907,200g
   =0.31 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.112 g/bhp-hr * 170 hp * 0.70 * 1,050 hr * 100%] * ton/907,200g
   =0.015 tons/yr

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Formula C-13: Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =
   (Annual Emissions for the Old Equipment 1 + Annual Emissions for the Old Equipment 2) – Annual Emissions for the New Equipment

   Annual NOx surplus emission reductions (tons/yr)
   = (0.46 tons/yr + 0.93 tons/yr) – 0.31 tons/yr = 1.08 tons/yr

Annual PM10 surplus emission reductions (tons/yr)
= (0.01 tons/yr + 0.03 tons/yr) – 0.015 tons/yr = 0.02 tons/yr

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

Annual NOx surplus emission reductions (tpd) =
1.08 tons/yr * yr/ 365 days = 0.002 tons/day

Annual PM10 surplus emission reductions (tpd) =
0.025tons/yr * yr/365 days = 0.00005 tons/day

(b) Load Factor Adjustment[7]

Annual NOx surplus emission reductions (tpd) =
0.002 tpd * 0.69 = .001 tpd

Annual PM10 surplus emission reductions (tpd) =
0.00005 tpd * 0.69 = 0.00003 tpd

(c) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[8] =
0.00003 tpd PM10 * 0.92 = 0.000027 tpd PM2.5

Example 1c. – 2017 Moyer Guidelines Agricultural Tractor Replacement

In the example, an applicant will scrap a 1990 engine model year diesel-powered agricultural tractor and replace it with a new agricultural tractor certified to the current CARB emission standard or Tier 4 Final (Tier 4f) engine. Emission rates for all agricultural equipment will be based on 2017 Moyer Guidelines Appendix D Tables D-8: *Uncontrolled Off-Road Diesel Engines Emission Factors and Deterioration Rates* and D-9: *Controlled Off-Road Diesel Engines Emission Factors and Deterioration Rates.*

Appendix C of the 2017 Moyer Guidelines includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load

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[7] Refer to Table 1: Load Factor Adjustment; This particular project is an agricultural tractor so the load factor adjustment is 0.69

[8] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table D-7: *Off-Road Diesel Engines Default Load Factors*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

Equipment Information
Region: San Joaquin Valley APCD
Calendar Year: 2018
Guideline: 2017 Carl Moyer Guideline
Vehicle Class: Off-Road Equipment Replacement

Old Equipment Information
Engine: Model Year (MY) 1990/Tier 0/Uncontrolled
Engine Horsepower: 200 horsepower (hp)
Hours of operation: 750 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 7.60 g/bhp-hr NOx, 0.274 g/bhp-hr PM10
Deterioration rates: 0.00018 g/bhp-hr-hr NOx, 0.0000199 g/bhp-hr-hr PM10

New Equipment Information
Engine: Tier 4f
Engine Horsepower: 200 hp
Hours of operation: 750 hr/yr
Load factor: 0.70
Emission factors: 0.26 g/bhp-hr NOx, 0.009 g/bhp-hr PM10
Deterioration rates: 0.0000036 g/bhp-hr-hr NOx, 0.0000003 g/bhp-hr-hr PM10

(a) Determine deterioration calculations for an uncontrolled to Tier 4f engine: emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate deterioration life (old equipment) (yrs):**
   Deterioration life (old equipment) (yrs) = expected first year of operation – baseline engine model year + project life/2

   Deterioration Life (old equipment) = 2018 – 1990 + (10/2) = 33 years

2. **Calculate deterioration life (new equipment) (yrs):**
   Deterioration life (new equipment) (yrs) = project life/2

   Deterioration Life (new equipment) = 10/2 = 5 years

3. **Calculate total equipment activity (hrs) and cap the old equipment activity when applicable[9]:**
   Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)

   Total old equipment activity = 750 (hrs/yr) * 33 (yrs) = 24,750 hrs
   Total new equipment activity = 750 (hrs/yr) * 5 (yrs) = 3,750 hrs

4. **Calculate hour-based deterioration rate for old and new equipment, for each pollutant (g/bhp-hr):**
   Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)

   Old equipment:
   NOx deterioration product = 0.00018 (g/bhp-hr-hr) * 12,000 hrs = 2.16 g/bhp-hr
   PM10 deterioration product = 0.0000199 (g/bhp-hr-hr) * 12,000 hrs = 0.2388 g/bhp-hr

   New equipment:
   NOx deterioration product = 0.0000036 (g/bhp-hr-hr) * 3,750 hrs = 0.135 g/bhp-hr
   PM10 deterioration product = 0.0000003 (g/bhp-hr-hr) *3,750 hrs = 0.001125 g/bhp-hr

(b) Determine emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   2017 Moyer Guidelines Formula C-6: Estimated Annual Emission Reductions based on hours of Operation (tons/year)

   *Annual emissions by pollutant (tons/yr) = [emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)] * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

   Old Equipment:
   Annual NOx emissions (tons/yr)
   = [7.60 g/bhp-hr + 2.16 g/bhp-hr) * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 1.1296 tons/yr

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[9] 2017 Moyer Guidelines, Appendix C, page C-7, Footnote (c), Total equipment activity used for deterioration rate is capped at 12,000 hours for off-road diesel engines

Annual PM10 emissions (tons/yr)
= [0.274 g/bhp-hr + 0.2388 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.0593 tons/yr

New Equipment:
Annual NOx emissions (tons/yr)
= [0.26 g/bhp-hr + 0.135 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.0457 tons/yr

Annual PM10 emissions (tons/yr)
= [0.009 g/bhp-hr + 0.001125 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.001 tons/yr

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Formula C-7: Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =

   Annual Emissions for the Old Equipment – Annual Emissions for the New Equipment

   Annual NOx surplus emission reductions (tons/yr)
   =1.1296 tons/yr – 0.0457 tons/yr = 1.0839 tons/yr

   Annual PM10 surplus emission reductions (tons/yr)
   = 0.0593 tons/yr – 0.001 tons/yr = 0.0583 tons/yr

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

   Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

   Annual NOx surplus emission reductions (tpd) = 1.0839 tons/yr * yr/365 days = 0.0029 tpd

   Annual PM10 surplus emission reductions (tpd) = 0.0583 tons/yr * yr/365 days = 0.00015 tpd

(c) Load Factor Adjustment

Annual NOx surplus emission reductions (tpd) =
0.0029 tpd * 0.69 = 0.002 tpd

Annual PM10 surplus emission reductions (tpd) =
0.00015 tpd * 0.69 = 0.0001 tpd

(d) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[10] =
0.0001 tpd PM10 * 0.92 = 0.000092 tpd PM2.5

Example 1d. – 2017 Moyer Guidelines 2 for 1 Agricultural Tractor Replacement

In the example, an applicant will scrap two 1985 and 1990 engine model year diesel-powered agricultural tractor and replace it with a new agricultural tractor certified to the current CARB emission standard or Tier 4 Final (Tier 4f) engine. Emission rates for all agricultural equipment will be based on 2017 Moyer Guidelines Appendix D Tables D-8: *Uncontrolled Off-Road Diesel Engines Emission Factors and Deterioration Rates* and D-9: *Controlled Off-Road Diesel Engines Emission Factors and Deterioration Rates.*

Appendix C of the 2017 Moyer Guidelines includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table D-7: *Off-Road Diesel Engines Default Load Factors*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

<u>Equipment Information</u>
Region: San Joaquin Valley APCD
Calendar Year: 2018
Guideline: 2017 Carl Moyer Guideline
Vehicle Class: Off-Road Equipment Replacement

<u>Old Equipment Information 1</u>
Engine: Model Year (MY) 1985/Tier 0/Uncontrolled
Engine Horsepower: 200 horsepower (hp)
Hours of operation: 200 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 10.23 g/bhp-hr NOx, 0.396 g/bhp-hr PM10
Deterioration rates: 0.00024 g/bhp-hr-hr NOx, 0.0000288 g/bhp-hr-hrPM10

[10] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

Old Equipment Information 2
Engine: Model Year (MY) 1990/Tier 0/Uncontrolled
Engine Horsepower: 200 horsepower (hp)
Hours of operation: 600 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 7.60 g/bhp-hr NOx, 0.274 g/bhp-hr PM10
Deterioration rates: 0.00018 g/bhp-hr-hr NOx, 0.0000199 g/bhp-hr-hr PM10

New Equipment Information
Engine: Tier 4f
Engine Horsepower: 200 hp
Hours of operation: 800 hr/yr
Load factor: 0.70
Emission factors: 0.26 g/bhp-hr NOx, 0.009 g/bhp-hr PM10
Deterioration rates: 0.0000036 g/bhp-hr-hr NOx, 0.0000003 g/bhp-hr-hr PM10

(a) Determine deterioration calculations for an uncontrolled to Tier 4f engine: emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate deterioration life (old equipment) (yrs):**
   Deterioration life (old equipment) (yrs) = expected first year of operation – baseline engine model year + project life/2

   Deterioration Life (old equipment 1) = 2018 – 1985 + (10/2) = 38 years

   Deterioration Life (old equipment 2) = 2018 – 1990 + (10/2) = 33 years

2. **Calculate deterioration life (new equipment) (yrs):**
   Deterioration life (new equipment) (yrs) = project life/2

   Deterioration Life (new equipment) = 10/2 = 5 years

3. **Calculate total equipment activity (hrs) and cap the old equipment activity when applicable[11]:**
   Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)

   Total old equipment 1 activity = 200 (hrs/yr) * 38 (yrs) = 7,600 hrs
   Total old equipment 2 activity = 600 (hrs/yr) * 33 (yrs) = 19,800 hrs
   Total new equipment activity = 800 (hrs/yr) * 5 (yrs) = 4,000 hrs

[11] 2017 Moyer Guidelines, Appendix C, page C-7, Footnote (c), Total equipment activity used for deterioration rate is capped at 12,000 hours for off-road diesel engines

4. **Calculate hour-based deterioration rate for old and new equipment, for each pollutant (g/bhp-hr):**
   Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)

   Old equipment 1:
   NOx deterioration product = 0.00024 (g/bhp-hr-hr) * 7,600 hrs = 1.82 g/bhp-hr
   PM10 deterioration product = 0.0000288 (g/bhp-hr-hr) * 7,600 hrs = 0.21 g/bhp-hr

   Old equipment 2:
   NOx deterioration product = 0.00018 (g/bhp-hr-hr) * 12,000 hrs = 2.16 g/bhp-hr
   PM10 deterioration product = 0.0000199 (g/bhp-hr-hr) * 12,000 hrs = 0.23 g/bhp-hr

   New equipment:
   NOx deterioration product = 0.0000036 (g/bhp-hr-hr) * 4,000 hrs = 0.01 g/bhp-hr
   PM10 deterioration product = 0.0000003 (g/bhp-hr-hr) *4,000 hrs = 0.001 g/bhp-hr

(b) Determine emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   2017 Moyer Guidelines Formula C-6: Estimated Annual Emission Reductions based on hours of Operation (tons/year)

   *Annual emissions by pollutant (tons/yr) = [emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)] * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

   Old Equipment 1:
   Annual NOx emissions (tons/yr)
   = [10.23 g/bhp-hr + 1.82 g/bhp-hr) * 200 hp * 0.70 * 200 hr * 100%] * ton/907,200g = 0.37 tons/yr

   Annual PM10 emissions (tons/yr)
   = [0.396 g/bhp-hr + 0.21 g/bhp-hr] * 200 hp * 0.70 * 200 hr * 100%] * ton/907,200g = 0.01 tons/yr

Old Equipment 2:
Annual NOx emissions (tons/yr)
= [7.60 g/bhp-hr + 2.16 g/bhp-hr) * 200 hp * 0.70 * 600 hr * 100%] * ton/907,200g = 0.90 tons/yr

Annual PM10 emissions (tons/yr)
= [0.274 g/bhp-hr + 0.23 g/bhp-hr] * 200 hp * 0.70 * 600 hr * 100%] * ton/907,200g = 0.04 tons/yr

New Equipment:
Annual NOx emissions (tons/yr)
= [0.26 g/bhp-hr + 0.01 g/bhp-hr] * 200 hp * 0.70 * 800 hr * 100%] * ton/907,200g = 0.03 tons/yr

Annual PM10 emissions (tons/yr)
= [0.009 g/bhp-hr + 0.001 g/bhp-hr] * 200 hp * 0.70 * 800 hr * 100%] * ton/907,200g = 0.001 tons/yr

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Formula C-7: Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =
   (Annual Emissions for the Old Equipment 1 + Annual Emissions for the Old Equipment 1) – Annual Emissions for the New Equipment

   Annual NOx surplus emission reductions (tons/yr)
   = (0.37 tons/yr + 0.90 tons/yr) – 0.03 tons/yr = 1.24 tons/yr

   Annual PM10 surplus emission reductions (tons/yr)
   = (0.01 tons/yr + 0.04 tons/yr) – 0.0001 tons/yr = 0.04 tons/yr

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

   Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

   Annual NOx surplus emission reductions (tpd) = 1.24 tons/yr * yr/365 days = 0.003 tpd

   Annual PM10 surplus emission reductions (tpd) = 0.04 tons/yr * yr/365 days = 0.0001 tpd

(c) Load Factor Adjustment

Annual NOx surplus emission reductions (tpd) =
0.003 tpd * 0.69 = 0.002 tpd

Annual PM10 surplus emission reductions (tpd) =
0.0001 tpd * 0.69 = 0.00006 tpd

(d) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[12] =
0.00006 tpd PM10 * 0.92 = 0.00055 tpd PM2.5

Example 1e. – Appendix B of the NRCS California Air Quality Technical Notes 4 Agricultural Tractor Replacement

In the example, an applicant will scrap a 1985 engine model year diesel-powered agricultural tractor and replace it with a new agricultural tractor certified to the current CARB emission standard at the time or Tier 3 engine. Emission rates for all agricultural equipment will be based on Appendix B of the NRCS California Air Quality Technical Notes 4.

Appendix B of the NRCS California Air Quality Technical Notes 4 includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table B-1: *Diesel Agricultural Equipment Default Load Factors*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

<u>Equipment Information</u>
Region: San Joaquin Valley APCD
Calendar Year: 2015
Guideline: NRCS FY 2015 Guidelines
Vehicle Class: Off-Road Equipment Replacement

[12] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

Old Equipment Information
Engine: Model Year (MY) 1985/Tier 0/Uncontrolled
Engine Horsepower: 170 horsepower (hp)
Hours of operation: 1,000 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 10.23 g/bhp-hr NOx, 0.396 g/bhp-hr PM10

New Equipment Information
Engine: Tier 3
Engine Horsepower: 170 hp
Hours of operation: 1,000 hr/yr
Load factor: 0.70
Emission factors: 2.32 g/bhp-hr NOx, 0.112 g/bhp-hr PM10

(a) Determine emission reductions calculations for an uncontrolled to Tier 3 engine:

Appendix B of the NRCS California Air Quality Technical Notes 4 Formula[13]: Estimated Annual Emission Reductions based on hours of Operation (tons/year)

*Annual emissions by pollutant (tons/yr) = emission factor (g/bhp-hr) * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   Annual NOx old equipment emissions (tons/yr)
   = [10.23 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =1.34 tons/yr

   Annual NOx new equipment emissions (tons/yr)
   = [2.32 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =0.30 tons/yr

   Annual PM10 old equipment emissions (tons/yr)
   = [0.396 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =.05 tons/yr

   Annual PM10 new equipment emissions (tons/yr)
   = [0.112 g/bhp-hr * 170 hp * 0.70 * 1,000 hr * 100%] * ton/907,200g
   =0.015 tons/yr

[13] 2011 Moyer Guidelines, Formula C-6

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =
   Annual Emissions for the Old Equipment – Annual Emissions for the New Equipment

   Annual NOx surplus emission reductions (tons/yr)
   = 1.34 tons/yr – 0.30 tons/yr = 1.04 tons/yr

   Annual PM10 surplus emission reductions (tons/yr)
   = 0.05 tons/yr – 0.015 tons/yr = 0.035 tons/yr

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

   Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

   Annual NOx surplus emission reductions (tpd) =
   1.04 tons/yr * yr/ 365 days = 0.003 tons/day

   Annual PM10 surplus emission reductions (tpd) =
   0.35 ns/yr * yr/365 days = 0.0001 tons/day

(b) Load Factor Adjustment[14]

Annual NOx surplus emission reductions (tpd) =
0.003 tpd * 0.69 = .002 tpd

Annual PM10 surplus emission reductions (tpd) =
0.01 * 0.69 = 0.00007 tpd

(c) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[15] =
0.00007 tpd PM10 * 0.92 = 0.000064 tpd PM2.5

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[14] Refer to Table 1: Load Factor Adjustment; This particular project is an agricultural tractor so the load factor adjustment is 0.69
[15] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

Example 1f. – Appendix A of the NRCS California Air Quality Technical Notes 4

In the example, an applicant will scrap a 1990 engine model year diesel-powered agricultural tractor and replace it with a new agricultural tractor certified to the current CARB emission standard or Tier 4 Final (Tier 4f) engine. Emission rates for all agricultural equipment will be based on Appendix A of the NRCS California Air Quality Technical Notes 4.

Appendix A of the NRCS California Air Quality Technical Notes 4 includes formulas for calculation emissions from off-road projects. One of the unique variables to the off-road formula is load factor. All load factors for off-road projects and non-mobile agricultural projects will be based on Table A-1: *NRCS Default Load Factors for Off-Road Diesel-Powered Equipment used in Agriculture*.

The load factor adjustment is applied at the end of the emission reduction calculation and demonstrated in the example below.

Note: Calculations may not add up due to rounding

<u>Equipment Information</u>
Region: San Joaquin Valley APCD
Calendar Year: 2018
Guideline: NRCS FY 2018 Guidelines
Vehicle Class: Off-Road Equipment Replacement

<u>Old Equipment Information</u>
Engine: Model Year (MY) 1990/Tier 0/Uncontrolled
Engine Horsepower: 200 horsepower (hp)
Hours of operation: 750 hours/year (hr/yr)
Load factor: 0.70
Emission factor: 7.60 g/bhp-hr NOx, 0.274 g/bhp-hr PM10
Deterioration rates: 0.00018 g/bhp-hr-hr NOx, 0.0000199 g/bhp-hr-hr PM10

<u>New Equipment Information</u>
Engine: Tier 4f
Engine Horsepower: 200 hp
Hours of operation: 750 hr/yr
Load factor: 0.70
Emission factors: 0.26 g/bhp-hr NOx, 0.009 g/bhp-hr PM10
Deterioration rates: 0.0000036 g/bhp-hr-hr NOx, 0.0000003 g/bhp-hr-hr PM10

(a) Determine deterioration calculations for an uncontrolled to Tier 4f engine: emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate deterioration life (old equipment) (yrs):**
   Deterioration life (old equipment) (yrs) = expected first year of operation – baseline engine model year + project life/2

   Deterioration Life (old equipment) = 2018 – 1990 + (10/2) = 33 years

2. **Calculate deterioration life (new equipment) (yrs):**
   Deterioration life (new equipment) (yrs) = project life/2

   Deterioration Life (new equipment) = 10/2 = 5 years

3. **Calculate total equipment activity (hrs) and cap the old equipment activity when applicable[16]:**
   Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)

   Total old equipment activity = 750 (hrs/yr) * 33 (yrs) = 24,750 hrs
   Total new equipment activity = 750 (hrs/yr) * 5 (yrs) = 3,750 hrs

4. **Calculate hour-based deterioration rate for old and new equipment, for each pollutant (g/bhp-hr):**
   Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)

   Old equipment:
   NOx deterioration product = 0.00018 (g/bhp-hr-hr) * 12,000 hrs = 2.16 g/bhp-hr
   PM10 deterioration product = 0.0000199 (g/bhp-hr-hr) * 12,000 hrs = 0.2388 g/bhp-hr

   New equipment:
   NOx deterioration product = 0.0000036 (g/bhp-hr-hr) * 3,750 hrs = 0.135 g/bhp-hr
   PM10 deterioration product = 0.0000003 (g/bhp-hr-hr) *3,750 hrs = 0.1125 -hr

[16] Appendix A of the NRCS California Air Quality Technical Notes 4, Total equipment activity used for deterioration rate is capped at 12,000 hours for off-road diesel engines

(b) Determine emission reductions calculations for an uncontrolled to Tier 4f engine:

1. **Calculate the estimated annual emissions for old and new equipment, for each pollutant (tons/yr):**

   Appendix B of the NRCS California Air Quality Technical Notes 4 Formula[17]:
   Estimated Annual Emission Reductions based on hours of Operation (tons/year)

   *Annual emissions by pollutant (tons/yr) = [emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)] * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in San Joaquin APCD * ton / 907,200g*

   Annual NOx old equipment emissions (tons/yr)
   = [7.60 g/bhp-hr + 2.16 g/bhp-hr) * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 1.1296 tons/yr

   Annual NOx new equipment emissions (tons/yr)
   = [0.26 g/bhp-hr + 0.135 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.0457 tons/yr

   Annual PM10 old equipment emissions (tons/yr)
   = [0.274 g/bhp-hr + 0.2388 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.0593 tons/yr

   Annual PM10 new equipment emissions (tons/yr)
   = [0.008 g/bhp-hr + 0.001125 g/bhp-hr] * 200 hp * 0.70 * 750 hr * 100%] * ton/907,200g = 0.0010 tons/yr

2. **Calculate annual surplus emission reductions by pollutant (tons/yr)**
   Formula C-7: Annual Surplus Emission Reductions by Pollutant (tons/yr)

   Annual Surplus Emission Reduction (by pollutant) =

   Annual Emissions for the Old Equipment – Annual Emissions for the New Equipment

   Annual NOx surplus emission reductions (tons/yr)
   =1.1296 tons/yr – 0.0457 tons/yr = 1.0839 tons/yr

   Annual PM10 surplus emission reductions (tons/yr)
   = 0.0593 tons/yr – 0.0010 tons/yr = 0.0583 tons/yr

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[17] 2017 Moyer Guidelines, Formula C-6

3. **Convert tons per year(tons/yr) to tons per day (tpd)**

   Annual Surplus Emission Reduction (tpd) = Annual Surplus Emission Reduction (tons/yr) * yr/365 days

   Annual NOx surplus emission reductions (tpd) = 1.0839 tons/yr * yr/365 days = 0.0029 tpd

   Annual PM10 surplus emission reductions (tpd) = 0.0583 tons/yr * yr/365 days = 0.00015 tpd

(c) Load Factor Adjustment

Annual NOx surplus emission reductions (tpd) =
0.0029 tpd * 0.69 = 0.002 tpd

Annual PM10 surplus emission reductions (tpd) =
0.00015 tpd * 0.69 = 0.0001 tpd

(d) Diesel PM10 to PM2.5 Ratio

Annual PM10 surplus emission reductions (tpd) * PM2.5 ratio[18] =
0.0001 tpd PM10 * 0.96 = 0.000096 tpd PM2.5

Example 2 – Calculating Future Project Emission Reductions

For future projects, staff calculated emissions based on the FARMER Guidelines which refer to the 2017 Moyer Guidelines. Approximately $155 million from FY 17/18 and 18/19 FARMER Program is available for this measure. Example 2 calculates how staff calculated an individual project using formulas[19] and emissions factors[20] found in Appendix C and D of the 2017 Moyer Guidelines, respectively. This calculation allowed CARB staff to identify and commit to turning over 2,050 mobile off-road agricultural equipment and achieve 2.13 tpd of NOx and 0.14 tpd of PM2.5 reductions. These future emission reductions for this measure were calculated according to the 2017 Moyer Guidelines methodology using data from reported District FARMER projects. Once these future projects are actually implemented, the

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[18] Appendix F CARB OFFROAD Diesel Engine Emissions Factors and Other References, Diesel PM10 to PM2.5 Ratio, Pg. 8, Table 4.12-5. PM Size Fractions

[19] Formula C-5*: Estimated Annual Emissions Based on Mileage using Emissions Factors*

[20] Table D-8: *Uncontrolled Off-Road Diesel Engines Emission Factors (g/bhp-hr) and Deterioration Rates (g/bhp-hr-hr)* and Table D-9: Controlled Off-Road Diesel Engines Emission Factors (g/bhp-hr) and Deterioration Rates (g/bhp-hr-hr)

data points will be included in reports to U.S. EPA that will be publicly available at https://www.arb.ca.gov/planning/sip/imp2016sip/imp2016sip.htm.

Appendix J below provides the initial implementation of FARMER. Appendix J includes project specific data exactly like Appendix H Carl Moyer Project List below, but with project information specific to FARMER. The emission reductions in Appendix J are calculated the same as Example 1b since FARMER follows the 2017 Moyer Guidelines. This first set of FARMER projects are used to estimate the emission reductions from the remaining first two years of FARMER funding. The tables below summarizes the FARMER projects from Appendix J demonstrating how FARMER will turnover dirty to cleaner agricultural equipment and the associated emission reductions. Also, the summary table below is derived from Appendix J so the public and U.S. EPA as replicate the calculations.

Table A-2: FARMER Emission Reduction Methodology

First two years of FARMER funding available for projects	**$155,000,000**
FARMER projects funded	**$19,432,040**
Remaining FARMER funds available	$155,000,000 - $19,432,040 = **$135,567,960**
Associated NOx (tpd) reductions from FARMER projects funded	**0.27**
Associated PM2.5 (tpd) reductions from FARMER projects funded	**0.02**
Average FARMER funding per NOx reduction (tpd)	$19,432,040/0.27 = **$72,631,624**
Average FARMER funding per PM2.5 reduction (tpd)	$19,432,040/0.02 = **$1,138,036,685**
NOx reductions from remaining FARMER funds (tpd)	$135,567,960/$72,631,624 = **1.87**
PM2.5 reduction from remaining FARMER funds (tpd)	$135,567,960/$1,138,036,685 = **0.12**

Table A-3: FARMER Project Count Methodology

FARMER projects funded (cost)	$19,432,040
FARMER projects funded (number of projects)	257
Cost per FARMER project	$19,432,040/257 = **$75,611.05**
FARMER projects funded	**$19,432,040**
Remaining FARMER funds available	$155,000,000 - $19,432,040 = **$135,567,960**
Associated NOx (tpd) reductions from FARMER projects funded	$135,567,960/$75,611.05 = **1,793**
Total FARMER projects from first two years funding	257+1,793= **2,050**